PRELIMINARY RESULTS – FOR DISCUSSION ONLY

RFP No. 10-407

Evaluation of ILUC Related Topics

New Geographically-Explicit Estimates of Soil and Biomass Carbon Stocks by GTAP Region and AEZ

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We are indebted to James Duffy, Richard Plevin and Sonia Yeh for their feedback throughout our analysis. We thank Nancy Harris and Sean Grimland for help with forest biomass estimates in the tropics, Paul West for input on cropland biomass estimates, and Mark Friedl and Damien Sulla-Menashe for the MODIS forest map. This report was submitted in fulfillment of ARB Contract 10-407 (Evaluation of ILUC Topics) by Dr. Holly Gibbs under partial sponsorship of the California Air Resources Board. Draft was completed as of September 2, 2011.

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ABSTRACT

We provide new, geographically-explicit estimates of soil and biomass carbon stocks for the same regions and agro-ecological zone (AEZ) combination as the version of the Global Trade Analysis Project (GTAP) model used to estimate indirect land use change (ILUC) for the Low Carbon Fuel Standard (LCFS). We use the Harmonized World Soil Database combined with cropland, forest and pasture maps to estimate soil carbon stocks. A range of spatially detailed forest biomass carbon databases was used to estimate forest carbon stocks. Our analysis substantially refined the estimates of carbon stocks used in the LCFS ILUC modeling. However, we recommend continued improvement as new databases become available and as land-use issues are updated in the version of GTAP used for the LCFS.

EXECUTIVE SUMMARY

This report summarizes the results of a geographically-explicit analysis of soil and biomass carbon stocks that significantly refined estimates of carbon stocks used for indirect land use change (ILUC) modeling for the California Air Resources Board's (CARB) Low Carbon Fuel Standard (LCFS). Previously, CARB modeling efforts relied on biomass and soil carbon stocks from the Woods Hole Research Center (WHRC) database, which is based on an extensive literature review by R.A. Houghton (See Gibbs et al. 2007 for synthesis of data sources). The WHRC data is not geographically explicit but rather provides a look-up table of average values across 10 broad regions that are then applied across many agro-ecological zones (AEZ). GTAP-BIO-ADV, the version of GTAP currently used by Purdue University researchers for ILUC modeling (e.g., Tyner, Taheripour et al. 2010). The version Global Trade Analysis Project (GTAP) model currently used by Purdue University researchers for ILUC modeling, GTAP-BIO-ADV, uses regions and AEZs are much more detailed than the broad WHRC categories, thus a given WHRC value is applied across the 204 unique GTAP regions (e.g., Tyner, Taheripour et al. 2010). A large amount of information is lost because of the coarse land cover categories in the WHRC look-up table. This is particularly problematic because the WHRC regions do not translate cleanly into the GTAP regions.

We synthesized a range of geographically-explicit forest, grassland and cropland biomass and soil carbon input data sources and used geographic information systems (GIS) software to create new estimates for each unique GTAP AEZ and region combination. Our work builds upon the geographically-explicit estimates led by Winrock International for the US Environmental Protection Agency's (EPA) Renewable Fuel Standard (RFS). The spatial detail of our analysis is a major advantage over the WHRC look-up table because it provides estimates tailored to the regions of interest and better accounts for the variation of carbon stocks across the landscape.

We quantified the average amount of soil carbon and biomass carbon stored in pastures, croplands and forests for each GTAP region and AEZ. These carbon stock estimates will be used in the emissions factor model to estimate carbon emissions from indirect land use change as predicted by GTAP. This new database provides a flexible framework that can be revised with regional updates in the future, and can be used with a range of emissions factor assumptions that will likely evolve over time. Carbon stock estimates for other pools including litter, understory vegetation, harvested wood products and peat soil carbon stocks are discussed in the companion report focused on the Emissions Factor Model (Plevin et al. 2011). Land use conversion and pools are described in different companion report on bringing land into focus for global economic models (Gibbs 2011).

Our new estimates are a major step forward in terms of estimates carbon emissions from ILUC, but many uncertainties remain. Spatial comparison between our results and those used by the EPA for the RFS and IPCC Tier-1 Default values indicates that our range is reasonable and does not appear to be biased high or low. We recommend updating the estimates of carbon stocks as new databases are published, as well as other minor refinements through time.

1.0 METHODS OVERVIEW

We used ArcGIS software to estimate the soil and biomass carbon stocks for forest, grazing land and cropland by overlaying the GTAP Region and AEZ boundaries on a range of geographically-explicit data sources, revisiting the approach used by Harris et al. (2009) for the EPA RFS2. There are 19 GTAP regions based on political boundaries that were stratified by 18 AEZs to create the final GTAP Region-AEZ map used to determine the carbon estimates (Figure 1). A total of 203 regions[3] were created from combining the two maps, but because the resolution is so coarse there are several regions that are extremely small that could be integrated into nearby larger regions in the future.

The GTAP Region-AEZ map was combined with the soil and biomass carbon maps for each region using the ‘combine’ tool (spatial analyst tool in ArcGIS). The resulting table from the combined dataset was exported to Microsoft Excel to calculate the weighted average carbon stocks for each region. Note that computing a weighted

[3] While the combination of 19 regions and 18 AEZs yields 342 distinct combinations, most regions contain only a small subset of the 18 possible AEZs.

average assumes that land selection is random across each land cover class or that carbon stocks vary little across the landscape (Plevin et al 2011). This approach could be improved in the future by mapping forest conversion probability based on accessibility, suitability, satellite-based information and so on, sand then estimating carbon stocks for the forest most likely to be cleared

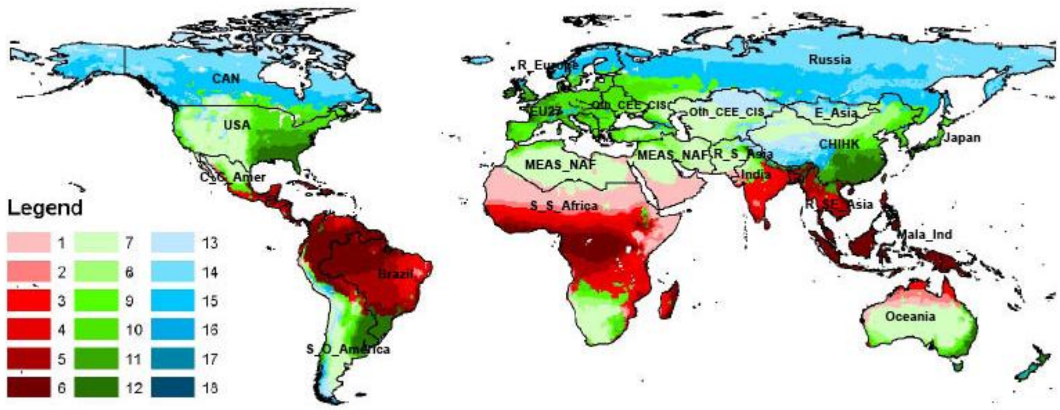

Figure 1: 19 GTAP regions combined with the 18 AEZs

2. SOIL CARBON

We used the Harmonized World Soil Database (HWSD) to estimate soil carbon stocks for forest, pasture and cropland (FAO/IIASA/ISRIC/ISSCAS/JRC, 2009). Soil carbon stock estimates and soil information in general have long been considered highly uncertain, and the HWSD makes major improvements by integrating existing regional and national soil information worldwide into a harmonized format, and is the best available spatially-explicit soil carbon data for most regions. The HWSD database is based on four different geographically-explicit data sources including the Soil Map of the World, SOTER Regional Studies, European Soil Database, and a Soil Map of China, and is considered the best available data at the global scale. However, notable exceptions include the USA, Canada, and Australia where the HWSD (FAO et al 2009) version does not include available national data for those regions[4].

[4] USA: NRCS US General Soil Map http://ncgc.nrcs.usda.gov/products/datasets/statsgo, Canada: Agriculture and Agri-Food Canada: The National Soil Database (NSDB) http://sis.agr.gc.ca/cansis/nsdb and Australia: CSIRO,natural Heritage Trust and National Land and Water Resources Audit: ASRIS http://www.asris.csiro.au/index_other.html, and with the recently released

The HWSD spatial data has several soil-mapping units; each unit includes the percent share of the type of soil in the given unit, as well as carbon content, depth, bulk density and several other characteristics necessary to calculate the soil carbon. We used equations from Guo and Gifford (2008) to convert the information in the HWSD into soil carbon estimates[5]. The HWSD provides estimates of soil carbon stocks to both 30cm and 100cm depths (Figures 2, 3) and we provide estimates at both depths (Table 1).

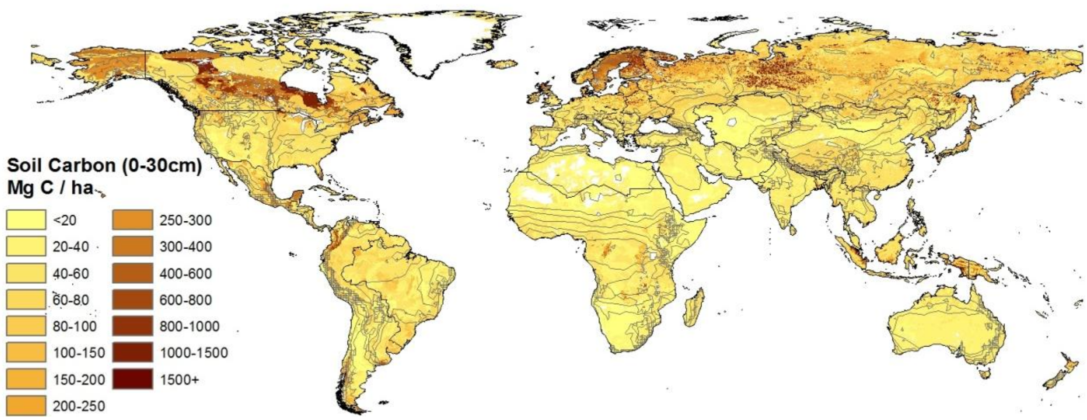

Figure 2: Harmonized World Soil Database soil carbon estimate 30cm

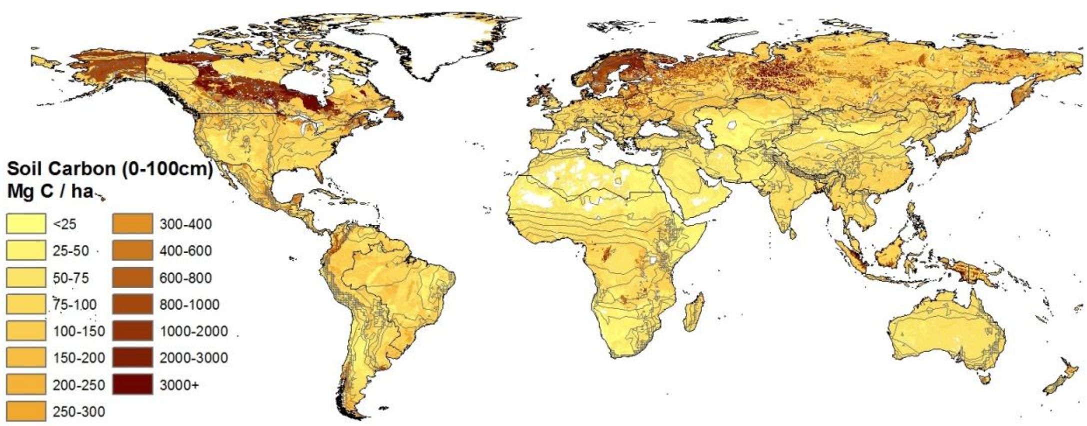

Figure 3: Harmonized World Soil Database soil carbon estimate 100cm

Purdue's recent ILUC modeling, based on GTAP-BIO-ADV, excludes wetlands, floodplains, deserts and lands with slopes > 5% from analysis, thus we attempted to match these conditions in our analysis. We removed wetland soils using a filter to ensure

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SOTER database for Central Africa (FAO/ISRIC/University Gent, 2007).

[5] Ct = BD * CC% * D; Ct = Total soil carbon stock (t C ha-1); BD = Bulk Density (g cm-3); CC% = % carbon content, D = Depth (cm); CC% = 0,58*OM%; OM% = % organic matter
BD = 100/ ((%OM/0.244) + ((100 - %OM)/1.64)))

we were estimating non-wetland soil carbon stocks rather than the average (Figures A1, A2). Two global wetlands map were combined and used as the wetlands filter: the USDA global wetlands map (Reich 1997), and the Global Lakes and Wetlands Database (GLWD) created by the Center for Environmental Systems Research in Kassel, Germany (Lehner and Döll 2004). The GLWD provides raster data with more recent information, higher spatial resolution, and more detailed classes of wetlands (Table A1). However, we used both the USDA wetlands dataset and the GLWD to capture more wetland areas.

In Indonesia and Malaysia we applied an additional filter to exclude lands with >500 Mg C/ ha to ensure that we removed most peatlands following methods in Gibbs et al (2008). We also removed deserts using the FAO ecofloristic zones (Figure A3). Figure 4 depicts the combined filters used from soil carbon. Floodplains and slopes >5% in future iterations to better march with GTAP assumptions. However, we strongly recommend reviewing this assumption in GTAP as many studies indicate that slopes, floodplains and wetlands are frequently converted to agricultural land around the world (CITATIONS).

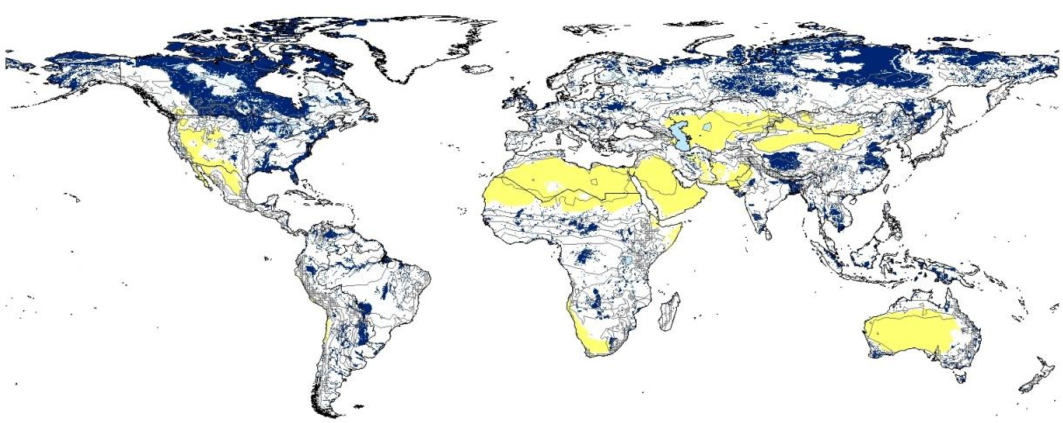

Figure 4: Total filter used to exclude area from the soil carbon analysis comprised of GLWD wetlands, USDA wetlands and FAO deserts.

2.1 Forest soil carbon stocks

We used a MODIS forest cover map based on imagery collected 2007-2010 to subset the forest carbon stocks from the broader HWSD map (Figure 5). Professor Mark Friedl, Boston University, who runs the MODIS Land Cover Science Team, created the forest cover map. He mapped the most stable forest pixels to ensure we would be estimating soil carbon for forest only, rather than a mix of vegetation types. We estimated forest soil carbon at 30cm (Figure 6) and 100cm depth (Figure 7).

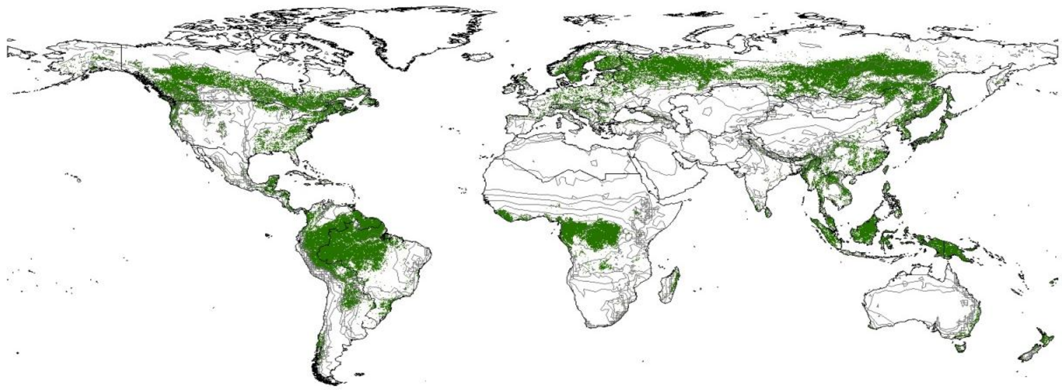

Figure 5: Forest map based on most stable forest pixels subset from MODIS imagery collected 2007-2010 (courtesy of Mark Friedl and Damien Sulla-Menashe, Boston University)

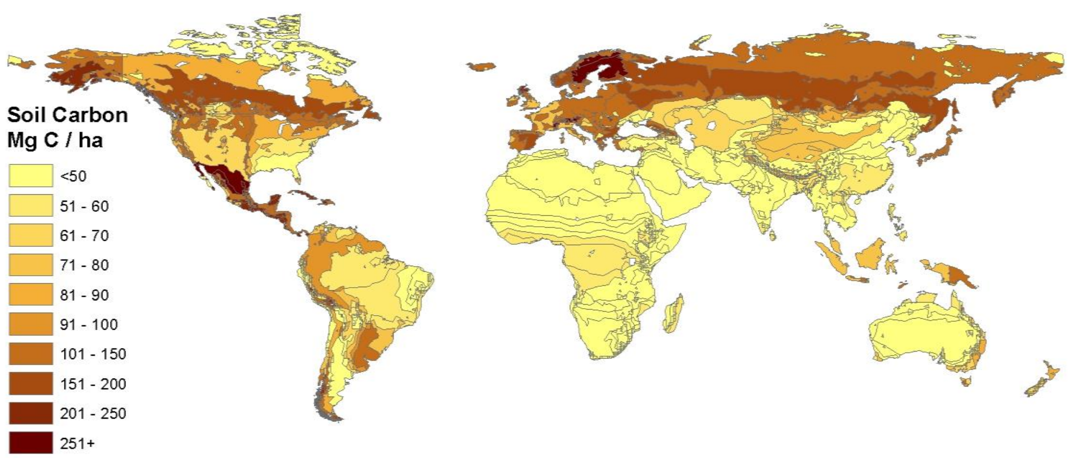

Figure 6: Weighted average forest soil carbon stocks by GTAP Region-AEZs at 30cm depth

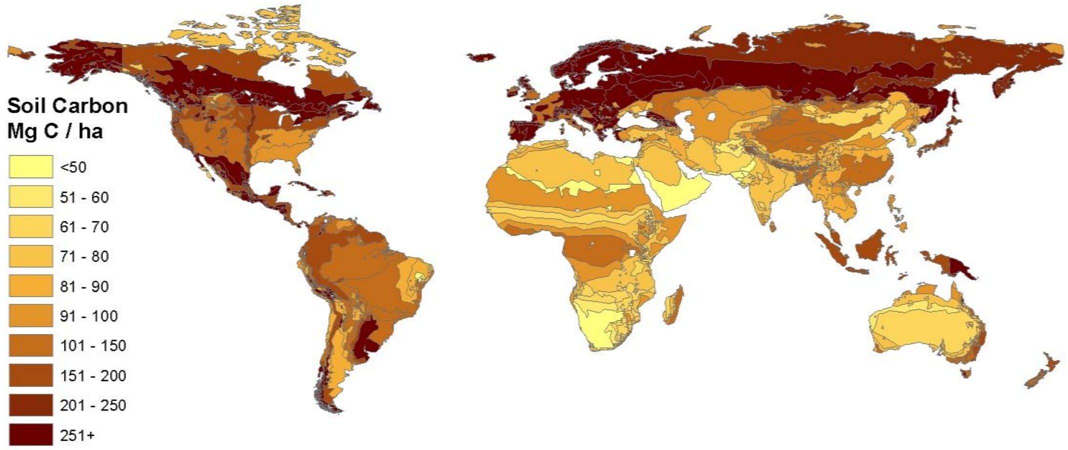

Figure 7: Weighted average forest soil carbon stocks by GTAP Region-AEZs at 100cm depth

2.2 Pasture soil carbon stocks

We used a map of pasture to subset the soil carbon map. GTAP now uses the M3 beta (formerly SAGE data) version for cropland and pasture data, circa 2004 (Ramankutty and Foley 1999, updated). However, this land cover data is at 0.5 degree resolution, which means that most pixels have several land cover categories mixed together. Our aim is to estimate soil carbon stocks for as pure of pasture pixels as possible so we opted to use an earlier version of the M3 dataset, circa 2000, (Ramankutty et al 2008) because of its higher, 5-minute spatial resolution. This data is continuous with values ranging from 0-100% so we had to make decisions to convert it to discrete information. In line with identifying pure pasture carbon stocks, we started with a 66% threshold, which indicates that most of the area is covered by pasture, and then successively lowered it to include 50%, 25%, and finally 10% for those regions with lower pasture coverage (Figure 8; Table 2). A region had to have at least 1% of the area covered by pasture at a given threshold or a lower threshold was used. A handful of regions did not have any pasture and we used expert judgment to assign logical values from other regions (Table 3). We estimated pasture soil carbon by GTAP AEZ at the 30cm (Figure 9) and 100cm depth (Figure 10)

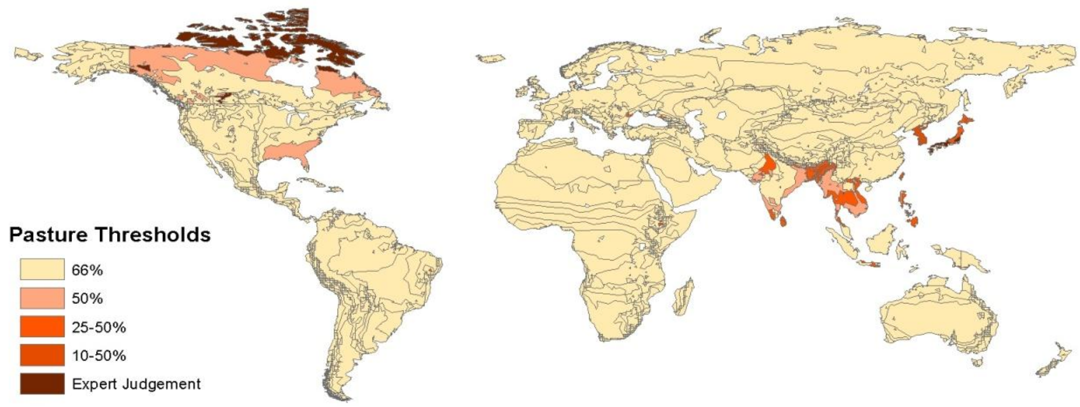

Figure 8: Pasture thresholds based on Ramankutty and Foley (1999; updated) used for soil carbon estimates

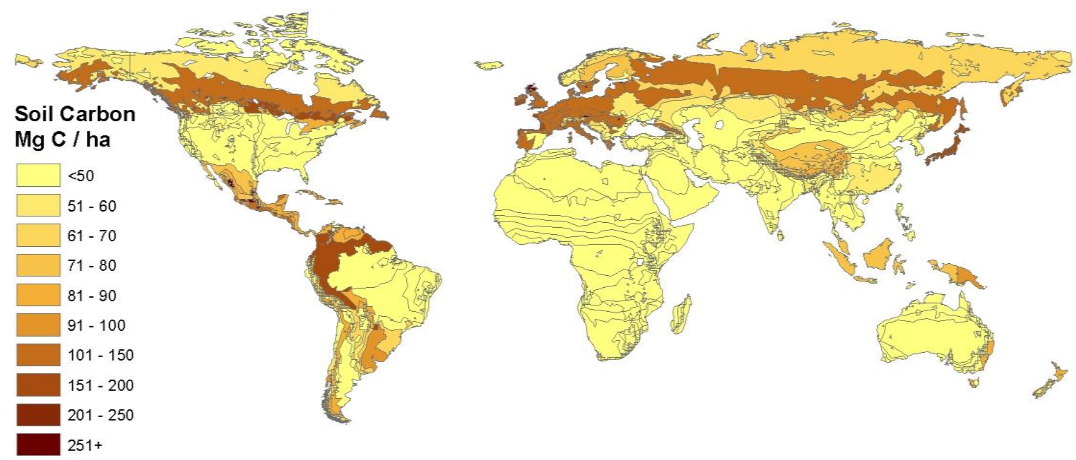

Figure 9: Weighted average pasture soil carbon stocks by GTAP Region-AEZs at 30cm depth

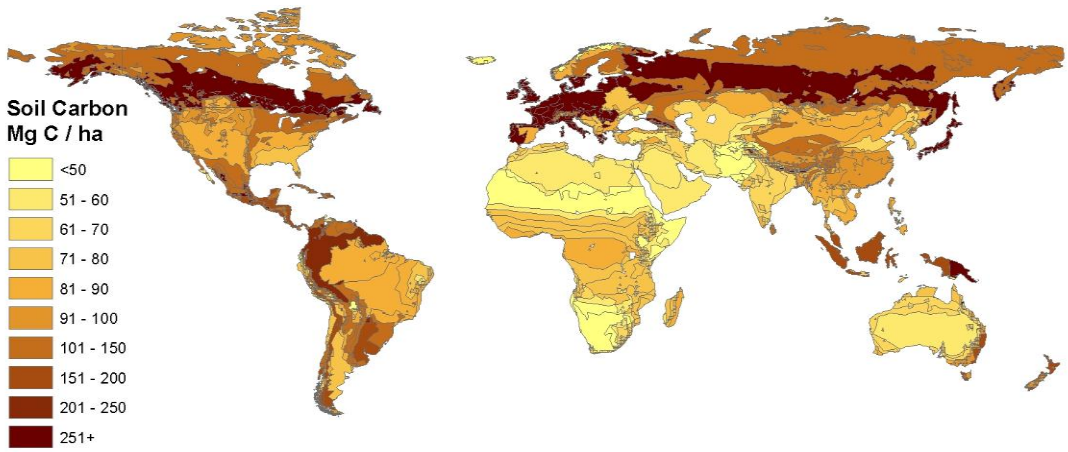

Figure 10: Weighted average pasture soil carbon stocks by GTAP Region-AEZs at 100cm depth

2.3 Cropland soil carbon stocks

As described in Section 2.2 for pasture, we used an earlier version of the M3 dataset, circa 2000, (Ramankutty et al 2008) to identify the locations of croplands to help ensure pure cropland pixels. This data is continuous with values ranging from 0-100% so we had to make decisions to convert it to discrete information. In line with identifying pure cropland carbon stocks, we started with a 66% threshold, and then lowered it to include 50%, 25%, and finally 10% for those regions with lower cropland coverage (Figure 11; Table 2). A region had to have at least 1% of the area covered by pasture at a given threshold or a lower threshold was used (Table 3). A handful of regions did not have any cropland and we used expert judgment to assign logical values from other regions. We estimated pasture soil carbon by GTAP AEZ at the 30cm (Figure 12) and 100cm depth (Figure 13).

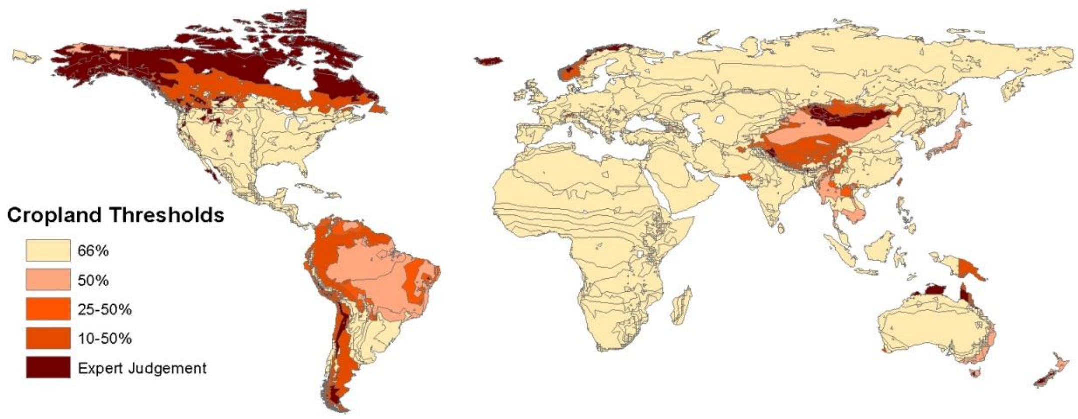

Figure 11: Cropland thresholds based on Ramankutty and Foley (1999; updated) used for soil carbon estimates

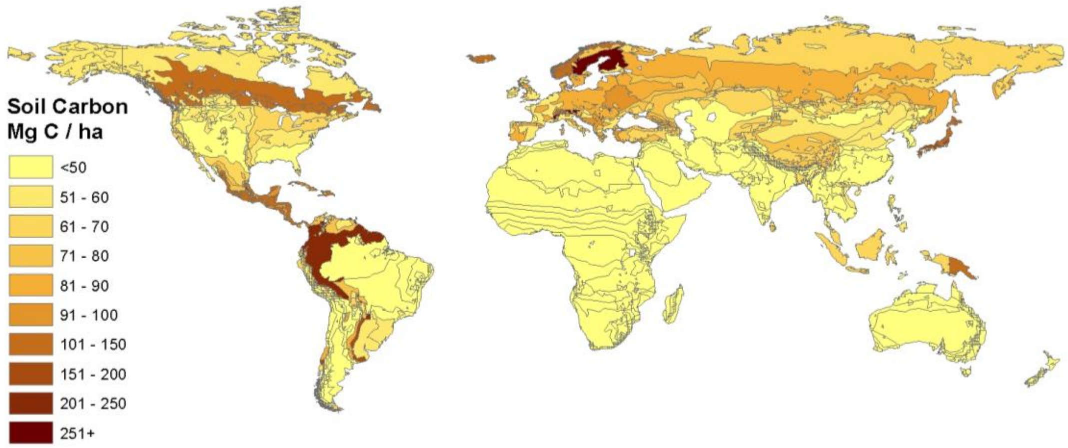

Figure 12: Weighted average cropland soil carbon stocks by GTAP Region-AEZs at 30cm depth

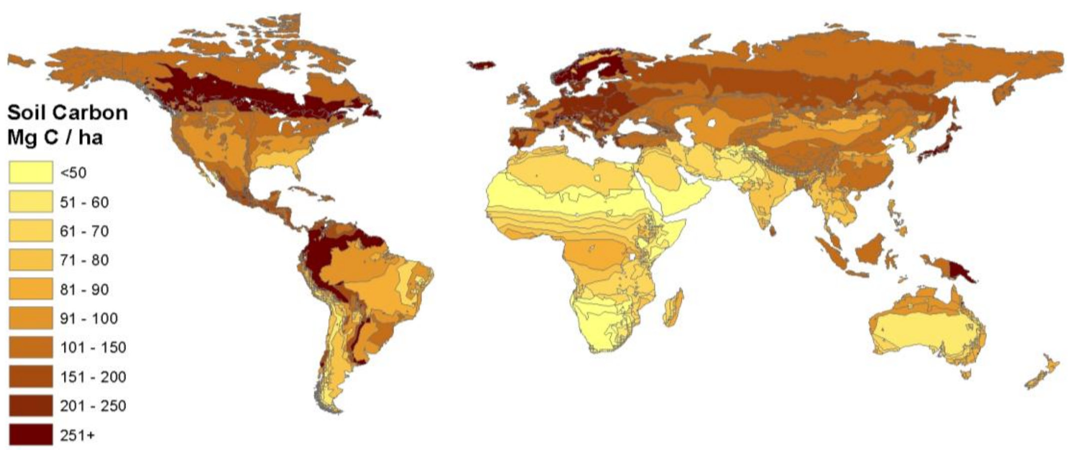

Figure 13: Weighted average cropland soil carbon stocks by GTAP Region-AEZs at 100cm depth

3. ABOVEGROUND AND BELOWGROUND LIVING BIOMASS CARBON

GTAP's recent model runs exclude wetlands, floodplains and slopes > 5% based on the assumption that no agricultural expansion will occur there. We did not remove these land areas for the biomass estimates, unlike the soil carbon stocks estimates that did account for wetlands and deserts. We estimate living aboveground and belowground biomass only. Other carbon pools including deadwood, understory vegetation and litter are discussed in Plevin et al (2011). Cropland carbon stocks are also discussed in Plevin et al. (2011).

3.1 Forest biomass carbon

We used a range of geographically-explicit datasets to estimate the living aboveground biomass (AGB), which includes trunks, branches, and leaves, and the belowground biomass (BGB) stored in roots (Figure 14, Table 4). We identified the best available databases but considerable uncertainty exists. Light Detection and Ranging (Lidar) remote sensing data is ideal to estimate the spatial distribution of aboveground forest biomass carbon, but the technology is only available on airplanes (not satellites), which grossly limits the area that it can cover. Consequently, scientists are using a range of available sensors and methods to estimate the spatial distribution of biomass in lieu of the Lidar ideal. The datasets used here are described below (Figure 15).

Tropics

A state-of-the-art map of forest biomass from Saatchi et al. (2010) was used to estimate carbon stocks in the tropics. The published version was not yet released during our analysis so we collaborated with Winrock International (co-authors) to estimate the carbon stocks. Saatchi et al. (2011) used global forest height data measured by the Geoscience Laser Altimeter System (GLAS) onboard the Ice, Cloud and land Elevation Satellite (ICESat) along with other remote sensing and ground-based data to model the spatial distribution of aboveground forest biomass. Data was calibrated and validated using 4,079 inventory and research plots. Belowground biomass carbon in roots was estimated from aboveground biomass using an allometric equation developed from literature ($BGB = 0.489AGB^{0.89}$). We assumed a carbon fraction of 0.50 to convert biomass to carbon stocks. The Saatchi et al (2011) map has a 1-km spatial resolution.

USA

The National Biomass and Carbon Dataset for the year 2000 produced by scientists at the Woods Hole Research Center was used to estimate forest carbon stocks in the United States (Kellndorfer et al. 2011). The dataset was created based on an empirical modeling approach that combines the USDA Forest Service Forest Inventory and Analysis (FIA) data with high-resolution InSAR data from the 2000 Shuttle Topography Mission (SRTM) and Landsat ETM+ satellite data. We assumed a carbon fraction of 0.50 to convert biomass to carbon stocks. The map has a 30-m spatial resolution. We used the IPCC Tier-1 default root-to-shoot ratios to add in BGB because the NBCD2000 only included AGB. Note that the NBDC2000 dataset is only for conterminous US but we have also applied it to Alaska. Values for Canada would be more accurate but we were unable to make that distinction without adjusting the average values for the entire US. We prioritized accuracy for the conterminous US over Alaska because we assume fewer

ILUC impacts in Alaska.

Russia

A map of forest biomass based on MODIS satellite imagery calibrated with forest inventory data was used to extract forest biomass data for Russia (Houghton et al. 2007). Data collected from twelve field sites were used along with the MODIS bi-directional reflectance distribution function (BRDF) product as the variable to predict biomass. Houghton et al. (2007) used a 0.50 carbon fraction to convert biomass to carbon stocks. Forest growing stock, which includes ABG, BGB, and understory carbon, measured by the inventory data was converted to biomass using allometric equations. The map has a 500-m spatial resolution. It is important to note that the error of biomass estimates was ~40%, indicating that only ~60% of the variation in predicted biomass was explained by the regression model. The authors describe their results as partially successful.

European Union, Canada, Australia and Other regions

The Ruesch and Gibbs (2008) global biomass carbon map was used for regions lacking other options. The biomass map applies the International Panel on Climate (IPCC) Tier-1 default values for AGB and BGB to the Global Land Cover (GLC2000) map for the year 2000, which as a spatial resolution of 1km by 1km. Specifically, Ruesch and Gibbs (2008) synthesized and mapped IPCC Tier-1 default values using the global land cover map stratified by continent, ecoregion and forest disturbance level. Ruesch and Gibbs (2008) used a carbon fraction of 0.47 to convert from biomass to carbon. Note that this dataset does not account for spatial variation within forest categories as captured by the satellite-based approaches used in other regions.

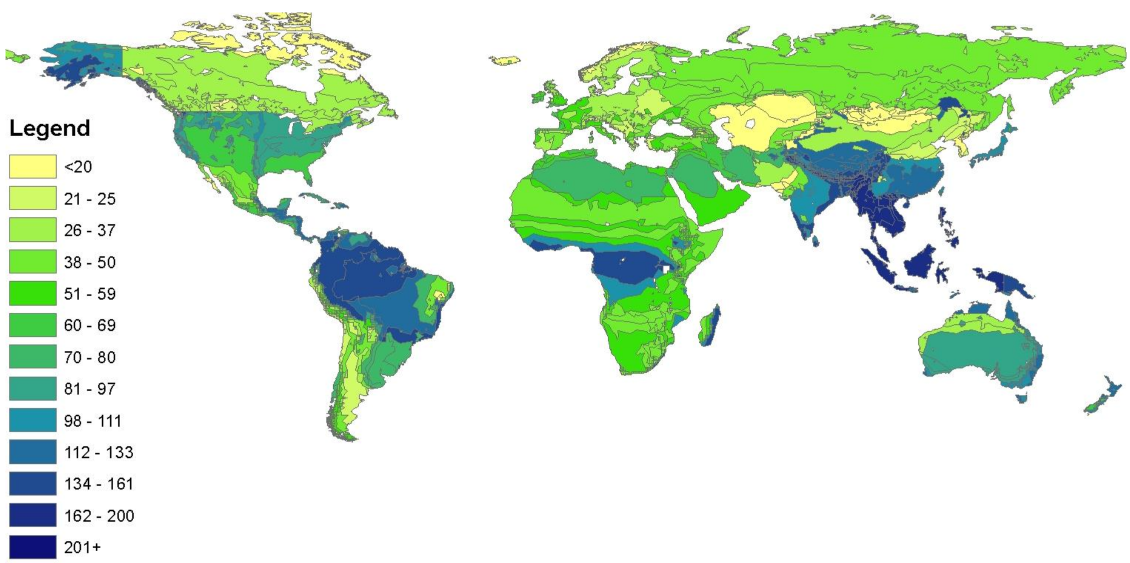

Figure 14: Weighted average forest biomass carbon stocks by GTAP Region-AEZs (Mg C / ha)

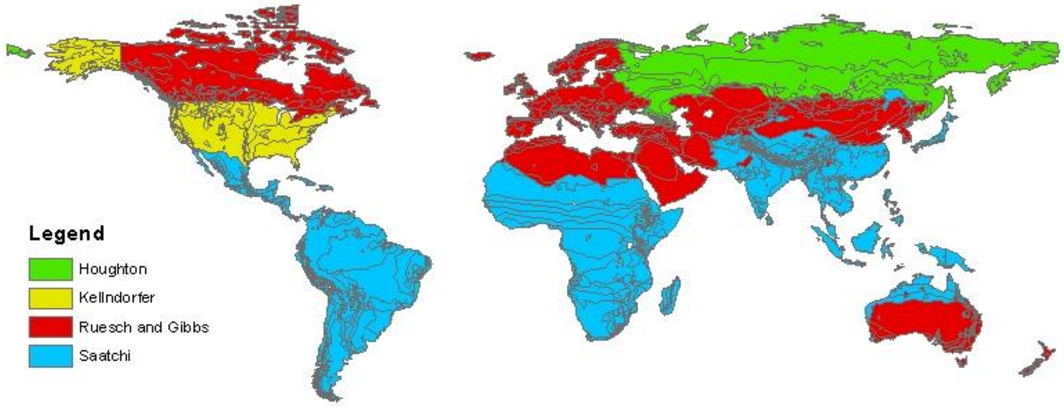

Figure 15: Sources for geographically-explicit forest biomass data

3.2 Pasture biomass carbon

We conducted a literature review but were unsuccessful in finding enough data for managed pastureland to apply worldwide. Consequently, we applied the IPCC Tier-1 default values for grasslands (Tables 6.1 and 6.4), which vary by 7 ecoflorisitc zones (Table 5). Note that we did not estimate carbon stocks for the Brazilian cerrado or other areas of unmanaged shrubland, grassland or savanna, which would have much higher carbon stocks (20-75 Mg / ha) because they are excluded from GTAP (Gibbs 2011).

4. DISCUSSION

The soil and biomass carbon stock analysis presented here provides CARB with an refined basis to estimate carbon emissions from ILUC. We conducted a spatial analysis to identify differences in our results compared with studies used elsewhere.

We compared our updated values with the WHRC values used in Hertel et al. (2010) and Tyner et al. (2010) (Figure 16). Our values were higher in much of South America and humid tropical Africa but lower in Southeast Asia. WHRC values were substantially higher (50+ Mg C / ha) in the US, Canada, Europe, and Russia. (Table A2).

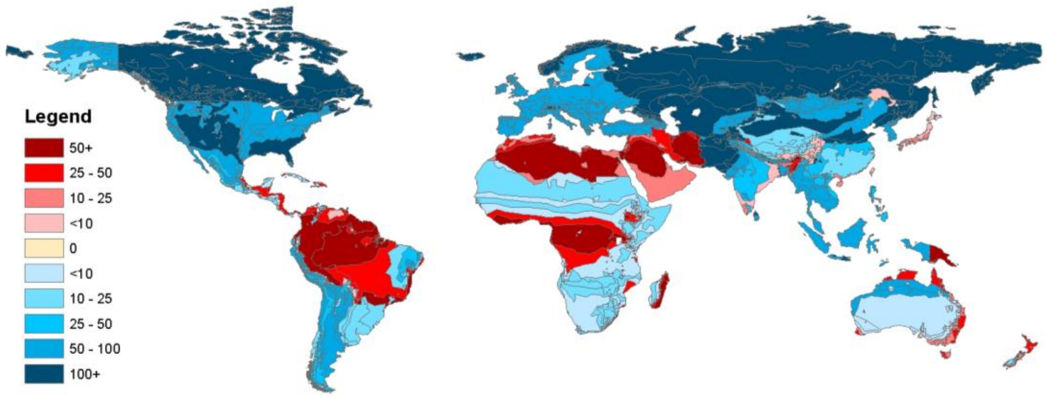

Figure 16: Difference in forest biomass carbon between our geographically-explicit estimates and WHRC values applied to map of GTAP Regions-AEZ
Red = our geographically-explicit estimates higher than WHRC values,
Blue = our geographically-explicit estimates lower than WHRC default values.

We also compared a GTAP Region-AEZ weighted average forest carbon map based on Ruesch and Gibbs (2008), which applied IPCC Tier-1 default values to a land cover map, to our map based on a range of datasets to further examine the differences between prominent estimates of forest carbon stocks (Figure 14). Across the Latin America, Africa and insular Southeast Asia, our estimates based on Saatchi et al. (2011) are 10-50 t C / ha lower than the IPCC Tier-1 default values (Figure 16). The Saatchi et al. (2011) dataset is spatially-explicit and thus captures a range of forest conditions including gaps due to streams, dead trees, and other sources of heterogeneity are averaged together across a single pixel. This averaging could lead to lower values than applying a single default value across a pixel that likely captures minimum heterogeneity. However, in parts of the US, Asia and continental Southeast Asia, our analysis was as higher.

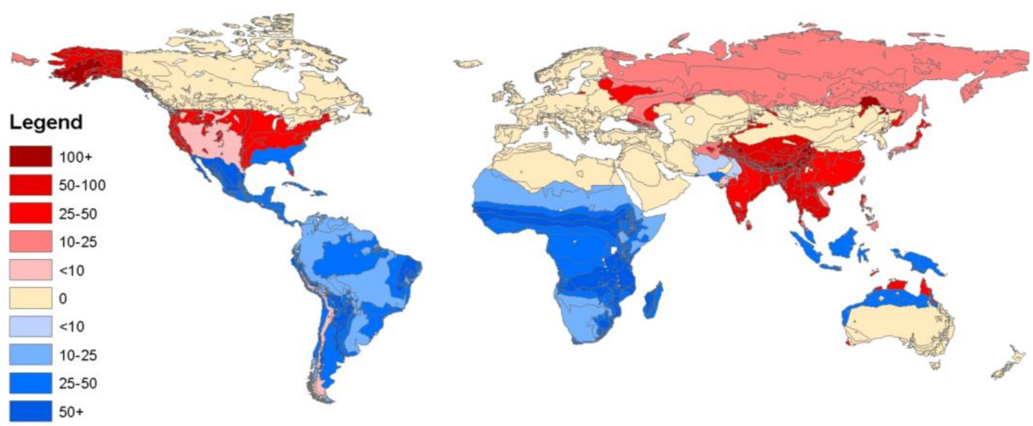

Figure 16: Difference in forest biomass carbon between our geographically-explicit estimates and IPCC Tier-1 values applied to forest map by Ruesch and Gibbs (2008).
Beige = no difference (Ruesch and Gibbs 2008 used IPCC Tier-1 defaults),

Red = our geographically-explicit estimates higher than IPCC Tier-1 default values,
Blue = our geographically-explicit estimates lower than IPCC Tier-1 default values.

Lastly, we compared our sources of forest biomass estimates with those used by Harris et al. (2009) for the US EPA in Table 6. Overall, our approach relied on more recently published data sources, particularly for the tropics, and improved upon the framework established by Harris et al. (2009) in some instances. A comparison between the Harris et al. (2009) values produced at the state-level and our values estimated at the GTAP-Region-AEZ level is difficult because of the different scales. However, general patterns can be observed. For example, our values are higher across most of the tropics but lower in Brazil. Our values were lower in Australia, Europe and Asia but mixed in the United States. Winrock used the HWSD to estimate soil carbon stocks as we did. Note that the Winrock estimates for soil carbon are for forest only, we provided the soil carbon estimates for forest, cropland and pasture separately.

We provide the best available estimates for forest biomass carbon stocks available, but it is important to note that uncertainty remains. The estimates we provide may be under or overestimating the values on the ground due to spatial variability. The science of mapping forest carbon stocks has improved considerably, but more attention has focused on estimating changing areas of forest rather than their carbon stocks. Moreover, our approach took a weighted average of forest carbon stocks within a region, and the actual value of any given forest may be higher or lower than the average. The HWSD soil database does not account for land use history in many cases, which can have large impacts on soil carbon content. We recommend the following future refinements in addition to occasional updates as merited by new datasets:

- Soil carbon:
    - Updating estimates for the US, Canada and Australia to account for high quality national data not included in the HWSD version 1.1.
    - Remove floodplains and slopes >5% in future iterations.

- Forest biomass carbon:
    - Wetland areas were excluded from soil carbon estimates but not from forest biomass; it would be ideal to also exclude from forest biomass for consistency.
    - Similarly, a MODIS forest map was used to clip the Saatchi et al. (2010) data for the tropics but not for other regions where various forest boundaries were used as identified by dataset creators. A consistent forest map could be used in the future.
    - Distinguishing between accessible and inaccessible forest would be an excellent next step. Here we provide estimates for average forest biomass carbon averaged across accessible and inaccessible forests.

- Pasture biomass carbon:

    - Consider using satellite-estimated net primary productivity to better scale pasture biomass carbon stocks.
    - Update estimates as improved datasets are published; current data is weak.

- Cropland biomass carbon:
    - Account for different carbon stocks of perennial and plantation crops if GTAP differentiates between crop types in the future.
    - Consider revisiting the West et al. (2010) methodology to account for variation in annual crops.

TABLES

Table 1: Soil carbon stock estimates for 0-30 and 0-100cm depths based on the Harmonized World Soil Database (Mg C / ha).

GTAP	Carbon in top 30 cm			Carbon in 30-100 cm			Carbon in 0-100 cm		
Region-AEZ	**Forest**	**Pasture**	**Crop**	**Forest**	**Pasture**	**Crop**	**Forest**	**Pasture**	**Crop**
Brazil-1	43.8	30.1	30.3	19.0	21.0	27.2	62.9	51.2	57.5
Brazil-2	23.3	29.7	30.3	16.8	24.6	27.2	40.1	54.3	57.5
Brazil-3	49.1	38.8	49.8	35.3	31.3	46.3	84.4	70.1	96.2
Brazil-4	44.0	44.2	31.9	39.1	37.0	29.5	83.0	81.2	61.4
Brazil-5	54.5	44.0	43.7	45.7	43.3	45.7	100.2	87.3	89.4
Brazil-6	57.3	45.0	48.1	45.0	38.0	50.4	102.3	83.0	98.5
Brazil-10	70.2	59.5	70.2	63.9	53.2	63.9	134.1	112.7	134.1
Brazil-11	17.4	30.1	53.3	12.1	27.4	51.9	29.5	57.5	105.3
Brazil-12	79.8	68.5	53.3	68.8	57.8	51.9	148.5	126.3	105.3
C_C_Am-1	32.8	24.4	32.4	35.0	26.0	32.3	67.8	50.3	64.8
C_C_Am-2	169.1	92.9	32.4	51.9	73.8	32.3	221.0	166.8	64.8
C_C_Am-3	75.9	86.6	108.7	44.3	28.4	47.1	120.1	114.9	155.8
C_C_Am-4	215.3	115.1	138.6	34.9	49.5	39.5	250.2	164.6	178.1
C_C_Am-5	219.9	88.1	90.1	43.9	61.3	50.7	263.8	149.5	140.8
C_C_Am-6	119.3	87.5	127.9	59.5	77.5	63.9	178.8	165.0	191.8
C_C_Am-7	292.7	75.6	60.3	19.1	62.0	61.1	311.8	137.6	121.4
C_C_Am-8	300.9	89.6	73.4	24.9	50.1	57.1	325.7	139.7	130.5
C_C_Am-9	129.5	70.9	79.4	55.7	54.0	80.4	185.3	124.9	159.8
C_C_Am-10	220.4	261.9	112.7	53.9	34.5	91.1	274.3	296.4	203.7
C_C_Am-11	221.8	65.5	256.0	58.5	46.5	93.6	280.2	112.0	349.5
C_C_Am-12	196.6	218.1	141.2	174.5	208.6	121.8	371.1	426.7	263.0
Canada-7	62.3	45.4	51.3	50.2	42.6	49.4	112.6	88.0	100.8
Canada-8	104.1	53.1	53.1	83.0	50.7	50.7	187.1	103.8	103.8
Canada-9	140.4	151.0	117.4	174.9	207.3	161.7	315.4	358.3	279.0
Canada-10	124.7	82.2	61.9	136.7	101.2	73.6	261.4	183.4	135.5
Canada-11	172.7	43.7	61.9	197.5	43.6	73.6	370.2	87.3	135.5
Canada-13	42.2	45.8	51.3	33.6	44.7	49.4	75.8	90.5	100.8
Canada-14	83.1	59.7	53.1	82.7	54.8	50.7	165.8	114.6	103.8
Canada-15	154.0	111.7	126.8	253.9	215.7	242.7	408.0	327.4	369.5
Canada-16	146.4	148.9	199.1	143.3	333.6	479.0	289.7	482.5	678.1
ChiHkg-5	55.4	74.7	54.8	46.5	59.6	35.1	101.9	134.3	89.8
ChiHkg-6	47.3	49.2	50.0	43.8	47.4	48.9	91.1	96.6	98.9
ChiHkg-7	75.6	45.1	56.2	41.1	40.6	43.3	116.7	85.6	99.5
ChiHkg-8	33.5	40.3	56.8	35.2	43.2	53.2	68.6	83.5	110.0
ChiHkg-9	41.9	30.3	56.5	48.2	38.4	52.7	90.1	68.7	109.2
ChiHkg-10	40.2	38.5	38.6	43.4	41.8	45.3	83.7	80.3	83.9
ChiHkg-11	45.2	47.3	43.1	41.4	45.2	52.4	86.6	92.6	95.4
ChiHkg-12	55.9	53.5	46.7	49.5	46.5	57.8	105.4	100.0	104.4
ChiHkg-13	72.6	76.0	77.1	30.5	31.8	34.5	103.1	107.8	111.5
ChiHkg-14	48.4	75.0	65.9	38.5	24.3	43.9	86.9	99.3	109.9
ChiHkg-15	42.8	84.2	75.2	39.3	28.5	61.6	82.1	112.7	136.8

ChiHkg-16	41.7	75.5	52.6	30.1	28.5	45.6	71.8	104.0	98.2
ChiHkg-17	38.9	65.3	31.1	33.3	19.9	34.0	72.2	85.2	65.1
E_Asia-4	55.5	58.8	59.5	61.4	59.6	55.3	117.0	118.4	114.8
E_Asia-5	51.3	48.9	45.8	54.2	52.6	52.8	105.5	101.4	98.6
E_Asia-6	52.9	46.4	59.1	41.4	79.8	49.1	94.3	126.2	108.2
E_Asia-7	42.7	46.8	48.8	22.2	40.1	38.3	65.0	86.9	87.1
E_Asia-8	52.0	51.5	48.8	31.2	44.2	38.3	83.1	95.7	87.1
E_Asia-9	53.7	44.8	47.8	28.7	24.5	18.6	82.4	69.3	66.4
E_Asia-10	49.6	44.6	41.4	23.5	29.4	34.4	73.1	74.0	75.8
E_Asia-11	51.4	44.6	42.0	27.5	29.4	34.5	78.9	74.0	76.5
E_Asia-12	49.7	45.3	48.0	39.4	64.5	64.2	89.1	109.8	112.3
E_Asia-13	60.7	48.5	69.4	20.5	26.8	40.2	81.2	75.3	109.6
E_Asia-14	81.3	71.2	69.4	49.2	39.4	40.2	130.4	110.6	109.6
E_Asia-15	91.7	80.7	60.4	63.2	48.1	33.3	154.9	128.8	93.7
EU27-4	64.6	59.9	46.6	48.4	52.7	47.6	113.0	112.7	94.2
EU27-8	54.0	34.1	57.3	30.3	38.0	60.3	84.3	72.1	117.5
EU27-9	187.7	50.0	55.9	314.9	37.5	66.3	502.6	87.5	122.3
EU27-10	149.0	128.7	83.4	246.6	194.6	122.2	395.6	323.3	205.6
EU27-11	73.3	102.1	58.4	75.5	148.6	63.6	148.8	250.7	122.0
EU27-12	141.0	159.5	53.2	180.9	241.1	44.8	321.9	400.6	98.0
EU27-13	85.1	58.7	73.4	61.0	22.5	7.1	146.1	81.2	80.6
EU27-14	275.4	61.7	73.4	471.5	18.3	7.1	746.9	80.0	80.6
EU27-15	358.7	74.8	266.0	688.2	28.7	505.7	1046.9	103.6	771.7
EU27-16	221.7	275.6	57.4	386.5	495.9	54.8	608.2	771.5	112.2
India-1	0.0	18.0	19.6	0.0	21.5	20.8	0.0	39.5	40.4
India-2	41.3	38.0	36.2	26.9	37.5	35.5	68.2	75.5	71.7
India-3	40.8	36.8	36.8	29.4	32.3	36.5	70.2	69.1	73.3
India-4	42.5	35.5	35.7	32.5	33.9	34.1	75.0	69.4	69.8
India-5	52.6	47.5	46.3	40.7	37.9	39.7	93.3	85.4	86.0
India-6	57.0	51.6	48.0	44.1	49.5	43.0	101.1	101.1	91.0
India-7	0.0	22.2	25.6	0.0	24.8	27.3	0.0	47.0	52.9
India-8	44.3	35.8	28.0	27.6	28.6	29.5	71.9	64.5	57.5
India-9	44.0	35.1	32.9	36.8	32.6	34.2	80.8	67.7	67.1
India-10	50.1	50.7	38.5	31.4	22.2	38.6	81.5	73.0	77.1
India-11	53.4	56.7	66.0	39.4	32.5	55.4	92.8	89.3	121.3
India-12	61.4	49.3	50.1	45.6	39.5	41.1	107.0	88.8	91.2
India-13	52.2	36.3	25.6	22.4	13.9	27.3	74.6	50.2	52.9
India-14	56.8	57.7	28.0	22.6	27.7	29.5	79.4	85.4	57.5
India-15	49.7	52.6	55.0	25.6	23.6	20.7	75.3	76.2	75.7
India-16	41.6	52.2	59.0	27.9	25.4	31.0	69.5	77.6	89.9
Japan-9	116.9	181.0	132.5	73.4	146.9	95.8	190.2	327.9	228.3
Japan-10	125.5	156.9	148.4	84.4	121.7	99.6	209.9	278.6	248.0
Japan-11	112.0	156.9	180.5	87.0	121.7	140.4	199.0	278.6	320.9
Japan-12	95.4	156.9	56.4	79.8	121.7	53.1	175.2	278.6	109.5
Japan-15	116.8	158.6	193.9	73.2	116.1	152.4	190.0	274.7	346.3
Mala_Indo-4	108.6	52.0	49.1	68.0	23.3	45.9	176.7	75.3	95.0
Mala_Indo-5	104.8	54.1	73.7	77.3	15.6	58.2	182.0	69.7	131.9
Mala_Indo-6	71.5	78.6	67.6	79.9	102.0	78.2	151.4	180.6	145.8
ME_N_Afr-1	0.0	30.6	31.5	0.0	19.5	16.1	0.0	50.2	47.6

ME_N_Afr-2	19.7	32.6	27.5	33.6	33.1	32.4	53.3	65.7	59.9
ME_N_Afr-3	0.0	30.8	35.1	0.0	33.7	31.3	0.0	64.5	66.4
ME_N_Afr-4	0.0	32.6	37.8	0.0	32.3	40.8	0.0	64.9	78.6
ME_N_Afr-7	37.9	32.1	32.4	34.8	25.6	33.9	72.8	57.8	66.3
ME_N_Afr-8	42.2	33.3	34.3	38.5	27.2	29.9	80.6	60.6	64.2
ME_N_Afr-9	48.6	35.7	38.3	29.5	28.5	33.6	78.1	64.1	71.9
ME_N_Afr-10	36.8	40.1	40.6	35.3	33.0	36.3	72.1	73.1	76.9
Oceania-1	23.6	29.6	42.8	28.7	32.5	49.5	52.4	62.1	92.3
Oceania-2	42.3	35.2	46.9	29.2	31.2	43.1	71.5	66.4	90.0
Oceania-3	51.5	38.0	46.9	41.6	34.7	43.1	93.1	72.7	90.0
Oceania-4	47.8	42.6	52.4	40.9	36.7	39.2	88.7	79.3	91.6
Oceania-5	77.9	21.2	42.6	100.7	26.4	34.7	178.6	47.6	77.3
Oceania-6	119.2	98.1	109.2	187.1	179.3	170.5	306.3	277.4	279.7
Oceania-7	32.9	28.7	29.3	31.3	31.1	30.3	64.2	59.8	59.6
Oceania-8	45.1	32.8	30.3	33.7	32.3	31.0	78.8	65.1	61.4
Oceania-9	39.8	30.6	32.0	37.6	32.3	35.8	77.4	62.8	67.8
Oceania-10	76.9	42.5	38.0	66.6	42.4	35.8	143.5	84.9	73.9
Oceania-11	69.6	49.2	49.0	75.1	47.6	37.3	144.7	96.9	86.3
Oceania-12	88.5	84.7	48.7	87.9	74.9	40.0	176.4	159.6	88.8
Oceania-15	74.6	61.4	32.0	39.1	44.1	35.8	113.7	105.5	67.8
Oceania-16	67.9	55.4	38.0	39.3	36.9	35.8	107.2	92.3	73.9
Oceania-17	114.9	64.2	49.0	205.2	68.5	37.3	320.1	132.7	86.3
Oth_CEE-7	67.0	35.2	47.2	23.6	30.9	44.7	90.6	66.2	91.8
Oth_CEE-8	49.6	31.9	64.0	29.5	26.3	62.8	79.1	58.2	126.8
Oth_CEE-9	55.0	47.3	74.5	35.5	32.9	72.6	90.5	80.2	147.2
Oth_CEE-10	106.8	54.1	95.7	148.1	23.5	122.0	254.9	77.5	217.7
Oth_CEE-11	61.3	60.1	53.5	44.5	21.0	31.6	105.7	81.1	85.1
Oth_CEE-12	61.1	52.3	56.7	35.9	20.4	29.5	97.0	72.7	86.2
Oth_CEE-13	58.1	50.5	62.7	38.7	34.4	57.8	96.8	84.9	120.6
Oth_CEE-14	63.4	56.5	66.5	32.5	27.2	55.5	96.0	83.6	122.0
Oth_CEE-15	67.6	66.1	59.7	26.4	16.9	35.0	94.0	83.0	94.7
Oth_CEE-16	61.2	61.9	56.0	36.1	15.5	35.5	97.2	77.4	91.6
Oth_Euro-9	185.1	50.0	55.9	314.7	37.5	66.3	499.8	87.5	122.3
Oth_Euro-10	130.0	66.9	119.4	196.5	93.3	191.1	326.5	160.2	310.5
Oth_Euro-11	61.0	66.9	119.4	31.7	93.3	191.1	92.8	160.2	310.5
Oth_Euro-13	65.9	22.7	73.4	32.9	7.4	7.1	98.8	30.1	80.6
Oth_Euro-14	111.1	22.7	142.3	157.2	7.4	201.5	268.3	30.1	343.8
Oth_Euro-15	180.7	50.5	142.3	314.7	31.9	201.5	495.4	82.5	343.8
Oth_Euro-16	143.5	165.1	94.1	211.7	253.3	132.0	355.2	418.4	226.1
R_S_Asia-1	0.0	26.5	26.5	0.0	19.4	19.4	0.0	45.9	45.9
R_S_Asia-2	0.0	26.5	26.5	0.0	19.4	19.4	0.0	45.9	45.9
R_S_Asia-3	42.6	35.9	47.0	38.7	37.0	51.1	81.3	72.9	98.0
R_S_Asia-4	49.4	56.3	55.9	47.0	49.9	49.3	96.4	106.3	105.2
R_S_Asia-5	59.9	51.8	66.1	53.8	39.5	56.3	113.7	91.3	122.4
R_S_Asia-6	57.6	48.3	72.4	72.2	59.0	117.4	129.8	107.2	189.8
R_S_Asia-7	29.4	27.8	27.8	32.9	20.9	26.4	62.3	48.7	54.2
R_S_Asia-8	39.0	28.8	28.8	14.8	17.2	31.2	53.8	46.0	59.9
R_S_Asia-9	45.3	37.3	27.9	14.2	14.5	24.2	59.4	51.8	52.1
R_S_Asia-10	72.8	38.7	32.2	86.7	38.0	32.5	159.5	76.7	64.7

R_S_Asia-11	77.9	72.4	33.6	79.7	73.2	35.6	157.6	145.6	69.3
R_S_Asia-12	80.5	101.2	41.7	77.0	149.4	33.8	157.6	250.6	75.5
R_S_Asia-13	47.0	35.2	36.6	32.9	10.2	10.8	79.9	45.4	47.4
R_S_Asia-14	54.2	33.2	35.3	37.3	10.0	10.0	91.5	43.1	45.3
R_S_Asia-15	78.8	44.3	78.3	84.1	12.9	79.6	162.9	57.2	157.9
R_S_Asia-16	75.7	44.6	32.2	60.5	18.2	32.5	136.2	62.8	64.7
R_SE_Asia-4	46.6	41.0	40.1	37.6	35.0	34.1	84.1	76.0	74.2
R_SE_Asia-5	48.0	44.7	40.6	38.5	36.3	39.4	86.5	81.0	79.9
R_SE_Asia-6	52.6	47.6	55.1	42.4	37.6	43.0	95.0	85.2	98.1
R_SE_As-10	46.3	47.7	44.2	37.2	38.4	35.7	83.4	86.1	79.8
R_SE_As-11	50.5	47.7	47.4	40.1	38.4	38.8	90.6	86.1	86.3
R_SE_As-12	53.6	47.5	50.3	37.8	38.6	38.1	91.5	86.1	88.4
R_SE_As-15	77.2	33.2	78.3	32.9	10.0	79.6	110.1	43.1	157.9
R_SE_As-16	71.9	44.3	44.2	32.9	12.9	35.7	104.8	57.2	79.8
Russia-7	62.1	41.9	53.0	57.4	39.9	52.0	119.5	81.8	105.1
Russia-8	65.7	57.4	72.1	53.7	55.4	70.2	119.4	112.8	142.3
Russia-9	123.4	68.4	74.4	206.5	71.5	68.9	329.9	139.9	143.3
Russia-10	162.1	109.7	86.3	301.2	161.7	93.9	463.3	271.5	180.2
Russia-11	57.3	72.0	84.6	26.3	39.3	85.4	83.6	111.3	170.0
Russia-12	48.1	72.0	84.6	34.3	39.3	85.4	82.4	111.3	170.0
Russia-13	41.0	55.6	56.6	53.8	49.4	52.7	94.8	105.0	109.3
Russia-14	110.0	61.6	63.7	118.7	57.9	60.5	228.7	119.5	124.3
Russia-15	152.8	101.1	81.0	243.7	150.5	87.5	396.5	251.5	168.4
Russia-16	45.5	71.4	60.9	43.6	70.9	44.5	89.1	142.3	105.4
S_O_Am-1	46.8	43.5	63.8	44.1	34.2	60.1	90.9	77.8	124.0
S_O_Am-2	66.5	20.1	74.3	51.8	31.6	76.4	118.3	51.7	150.7
S_O_Am-3	58.9	16.9	68.9	55.5	19.8	42.2	114.4	36.7	111.1
S_O_Am-4	52.2	81.6	53.5	47.6	59.6	55.4	99.8	141.3	108.9
S_O_Am-5	72.0	85.0	79.6	53.7	57.8	76.2	125.6	142.9	155.8
S_O_Am-6	93.0	157.0	223.1	59.7	80.1	126.3	152.7	237.1	349.5
S_O_Am-7	45.3	35.0	39.6	35.3	40.6	32.9	80.6	75.6	72.5
S_O_Am-8	45.8	41.9	39.7	38.0	40.2	39.2	83.8	82.1	78.9
S_O_Am-9	67.3	63.6	49.1	57.4	60.4	47.1	124.7	124.1	96.2
S_O_Am-10	73.2	50.9	84.8	55.4	55.1	65.2	128.6	106.0	150.0
S_O_Am-11	95.9	64.9	164.4	83.6	49.1	109.8	179.5	114.0	274.2
S_O_Am-12	143.3	92.8	50.6	121.3	68.1	41.0	264.6	161.0	91.6
S_O_Am-13	80.6	88.6	46.9	73.3	82.1	10.8	154.0	170.8	57.7
S_O_Am-14	137.4	85.6	46.9	132.1	89.0	10.8	269.5	174.6	57.7
S_O_Am-15	197.7	63.0	61.3	107.6	29.0	23.1	305.3	92.0	84.4
S_O_Am-16	202.4	47.0	48.1	150.9	22.3	23.6	353.3	69.4	71.8
S_O_Am-17	220.3	49.5	48.1	183.4	8.0	23.6	403.8	57.6	71.8
S_O_Am-18	50.3	36.8	48.1	23.8	12.6	23.6	74.1	49.3	71.8
S_S_Afr-1	45.2	24.4	21.3	54.6	21.4	24.8	99.8	45.9	46.1
S_S_Afr-2	39.5	28.7	24.3	33.4	27.9	26.8	72.9	56.5	51.2
S_S_Afr-3	39.0	37.7	33.5	25.7	36.3	27.7	64.7	74.1	61.3
S_S_Afr-4	39.7	40.9	38.9	34.0	36.3	29.7	73.7	77.2	68.6
S_S_Afr-5	52.2	41.3	41.2	46.4	32.6	33.7	98.6	73.9	74.9
S_S_Afr-6	54.6	45.7	47.0	49.7	40.6	40.3	104.4	86.3	87.4
S_S_Afr-7	22.7	16.2	18.5	14.6	15.7	25.0	37.3	31.9	43.5

S_S_Afr-8	32.6	17.4	18.9	19.3	18.2	25.7	51.8	35.6	44.6
S_S_Afr-9	35.1	31.9	22.9	28.5	26.8	22.6	63.6	58.7	45.5
S_S_Afr-10	36.0	35.9	29.5	28.9	26.5	29.1	64.9	62.4	58.6
S_S_Afr-11	38.8	43.1	27.8	24.5	24.1	15.0	63.3	67.2	42.8
S_S_Afr-12	34.2	28.8	36.0	34.2	26.0	37.9	68.3	54.9	73.9
USA-7	62.3	38.9	45.5	50.2	43.5	46.4	112.6	82.4	91.9
USA-8	104.1	43.2	55.8	83.0	47.9	53.1	187.1	91.1	108.9
USA-9	101.3	47.4	59.5	106.0	48.3	57.2	207.3	95.7	116.7
USA-10	81.2	49.6	62.7	90.5	50.9	56.2	171.7	100.5	118.9
USA-11	53.6	43.7	53.1	44.8	43.6	46.3	98.4	87.3	99.5
USA-12	46.5	39.6	41.8	44.5	37.0	35.8	91.0	76.6	77.6
USA-13	81.5	45.8	50.2	71.5	44.7	50.1	153.0	90.5	100.3
USA-14	119.5	59.7	50.2	158.0	54.8	50.1	277.5	114.6	100.3
USA-15	229.7	111.7	59.5	406.5	215.7	57.2	636.2	327.4	116.7
USA-16	303.0	148.9	62.7	467.5	333.6	56.2	770.5	482.5	118.9

Table 2: Range of canopy thresholds used to identify the area and locations of cropland and pasture for the soil carbon estimation. The estimates are based on a minimum of 1% area coverage at the given threshold. No star indicates 66% Pasture / Cropland Coverage, * 50% Pasture / Cropland Coverage, ** 25-50% Pasture / Cropland Coverage, *** 10-25% Pasture / Cropland Coverage, **** Less than 10% Pasture / Cropland Coverage

GTAP Region –AEZ	% Pasture	% Cropland
Brazil-1	**	****
Brazil-2		**
Brazil-3		*
Brazil-4		**
Brazil-5		*
Brazil-6		*
Brazil-10		***
Brazil-11		****
Brazil-12		
C_C_Amer-1		****
C_C_Amer-2		
C_C_Amer-3		
C_C_Amer-4		
C_C_Amer-5		
C_C_Amer-6		
C_C_Amer-7		
C_C_Amer-8		
C_C_Amer-9		
C_C_Amer-10		
C_C_Amer-11		
C_C_Amer-12	*	
Canada-7		
Canada-8		**
Canada-9	*	
Canada-10	***	
Canada-11	****	****
Canada-13	****	****
Canada-14	****	****
Canada-15	***	***
Canada-16	**	
ChiHkg-5	*	
ChiHkg-6		
ChiHkg-7		*
ChiHkg-8		
ChiHkg-9		
ChiHkg-10		
ChiHkg-11		
ChiHkg-12		

ChiHkg-13		***
ChiHkg-14		***
ChiHkg-15		
ChiHkg-16		**
ChiHkg-17		***
E_Asia-4	**	***
E_Asia-5	**	**
E_Asia-6	**	***
E_Asia-7		****
E_Asia-8		***
E_Asia-9	***	**
E_Asia-10	***	
E_Asia-11	****	
E_Asia-12	**	**
E_Asia-13		****
E_Asia-14		***
E_Asia-15		**
EU27-4	***	***
EU27-8	**	
EU27-9	**	
EU27-10		
EU27-11		
EU27-12		
EU27-13		****
EU27-14	***	
EU27-15	*	
EU27-16		
India-1	***	
India-2	**	
India-3	***	
India-4	***	
India-5	**	
India-6	***	
India-7	***	
India-8	***	
India-9	***	
India-10		
India-11		
India-12	***	*
India-13	***	****
India-14	**	****
India-15		***
India-16		***
Japan-9	***	*
Japan-10	***	*
Japan-11	****	*

Japan-12	****	*
Japan-15	***	
Mala_Indo-4	*	
Mala_Indo-5	**	
Mala_Indo-6	***	
ME_N_Afr-1		
ME_N_Afr-2		
ME_N_Afr-3	**	
ME_N_Afr-4		
ME_N_Afr-7		
ME_N_Afr-8		
ME_N_Afr-9		
ME_N_Afr-10		
Oceania-1		
Oceania-2		
Oceania-3		****
Oceania-4		***
Oceania-5		***
Oceania-6	***	***
Oceania-7		
Oceania-8		
Oceania-9		
Oceania-10		
Oceania-11		*
Oceania-12		*
Oceania-15		****
Oceania-16		****
Oceania-17		****
Oth_CEE_CIS-7		
Oth_CEE_CIS-8		
Oth_CEE_CIS-9		
Oth_CEE_CIS-10	*	
Oth_CEE_CIS-11		
Oth_CEE_CIS-12		
Oth_CEE_CIS-13		
Oth_CEE_CIS-14		
Oth_CEE_CIS-15		*
Oth_CEE_CIS-16		*
Oth_Europe-9	****	****
Oth_Europe-10		
Oth_Europe-11	****	****
Oth_Europe-13		****
Oth_Europe-14	****	****
Oth_Europe-15	**	***
Oth_Europe-16	**	*
R_S_Asia-1	***	**

R_S_Asia-2	****	****
R_S_Asia-3	***	*
R_S_Asia-4	**	
R_S_Asia-5	**	
R_S_Asia-6	**	
R_S_Asia-7		
R_S_Asia-8		
R_S_Asia-9		
R_S_Asia-10	**	
R_S_Asia-11	*	
R_S_Asia-12	**	
R_S_Asia-13		**
R_S_Asia-14		**
R_S_Asia-15		***
R_S_Asia-16		****
R_SE_Asia-4	***	
R_SE_Asia-5	***	*
R_SE_Asia-6	***	
R_SE_Asia-10	****	**
R_SE_Asia-11	***	**
R_SE_Asia-12	***	**
R_SE_Asia-15	****	****
R_SE_Asia-16	****	****
Russia-7		
Russia-8		
Russia-9	*	
Russia-10	**	
Russia-11	***	
Russia-12	****	****
Russia-13	*	
Russia-14	**	
Russia-15	**	
Russia-16		
S_O_Amer-1	*	**
S_O_Amer-2		***
S_O_Amer-3		**
S_O_Amer-4		*
S_O_Amer-5		**
S_O_Amer-6		***
S_O_Amer-7		***
S_O_Amer-8		
S_O_Amer-9		
S_O_Amer-10		
S_O_Amer-11		
S_O_Amer-12		
S_O_Amer-13		****

S_O_Amer-14		***
S_O_Amer-15		***
S_O_Amer-16		**
S_O_Amer-17	**	****
S_O_Amer-18	***	****
S_S_Afr-1		
S_S_Afr-2		
S_S_Afr-3		
S_S_Afr-4		
S_S_Afr-5		
S_S_Afr-6		
S_S_Afr-7		
S_S_Afr-8		
S_S_Afr-9		
S_S_Afr-10		
S_S_Afr-11		
S_S_Afr-12	**	*
USA-7		
USA-8		
USA-9		
USA-10		
USA-11	*	
USA-12	**	
USA-13		*
USA-14	*	****
USA-15	****	****
USA-16	****	****

Table 3: Portion of region covered by each pasture and cropland threshold

Land Cover	**Threshold**	**% of GTAPAEZ**
Crop	66%	59%
	50%	6%
	25-50%	13%
	10-50%	14%
	Expert Judgment	8%
Pasture	66%	56%
	50%	9%
	25-50%	9%
	10-50%	11%
	Expert Judgment	15%

Table 4: Total aboveground and belowground living forest biomass carbon stocks (Mg C / ha) estimated from a range of spatially-explicit datasets; source data indicated.

GAEZ_ID	Total Living Biomass Carbon (Mg C / ha)	Data Source
BRAZIL1	13.5	Saatchi
BRAZIL2	10.5	Saatchi
BRAZIL3	44.1	Saatchi
BRAZIL4	71.5	Saatchi
BRAZIL5	128.1	Saatchi
BRAZIL6	149.1	Saatchi
BRAZIL10	68.5	Saatchi
BRAZIL11	48.8	Saatchi
BRAZIL12	72.3	Saatchi
C_C_Amer1	14.5	Saatchi
C_C_Amer2	31.7	Saatchi
C_C_Amer3	63.0	Saatchi
C_C_Amer4	67.7	Saatchi
C_C_Amer5	83.6	Saatchi
C_C_Amer6	121.6	Saatchi
C_C_Amer7	39.1	Saatchi
C_C_Amer8	42.3	Saatchi
C_C_Amer9	32.7	Saatchi
C_C_Amer10	51.3	Saatchi
C_C_Amer11	67.1	Saatchi
C_C_Amer12	100.1	Saatchi
CAN7	21.86	Ruesch and Gibbs
CAN8	29.36	Ruesch and Gibbs
CAN9	32.74	Ruesch and Gibbs
CAN10	36.96	Ruesch and Gibbs
CAN11	31.65	Ruesch and Gibbs
CAN13	13.09	Ruesch and Gibbs
CAN14	25.04	Ruesch and Gibbs
CAN15	30.47	Ruesch and Gibbs
CAN16	35.50	Ruesch and Gibbs
CHIHKG5	156.51	Saatchi
CHIHKG6	149.06	Saatchi
CHIHKG7	27.60	Ruesch and Gibbs
CHIHKG8	36.58	Ruesch and Gibbs
CHIHKG9	23.87	Ruesch and Gibbs
CHIHKG10	24.84	Ruesch and Gibbs
CHIHKG11	107.78	Saatchi

CHIHKG12	121.60	Saatchi
CHIHKG13	121.13	Saatchi
CHIHKG14	125.02	Saatchi
CHIHKG15	142.97	Saatchi
CHIHKG16	136.55	Saatchi
CHIHKG17	140.90	Saatchi
E_Asia4	90.91	Ruesch and Gibbs
E_Asia5	89.65	Ruesch and Gibbs
E_Asia6	101.06	Ruesch and Gibbs
E_Asia7	8.13	Ruesch and Gibbs
E_Asia8	18.98	Ruesch and Gibbs
E_Asia9	13.55	Ruesch and Gibbs
E_Asia10	13.44	Ruesch and Gibbs
E_Asia11	24.15	Ruesch and Gibbs
E_Asia12	98.99	Ruesch and Gibbs
E_Asia13	16.34	Ruesch and Gibbs
E_Asia14	17.66	Ruesch and Gibbs
E_Asia15	22.01	Ruesch and Gibbs
EU274	0.00	no forest
EU278	24.79	Ruesch and Gibbs
EU279	40.38	Ruesch and Gibbs
EU2710	35.17	Ruesch and Gibbs
EU2711	54.58	Ruesch and Gibbs
EU2712	60.22	Ruesch and Gibbs
EU2713	26.94	Ruesch and Gibbs
EU2714	20.07	Ruesch and Gibbs
EU2715	31.93	Ruesch and Gibbs
EU2716	44.10	Ruesch and Gibbs
INDIA1	7.57	Saatchi
INDIA2	43.99	Saatchi
INDIA3	98.16	Saatchi
INDIA4	141.67	Saatchi
INDIA5	154.14	Saatchi
INDIA6	184.51	Saatchi
INDIA7	8.52	Ruesch and Gibbs
INDIA8	41.32	Saatchi
INDIA9	103.37	Saatchi
INDIA10	110.90	Saatchi
INDIA11	147.49	Saatchi
INDIA12	187.46	Saatchi
INDIA13	161.46	Saatchi
INDIA14	105.64	Saatchi
INDIA15	131.11	Saatchi
INDIA16	145.76	Saatchi
JAPAN9	51.69	Ruesch and Gibbs
JAPAN10	97.81	Saatchi

JAPAN11	109.19	Saatchi
JAPAN12	116.93	Saatchi
JAPAN15	50.85	Ruesch and Gibbs
Mala_Ind4	133.26	Saatchi
Mala_Ind5	119.26	Saatchi
Mala_Ind6	163.92	Saatchi
MEAS_NAfr1	50.03	Ruesch and Gibbs
MEAS_NAfr2	58.34	Ruesch and Gibbs
MEAS_NAfr3	50.21	Ruesch and Gibbs
MEAS_NAfr4	66.87	Ruesch and Gibbs
MEAS_NAfr7	79.81	Ruesch and Gibbs
MEAS_NAfr8	66.44	Ruesch and Gibbs
MEAS_NAfr9	51.31	Ruesch and Gibbs
MEAS_NAfr10	67.23	Ruesch and Gibbs
Oceania1	31.41	Saatchi
Oceania2	32.51	Saatchi
Oceania3	123.59	Saatchi
Oceania4	128.88	Saatchi
Oceania5	110.38	Saatchi
Oceania6	158.59	Saatchi
Oceania7	86.36	Ruesch and Gibbs
Oceania8	90.29	Ruesch and Gibbs
Oceania9	89.25	Ruesch and Gibbs
Oceania10	102.30	Ruesch and Gibbs
Oceania11	107.22	Ruesch and Gibbs
Oceania12	128.10	Ruesch and Gibbs
Oceania15	57.72	Ruesch and Gibbs
Oceania16	68.76	Ruesch and Gibbs
Oceania17	117.54	Ruesch and Gibbs
Oth_CEE_CIS7	15.24	Ruesch and Gibbs
Oth_CEE_CIS8	46.14	Ruesch and Gibbs
Oth_CEE_CIS9	57.36	Ruesch and Gibbs
Oth_CEE_CIS10	23.67	Ruesch and Gibbs
Oth_CEE_CIS11	28.56	Ruesch and Gibbs
Oth_CEE_CIS12	70.21	Ruesch and Gibbs
Oth_CEE_CIS13	17.93	Ruesch and Gibbs
Oth_CEE_CIS14	31.61	Ruesch and Gibbs
Oth_CEE_CIS15	33.75	Ruesch and Gibbs
Oth_CEE_CIS16	58.13	Ruesch and Gibbs
R_Europe9	28.11	Ruesch and Gibbs
R_Europe10	41.53	Ruesch and Gibbs
R_Europe11	65.43	Ruesch and Gibbs
R_Europe13	49.75	Ruesch and Gibbs
R_Europe14	8.76	Ruesch and Gibbs
R_Europe15	21.27	Ruesch and Gibbs
R_Europe16	21.95	Ruesch and Gibbs

R_SAsia1	11.29	Saatchi
R_SAsia2	0.00	too small
R_SAsia3	85.90	Saatchi
R_SAsia4	105.76	Saatchi
R_SAsia5	138.13	Saatchi
R_SAsia6	141.12	Saatchi
R_SAsia7	36.50	Saatchi
R_SAsia8	73.35	Saatchi
R_SAsia9	89.37	Saatchi
R_SAsia10	141.05	Saatchi
R_SAsia11	152.16	Saatchi
R_SAsia12	169.09	Saatchi
R_SAsia13	117.92	Saatchi
R_SAsia14	117.38	Saatchi
R_SAsia15	165.17	Saatchi
R_SAsia16	172.03	Saatchi
R_SE_Asia4	161.83	Saatchi
R_SE_Asia5	170.22	Saatchi
R_SE_Asia6	171.14	Saatchi
R_SE_Asia10	131.66	Saatchi
R_SE_Asia11	174.03	Saatchi
R_SE_Asia12	186.00	Saatchi
R_SE_Asia15	152.64	Saatchi
R_SE_Asia16	185.80	Saatchi
Russia7	39.96	Houghton
Russia8	45.75	Houghton
Russia9	46.98	Houghton
Russia10	45.84	Houghton
Russia11	49.91	Houghton
Russia12	0.00	too small
Russia13	28.05	Houghton
Russia14	39.34	Houghton
Russia15	44.44	Houghton
Russia16	48.16	Houghton
S_o_Amer1	33.87	Saatchi
S_o_Amer2	74.02	Saatchi
S_o_Amer3	58.77	Saatchi
S_o_Amer4	96.76	Saatchi
S_o_Amer5	120.02	Saatchi
S_o_Amer6	160.56	Saatchi
S_o_Amer7	24.27	Saatchi
S_o_Amer8	25.36	Saatchi
S_o_Amer9	38.30	Saatchi
S_o_Amer10	71.74	Saatchi
S_o_Amer11	71.61	Saatchi
S_o_Amer12	79.87	Saatchi

S_o_Amer13	41.05	Saatchi
S_o_Amer14	56.38	Saatchi
S_o_Amer15	51.61	Saatchi
S_o_Amer16	55.92	Saatchi
S_o_Amer17	67.37	Saatchi
S_o_Amer18	84.92	Saatchi
S_S_AFR1	49.28	Saatchi
S_S_AFR2	50.88	Saatchi
S_S_AFR3	39.22	Saatchi
S_S_AFR4	52.95	Saatchi
S_S_AFR5	108.42	Saatchi
S_S_AFR6	159.34	Saatchi
S_S_AFR7	56.58	Saatchi
S_S_AFR8	49.74	Saatchi
S_S_AFR9	49.30	Saatchi
S_S_AFR10	48.82	Saatchi
S_S_AFR11	53.92	Saatchi
S_S_AFR12	68.82	Saatchi
USA7	60.77	Kellndorfer
USA8	91.58	Kellndorfer
USA9	107.89	Kellndorfer
USA10	86.73	Kellndorfer
USA11	89.16	Kellndorfer
USA12	67.63	Kellndorfer
USA13	90.45	Kellndorfer
USA14	103.63	Kellndorfer
USA15	152.77	Kellndorfer
USA16	219.89	Kellndorfer

Table 5: Pasture biomass carbon stocks based on IPCC Tier-1 default values

AEZ Zone ID	Latitude	Humidity	Total C (Mg C /ha)
1	Boreal	Dry & Wet	4.3
2	Temperate	Cold, dry	3.2
3	Temperate	Cold, wet	6.0
4	Temperate	Warm, dry	3.0
5	Temperate	Warm, wet	6.8
6	Tropical	Dry	4.4
7	Tropical	Moist & wet	8.1
8	Temperate	Dry (avg cold & warm)	3.1
9	Temperate	Wet (avg cold & warm)	6.4

Table 6: Comparison between data sources used for CARB analysis presented here and the USEPA created by Harris et al. (2009)

Parameter	**CARB (Gibbs & Yui 2011l)**	**USEPA (Harris et al 2009)**	**Comments**
Soil Carbon	HWSD	HWSD	Same
Crop Biomass	IPCC Default	IPCC Default	Same
Pasture Biomass	IPCC Default	IPCC Default & Castro and Kauffman (1998) for Brazil	CARB only considers managed pasture whereas USEPA has a broader grassland, savanna, and shrubland continuum
Forest Biomass - Tropics	Saatchi et al. (2011)	Saatchi et al (2011) for S. Am, Gibbs and Brown (2007) for Africa, & Brown et al. (2001) for SE Asia	The finalized Saatchi et al. (2011) satellite-based data was not available until after the USEPA work was completed, and represents an improvement
Forest Biomass - Russia	Houghton et al. (2011)	Houghton et al. (2011)	Same
Forest Biomass - USA	NLCD2000	Blackard et al. (2008)	NLCD2000 combines Forest Inventory Analysis (FIA) data with satellite information while Blackard et al. (2008) used the FIA directly to generate a spatially-explicit dataset
Forest Biomass - China	Saatchi et al. (2011) & Ruesch and Gibbs (2008)	Piao et al. (2008)	Piao et al. (2005) is not spatially explicit; Saatchi et al (2011) is an improvement
Forest Biomass - Europe	Ruesch and Gibbs (2008)	Naburrs et al. (2003)	Nabuurs et al. (2003) is not spatially explicit but has the strength of more regional data than Ruesch and Gibbs (2008).
Forest Biomass - Australia	Ruesch and Gibbs (2008)	Ruesch and Gibbs (2008)	Same
Forest Biomass - Canada	Ruesch and Gibbs (2008)	Ruesch and Gibbs (2008)	Same
Forest Biomass - Other	Ruesch and Gibbs (2008)	Ruesch and Gibbs (2008)	Both CARB and USEPA used Ruesch and Gibbs (2008) to fill in gaps between other, more detailed datasets

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APPENDIX

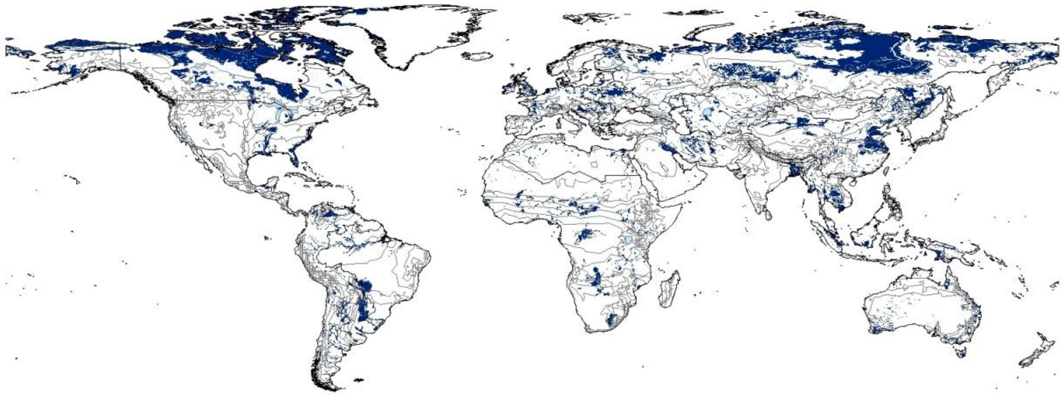

Figure A1: USDA wetlands map used as part of wetlands filter (Reich 1997)

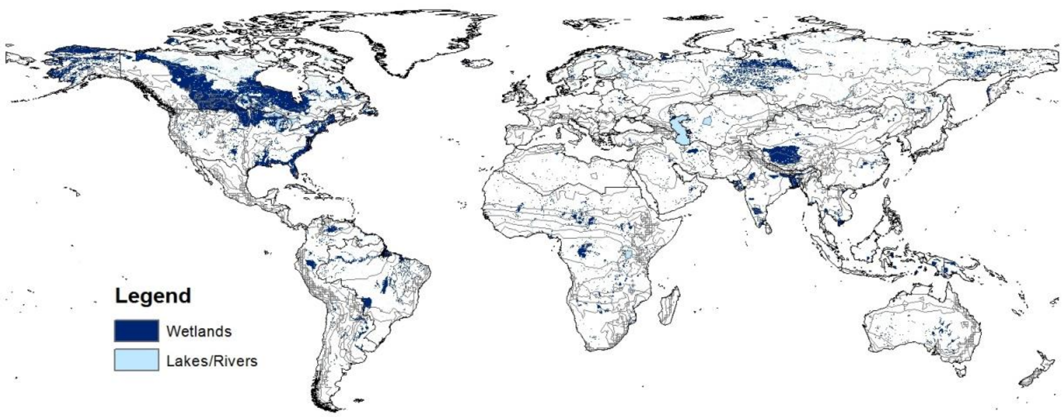

Figure A2: Global Lakes and Wetlands Database used as part of wetlands filter (GLWD; Lehner and Döll 2004).

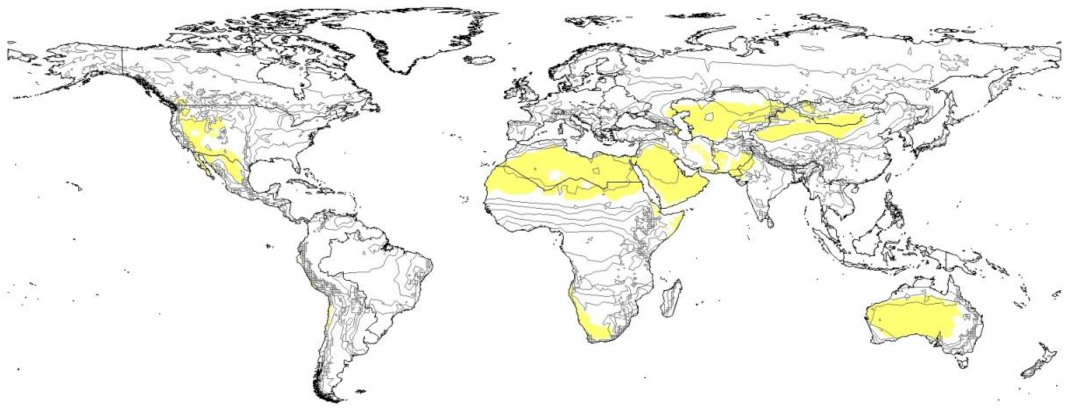

Figure A3: Desert map used as part of desert filter (FAO Ecoregion)

Table A1: Comparison of GLWD with USDA global wetland map

	GLWD (Lehner and 2004)	USDA (Reich 1997)
Date published	2004	1997
Source data	Existing maps, data, & info	FAO – UNESCO Soil Map of the World combined with soil climate map
Time period covered by source data	1992-2000 (see literature for details)	FAO/UNESCO 1971-1981; soil climate map dates unknown
Spatial resolution	1:3,000,000	1:5,000,000
Spatial resolution	0.5 minute grid cell (~1km)	2 minute grid cell (~4km)
Number of classes	9	5
Coverage	Global	Global

Table A2: Forest carbon estimates by GTAP regions based on WHRC carbon values*

GTAP	**WHRC**	**Forest Mg C/ha****
USA	United States	171
EU27	Europe	123
BRAZIL	Latin America	91
CAN	Canada	160
JAPAN	Pacific Developed	92
CHIHKG	China India Pakistan	136
INDIA	China India Pakistan	136
C_C_AMER	Latin America	91
S_O_AMER	Latin America	91
E_ASIA	Pacific Developed	92
MALA_INDO	South & Southeast Asia	221
R_SE_ASIA	South & Southeast Asia	221
R_S_ASIA	South & Southeast Asia	221
RUSSIA	Former Soviet Union	150
OTH_CEE_CIS	Europe	123
R_EUROPE	Europe	123
MEAS_NAFR	North Africa/Mid East	27
S_S_AFR	Africa	60
OCEANIA	Pacific Developed	92

* Table from Tyner et al 2010 Table 11
** Estimates from Searchinger et al 2008 SI – Average carbon stocks in undisturbed vegetation