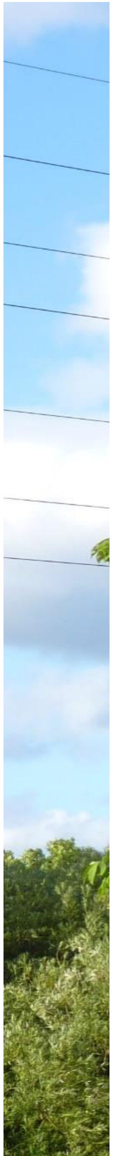


Examining the Role of Forests and Trees in Montgomery County's Greenhouse Gas Inventory

July 2020

Summary

Forests and trees outside of forests are a significant part of the earth's "carbon cycle," which is the natural transfer of carbon between the atmosphere, plants and animals, oceans, soils and rocks, and other carbon-containing elements of the natural world. Forests and trees can absorb and retain carbon (removing CO2 from the atmosphere, and thus be a carbon "sink") or they can release carbon (be a carbon "source"). As trees grow, they retain carbon, and when the die, they release carbon. Adopting strategies to retain and increase forests and trees and to minimize their removal can help lower net greenhouse gas (GHG) emissions in the County.

Forests and trees play a key role in mitigating climate change, yet they are often not included in local GHG inventories or climate action plans. In 2019, Montgomery County engaged in this study as the first step towards understanding how local changes in land use and tree canopy have contributed to the county's net greenhouse gas profile. This information can be useful when designing climate actions that reduce GHG emissions and/or increase removals of GHGs from the atmosphere.

Data on the extent of land covered by forests and trees in the County has been collected for many years, first through analysis of satellite imagery as part of the National Land Cover Database (NLCD) and more recently with a remote sensing technique known as LiDAR (which stands for Light Detection and Ranging). Although the timing of data collection for forests and trees did not coincide exactly with the County's GHG emissions inventories – which analyzed emissions from building energy use, transportation, and several other sources in 2005 and 2015 – reasonable surrogates were identified. In order to determine the extent to which changes in forest and tree cover impacted GHG emissions in these inventory years, this study utilized available data showing the changes in these resources from 2001 to 2011 (to represent the 2005 inventory) and 2011 to 2016 (to represent the 2015 inventory). Because LiDAR data is significantly more precise than the NLCD data, the analysis was supplemented with LiDAR data available from 2009 and 2014. More details on these analysis techniques are provided in the *Data Input* section.

Key findings:

- **Roughly one third of Montgomery County's land base is forest. Many areas outside of forests are also covered by trees, including an average of nearly 50 percent tree canopy in developed areas.**
- **In the period 2011-2016, average annual emissions as a result of the loss of forests and trees were less than the period 2001-2011.**
- **The County's tree canopy also increased during the 2011-2016 period, which resulted in higher annual removals of CO_2 compared to 2001-2011.**
- **Between 2005 and 2015, overall (i.e. all sectors) emissions in Montgomery County dropped 14%. When including the impact of forests and trees, this emission reduction increases to 16%.**
- **Montgomery County's net GHG emissions could be lower if additional forests and trees were added to its land base, or if losses of these resources were reduced further.**

Figure 1. Montgomery County's average annual GHG emissions from forests and trees for 2001-2011 and 2011-2016

All values in metric tons of CO_2/year. Positive values represent a CO_2 emission, negative values represent a CO_2 removal.

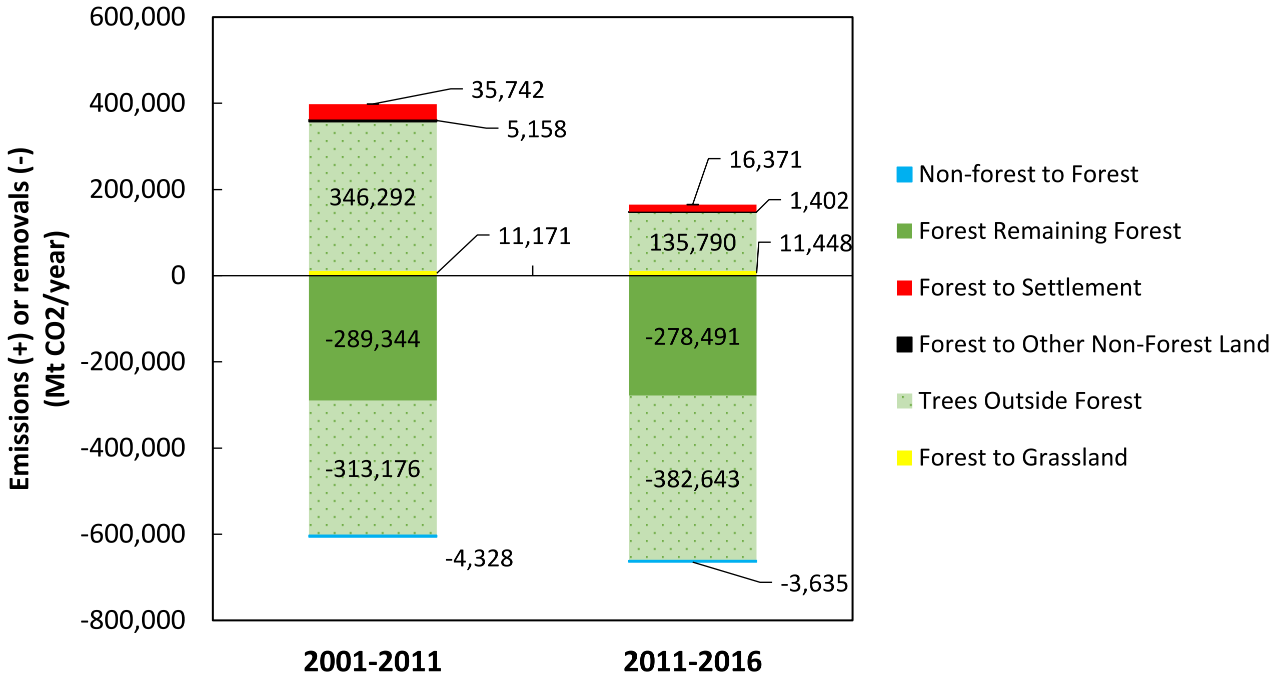


Table 1. Montgomery County's average annual GHG emissions from forests and trees for 2001-2011 and 2011-2016

All values in metric tons of CO_2/year. Positive values represent a CO_2 emission, and negative values represent a CO_2 removal.

Reporting category	2001-2011	2011-2016
Emissions of CO_2 (Mt) per year		
Forest → Settlement[1]	35,742	16,371
Forest → Other Land[1]	5,158	1,402
Forest → Grassland[1]	11,171	11,448
TOTAL FORESTS	52,071	29,221
Trees outside forest[2]	346,292	135,790
TOTAL ALL LANDS	398,362	165,011
Removals of CO_2 (Mt) per year		
Forest → Forest[3]	-289,344	-278,491
Non-forest → Forest[4]	-4,328	-3,635
TOTAL FORESTS	-293,672	-282,126
Trees outside forest[5]	-313,176	-382,643
TOTAL ALL LANDS	-606,848	-664,769
Net change in CO_2 Emissions (Mt) per year		
TOTAL ALL LANDS	**-208,486**	**-499,759**

[1] Emissions of stored carbon from converting forest land to a non-forest use.
[2] Emissions of stored carbon from loss of tree canopy outside forest.
[3] Net CO_2 removals for forest remaining forest, including both removals of CO_2 due to growth and emissions of CO_2 from normal mortality (trees that die during the natural process of self-thinning during stand development) and disturbance (larger-scale, episodic events such as wildfire or insect outbreaks).
[4] Net CO_2 removals for afforestation and reforestation, average of first 20 years after conversion from non-forest.
[5] Net CO_2 Removals from trees that remained or were added during the inventory period.

Data Inputs

Data sets used as inputs into the carbon emission and removal calculations are described below.

Land Cover

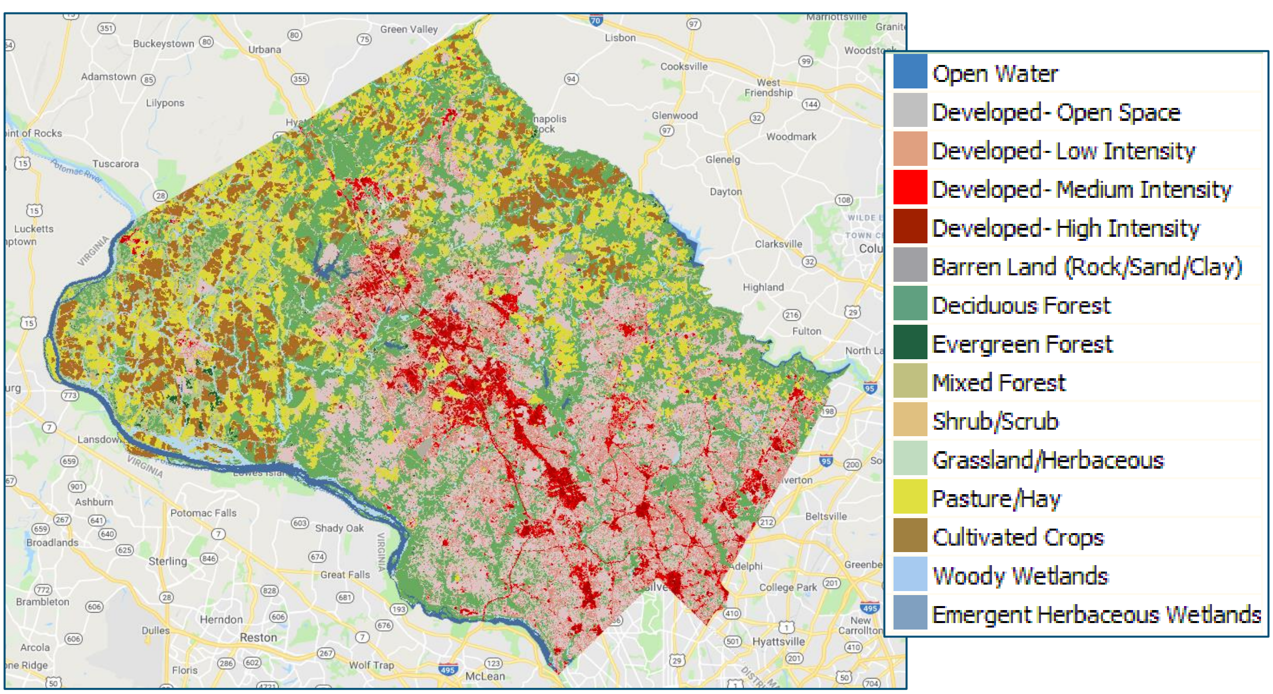
GHG inventories for lands are reported in six "land use" categories—forest land, grassland, cropland, wetland, settlement and other land (barren, snow, ice)—and the National Land Cover Database (NLCD) was used to classify all lands within Montgomery County into these categories. In 2016, Montgomery County was nearly 40% "settlement" (i.e. developed areas of varying intensity), around one-third forest, 17% grassland (which includes hay/pasture, shrub/scrub and other herbaceous cover), 8% cropland and 2% wetland. There was an insignificant amount (i.e. less than 1%) of "other land".

Table 2: Land cover in Montgomery County (in hectares)

Source: National Land Cover Database

	2001	%	2011	%	2016	%
Forest land	44,890	34.2	44,212	33.7	44,229	33.7
Grassland	23,927	18.2	22,331	17.0	21,662	16.5
Cropland	10,192	7.8	10,629	8.1	10,754	8.2
Wetland	3,010	2.3	3,046	2.3	2,997	2.3
Settlement	49,004	37.3	50,832	38.7	51,408	39.2
Other land	244	0.2	217	0.2	217	0.2
Total	131,267	100	131,267	100	131,267	100

Figure 2. Land cover in Montgomery County from the National Land Cover Database (2011)

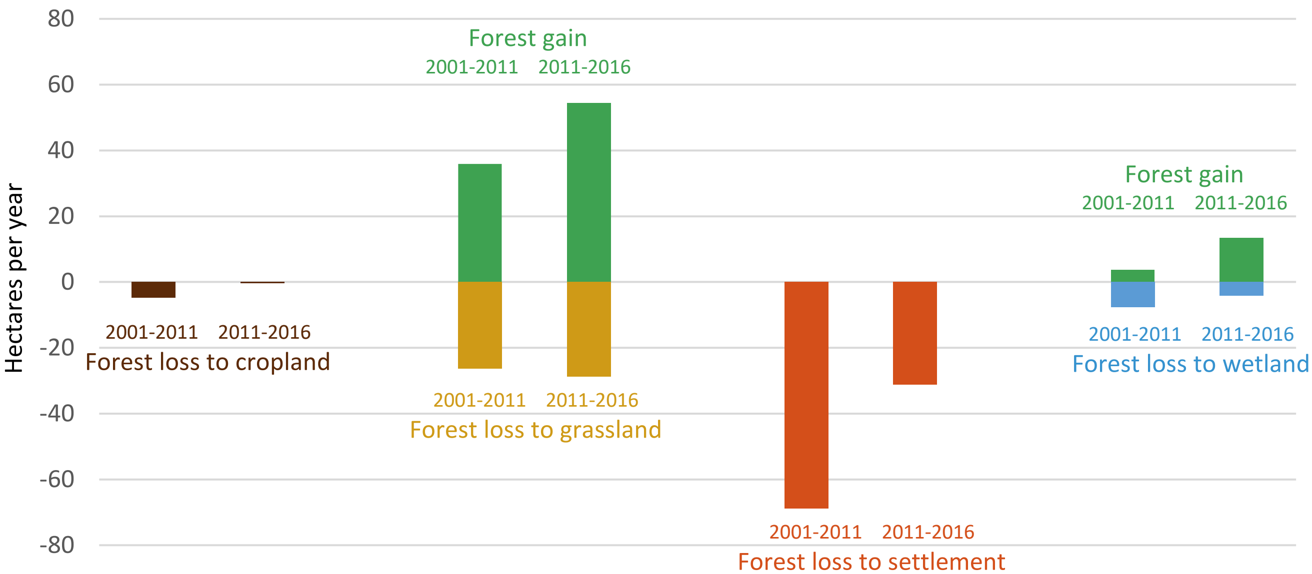


Forest Cover Change

Generating GHG estimates requires data not just on areas of land use, but also data on how land use has changed over time. Over the first period (2001-2011), the county lost around 68 hectares of forest land per year, largely conversion to Settlement (i.e. developed areas). More recently, in the period 2011-2016, there was a net gain of forest area of just over 3 hectares per year.

Figure 3. Average annual gain and loss of forests from / to other land use types

Note: Positive number = gain in forest area; negative number = loss of forest to other land uses.

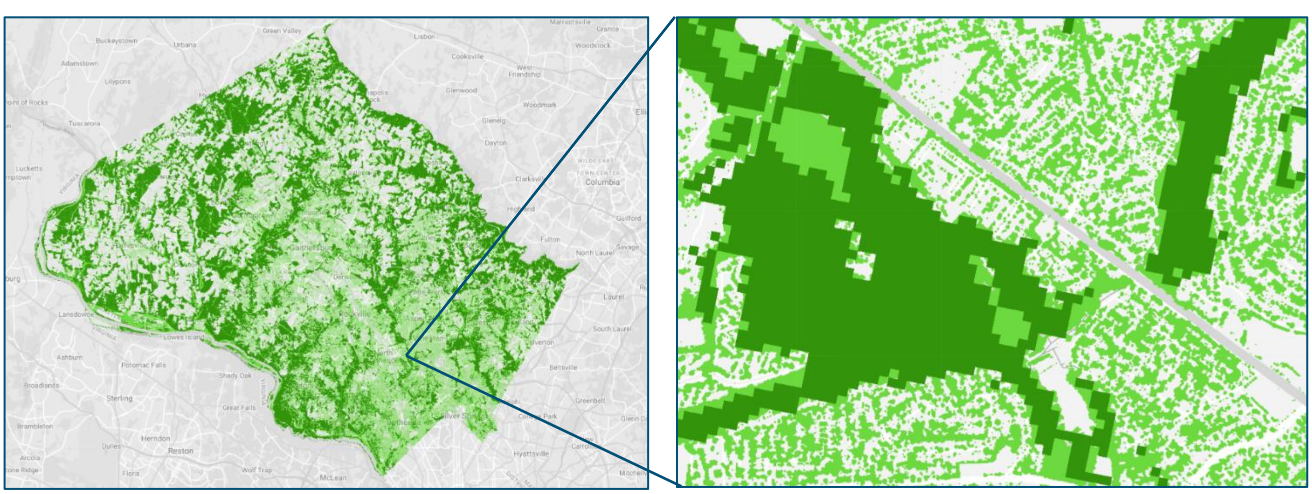


Source: National Land Cover Database (USGS, 2018)

Trees outside forests

In addition to utilizing the NLCD, data using LiDAR provided by the county provides maps of tree canopy and canopy change at a spatial resolution of 1 meter. The images below show the areas delineated as forest in the NLCD (30-meter resolution) and the extensive areas of tree canopy outside of forests captured by the high-resolution LiDAR data.

Figure 4. NLCD defined forests (dark green) and LiDAR tree canopy cover (light green).



LiDAR data are only available for the years 2009 and 2014. In 2014, Montgomery County had approximately 29,750 hectares of tree canopy cover *outside* forests. Settlements have the highest percentage of tree cover outside forests at nearly 50% of the settlement area. Standing trees sequester carbon, i.e. they contribute to the total CO_2 removals of the county.

Table 3: Tree canopy outside forest areas in Montgomery County (in hectares)

Source: Montgomery County tree canopy data from LiDAR

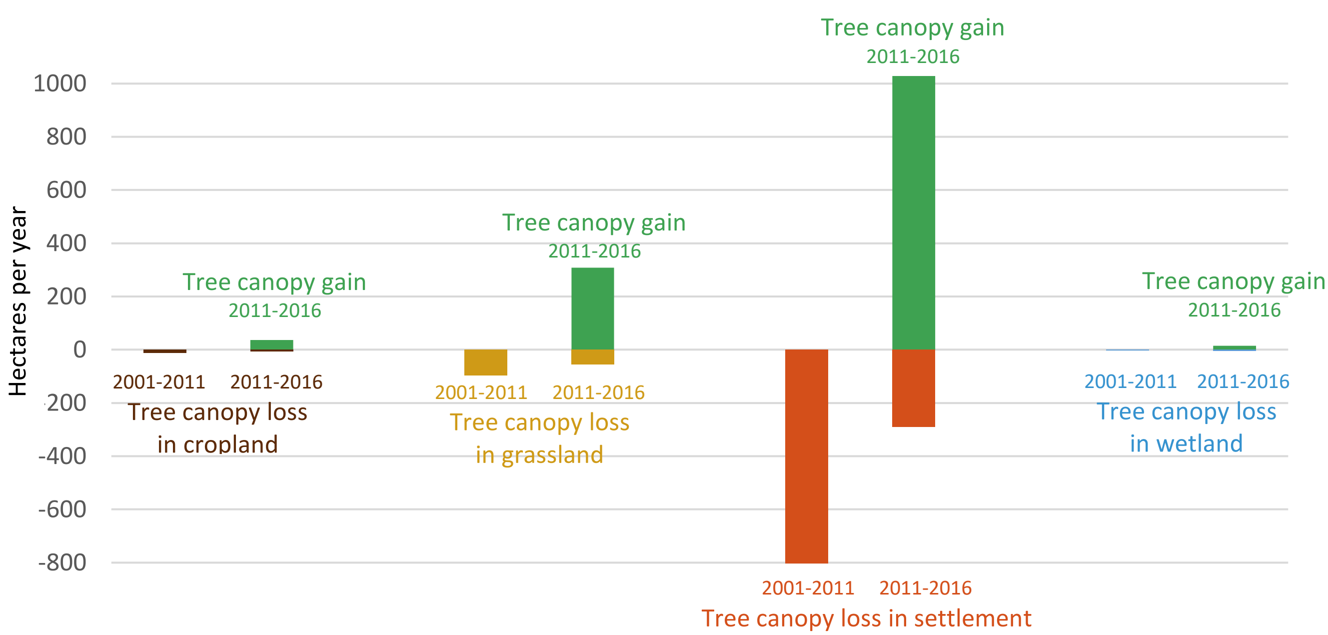
	2009 extent	% area w/tree cover in 2009	2014 extent	% area w/tree cover in 2014
Cropland	694	7	845	8
Grassland	3,797	17	5,053	23
Settlement	19,800	39	23,490	45
Wetland	318	10	365	12
Total	**24,609**	**28**	**29,753**	**34**

Change in tree canopy outside forests

Because LiDAR data are only available for 2009 and 2014, change in tree canopy between these years—comprised of both losses and gains—was assumed to reflect change over the 2011-2016 inventory period. As shown in Figure 5, the majority of tree canopy losses and gains were in the Settlement category followed by Grassland. Tree loss and gain are calculated separately since loss represents a large, immediate emission in the time period analyzed. By contrast, planting new trees adds to carbon removals, but more slowly over a long period of time.

Figure 5. Average annual tree canopy loss and gain

Note: Tree canopy gain for 2001-2011 is not available, see explanation following the Figure below.



Source: Montgomery County tree canopy data from LiDAR, years 2009/2014.

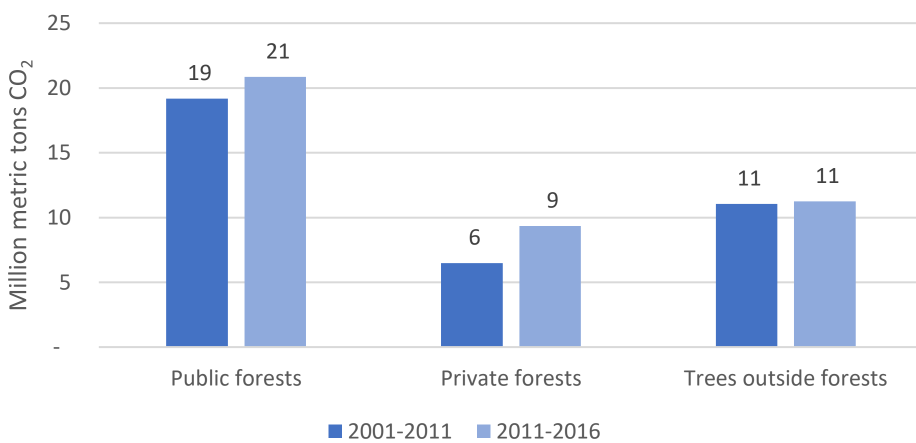
Since no LiDAR information was available to estimate tree canopy change for the first inventory period (2001-2011), this was estimated from 30-meter Landsat data for 2000-2010 (Source: University of Maryland) and the same proportion of loss calculated from Landsat data was applied to the 2009 LiDAR data. While this approach is imperfect, it retains information relevant to the time period of interest (2001-2011) to compare loss between the two periods. If LiDAR data were available for the first time period, actual tree canopy loss values would likely be higher than estimated, because the high-resolution LiDAR data would have picked up more areas of tree canopy loss than the coarser resolution Landsat data. A comparison of the loss in tree canopy outside forests between the two inventory periods, within the land use classes defined by NLCD 2011 is shown in Figure 5. Because tree canopy gains are difficult to detect using Landsat imagery, the same approach was not used to estimate gain in tree canopy over the first inventory period.

Forest and Tree Carbon Stocks

The total amount of carbon stored in Montgomery County's forests and trees is approximately 11.3 million metric tons, or around 41 million metric tons of CO_2, as of the latest period of analysis (2011-2016). Around 8.2 million metric tons of carbon (over 30 million metric tons of CO_2) are in forests, and around 3.1 million metric tons of carbon (over 11 million metric tons of CO_2) are in trees outside forests. The amount of carbon stored in public forests, private forests, and trees outside forests increased between inventory periods.

Total carbon in forests is estimated from Forest Inventory and Analysis (FIA) plots established in the county by the U.S. Forest Service. Total carbon in trees outside forests is estimated from the average area of tree canopy (Table 3 above) multiplied by the average carbon stock for trees outside forests, as estimated from tree inventory data collected for a nearby city (Baltimore, MD) [1].

Figure 6. Carbon stored in forests (by owner group) and trees outside forests



Source: U.S. Forest Service FIA plots (forests) and Nowak et al. 2013 (trees outside forests).

[1] Nowak, D.J., E.J. Greenfield, R. Hoehn, and E. LaPoint. 2013. Carbon storage and sequestration by trees in urban and community areas of the United States. Environmental Pollution, 178:229-236.

Caveats

Information presented here represents a snapshot in time of the net GHG balance and many of the factors contributing to that balance. The estimates can help identify where policies may be designed to reduce net GHG emissions. For example, conversion of forest to settlement could prospectively be reduced to improve the future GHG balance.

We note that forest emissions from harvesting and carbon stored in harvested wood products were not estimated due to a lack of data about how much forest area, if any, was harvested during the inventory period. Likewise, we could not determine if any trees removed during conversion of forest land to non-forest, or any trees removed during maintenance of trees outside forests, were used for wood products. When trees are cut and put into long-term uses, such as buildings or furniture, this can reduce the immediate emissions from loss of trees. Because of lack of data, this inventory currently uses a simplifying assumption that a loss of forest or trees results in immediate emissions to the atmosphere. If data were available, the delayed emissions from tree biomass that is lost from the land and temporarily stored in wood products or landfills could be considered as an addition to carbon stocks in the calculations.

In general, it is important to consider that these estimates represent a relatively short period of time compared with the long-term consequences of policy decisions and land management actions. For example, a forest converted to settlement represents a permanent loss of removal capacity. Over the long term, maintaining forests will sustain a higher rate of carbon removal, depending on age-related growth rates and occurrence of disturbances.

There are significant uncertainties in the estimates. Although not quantified here, typical greenhouse gas inventories of forests using similar approaches, including the national GHG inventory, report uncertainties in the net GHG balance that can be as high as ±45% (with 95% confidence). In the results presented here, the most uncertain estimates involve emissions from land-use change which are based on well-documented remote-sensing products, but relatively few field observations from a statistical sampling of county forests. While uncertainties can be high, the estimates can still provide useful information on the relative magnitude and importance of such GHGs; subsequent analyses can also provide information on the directionality of emissions and removals from land management.

Finally, it is recommended that additional analyses be done using models that project impacts of alternatives over coming decades. Such models are available and have been used in other studies at county scale. The GHG inventory presented here is only the first step to providing science-based information to support policy decisions. To more fully explore the prospective impacts of alternate policies, projection models should be used to compare long-term results among the alternatives which typically include a “business as usual” (i.e. no change in policy) alternative.

Acknowledgements

This GHG inventory was compiled by a team of experts in close collaboration with representatives of several agencies in Montgomery County. It is part of an ongoing effort to enable communities to include the land sector in their GHG inventories. The work was linked to the development of new guidance for communities to measure the GHGs from forests and trees that now is available in ICLEI-USA's US Community Scale Protocol for Accounting and Reporting of Greenhouse Gas Emissions (http://icleiusa.org/ghg-protocols/).

This work was sponsored by the Climate and Land Use Alliance and the Doris Duke Charitable Foundation. The team of experts represents the World Resources Institute, the Climate and Land Use Alliance, and the Woods Hole Research Center.

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