Maryland Forest Carbon Inventory

Forest Carbon

Forests represent an important component of the global carbon cycle and a critical tool to mitigate climate change. In the US, forests are estimated to offset 11.6% of national emissions while forests in Maryland offset 14.8% of the state's gross emissions in the 2017 inventory. Preserving the carbon that is currently stored in forests by reducing land use change and making forests more resilient to other disturbances is one of the most effective actions we can take to mitigate climate change.

Forests can also be expanded and sustainably managed to remove additional carbon from the atmosphere. A recent study[1] estimated that global forest cover could be increased to offset an additional 25% of GHG emissions every year, while still maintaining current levels of food production. Another recent study by U.S. Forest Service scientists estimates that carbon uptake by existing forests in the United States could be increased by 20% just by planting more trees on existing forest lands.[2] While planting trees and practicing climate smart forest management have long-term climate benefits, there may be a delay between the management action and its effect on carbon removal. Trees take time to grow and management actions can take time to result in increased growth rates. Therefore, it is imperative to take advantage of available near-term actions to increase carbon storage in forests to achieve their full potential for carbon removal by midcentury, when scientists believe society needs to reach net-zero emissions to avoid the worst impacts of climate change.

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Greenhouse gas inventories are the measuring stick for whether the actions being taken are leading to real world decreases in annual emissions or increases in carbon sinks. The GHG inventory included in Maryland's 2020 GHG plan uses the EPA State Inventory Tool (SIT) Forestry and Land-use Module, the best option available at that time. The EPA SIT inventory has been inconsistent in methodology as it has been updated over time, making it impossible to track progress from the 2006 baseline year. The tool has adopted the USFS methodology in the 2020 inventory update for forest growth. For this reason, MDE has assumed that annual carbon removals by forests and other land use have remained constant through time. However, forest carbon monitoring has improved tremendously over the past few years and Maryland is now poised to take advantage of these advancements in its 2020 GHG inventory. The World Resources Institute (WRI) produced a document for the U.S. Climate Alliance (USCA) suggesting ways to improve the Natural and Working Lands portion of states' GHG inventories, many of which were incorporated in the following project.

Building on research from the NASA Carbon Monitoring System, the USCA funded a project led by the University of Maryland working with partners, including Maryland DNR, Delaware Department of Natural Resources and Environmental Control, and the World Resources Institute, to combine high

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1 Cook-Patton, S.C., Leavitt, S.M., Gibbs, D. et al. Mapping carbon accumulation potential from global natural forest regrowth. Nature 585, 545–550 (2020). https://doi.org/10.1038/s41586-020-2686-x

2 Domke et al. 2020. Tree planting has the potential to increase carbon sequestration capacity of forests in the United States. Proceedings of the National Academy of Sciences. 202010840; DOI: 10.1073/pnas.2010840117

resolution LiDAR based estimates of forest carbon,[3,4] a prognostic ecosystem model,[5,6] and annual estimates of forest cover change from LANDSAT satellite imagery[7,8] to quantify changes in forest carbon stocks. The method improves Maryland's GHG inventory by reducing the uncertainty associated with estimates of forest carbon stock change, increasing the temporal and spatial resolution of those estimates, and providing a consistent methodology to estimate carbon stock change in forests and trees outside of forests. The project estimates the change forest area and carbon stock change across the state on a yearly basis with approximately a 6-month delay in data availability (i.e. the assessment for 2020 will be available in the summer of 2021). The approach is calibrated off of USFS field plot data, but uses remote sensing and modeling to provide mapped coverage over the state. This will allow Maryland to more frequently and accurately track progress towards the state's forest carbon goals. The estimates of carbon stock change in forests and trees outside of forests from this project are within the margin of error of comparable estimates published by the USFS[9]. The USFS uses annual field monitoring to update the forest carbon inventory, but only ~20% of the field plots are revisited each year, so its estimates of annual carbon stock change are really "rolling averages" over the last 5 years of change. Furthermore, the USFS inventory relies on more approximate methods to estimate the sink from "settlement trees" or urban forests and does not include non-urban trees outside of what USFS defines as forest. The USFS uses land-use change from the updated every 5-year National Land Cover Dataset whereas UMD uses annually updated change data from LANDSAT satellite imagery. The resulting inventory estimates are available for use in Maryland's 2020 GHG inventory and have been back-casted to 2006 in order to assess progress towards Maryland's GHG goals.

Comparison of Inventories

The long term average values for carbon stock change are very similar and within the margin of error for the UMD and USFS inventories. This can be expected because they both rely on the same fundamental data from the USFS Forest Inventory and Analysis program, and the UMD NASA Carbon Monitoring System research is conceptualized as "value-add" to the USFS inventory, rather than a competing product. A key difference in output is that the the UMD inventory shows an increase in the sink of ~1 MMT from 2006 while the USFS shows a decrease of a similar magnitude over that time period. These values are still within the expected margin of error for both datasets, and the difference likely stems from the higher temporal frequency of the data being used for the UMD inventory. An important detail to note is that the margins of error in assessing forest carbon stock change are very large; the

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[3] Wenli Huang et al 2019 High-resolution mapping of aboveground biomass for forest carbon monitoring system in the Tri-State region of Maryland, Pennsylvania and Delaware, USA Environ. Res. Lett. 14 095002, https://doi.org/10.1088/1748-9326/ab2917

[4] Hurtt, G.C., M. Zhao, R. Sahajpal, A. Armstrong, R. Birdsey, E. Campbell, K. Dolan, R.O. Dubayah, J.P. Fisk, S. Flanagan, C. Huang, W. Huang, K. Johnson, R. Lamb, L. Ma, R. Marks, D. O'Leary III, J. O'Neil-Dunne, A. Swatantran, and H. Tang. 2019. Forest Aboveground Biomass and Carbon Sequestration Potential for Maryland, USA. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1660

[5] Hurtt G C et al 2019 Beyond MRV: high-resolution forest carbon modeling for climate mitigation planning over Maryland, USA Environ. Res. Lett. https://doi.org/10.1088/1748-9326/ab0bbe

[6] Ma et al 2021 High-resolution forest carbon modelling for climate mitigation planning over the RGGI region, USA. Res. Lett. https://doi.org/10.1088/1748-9326/abe4f4

[7] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest.

[8] Goward, S.N., C. Huang, F. Zhao, K. Schleeweis, K. Rishmawi, M. Lindsey, J.L. Dungan, and A. Michaelis. 2015. NACP NAFD Project: Forest Disturbance History from Landsat, 1986-2010. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1290

[9] Domke, G. M., Walters, B. F., Nowak, D. J., Smith, J., Ogle, S. M., Coulston, J. W., & Wirth, T. C. (2020). Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990-2018. Resource Update FS-227. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. 5 p.

aforementioned WRI document estimated that the US national inventory for forests had a 95% confidence interval of +/- 75% of the estimate. Plot-based statistical extrapolation inherently entails a lot of uncertainty, which increases for small areas like states as the sample size gets smaller. Using remote sensing data removes a key driver of uncertainty because it provides comprehensive (wall-to-wall) data on trees across the landscape. There is still uncertainty in calibrating the RS data to plot measurements and modeling changes over time, but it should be less overall than the purely plot-based approach. MD incorporates annual estimate of disturbance on a ~1- year delay compared to the USFS using the National Landcover Dataset (NLCD) 5-year trend that is then extrapolated. This means that emissions from land-use change incorporated into recent inventories are based on the 2011-2016 trend and will not reflect recent trends in land-use change. The USFS inventory includes carbon lost when land-use change occurs and reports this loss separately from forest stock change. The value including land-use change is comparable to the UMD model estimate, which also includes loss of carbon due to land-use change.

Some other considerations are that the UMD model outputs carbon change in Above Ground Biomass (AGB). As this is only one forest carbon pool, these estimates were adjusted to estimate total ecosystem carbon using the average ratio of AGB to total carbon observed in the USFS inventory. The UMD model does not include other GHG's than carbon (i.e., CH_4 and N_2O from forest fires), although this omission has not been a significant factor in MD. Neither inventory includes carbon in harvested wood products but this is a planned addition to the USFS state level inventory. The UMD model shows influence of interannual variability and trend in climate conditions (rainfall and temperature), CO2 concentration, and disturbance. Below 3- and 5- year running averages are presented to modulate this variability for comparison to the USFS model, but the annual sum and averages are the most accurate points of comparison.

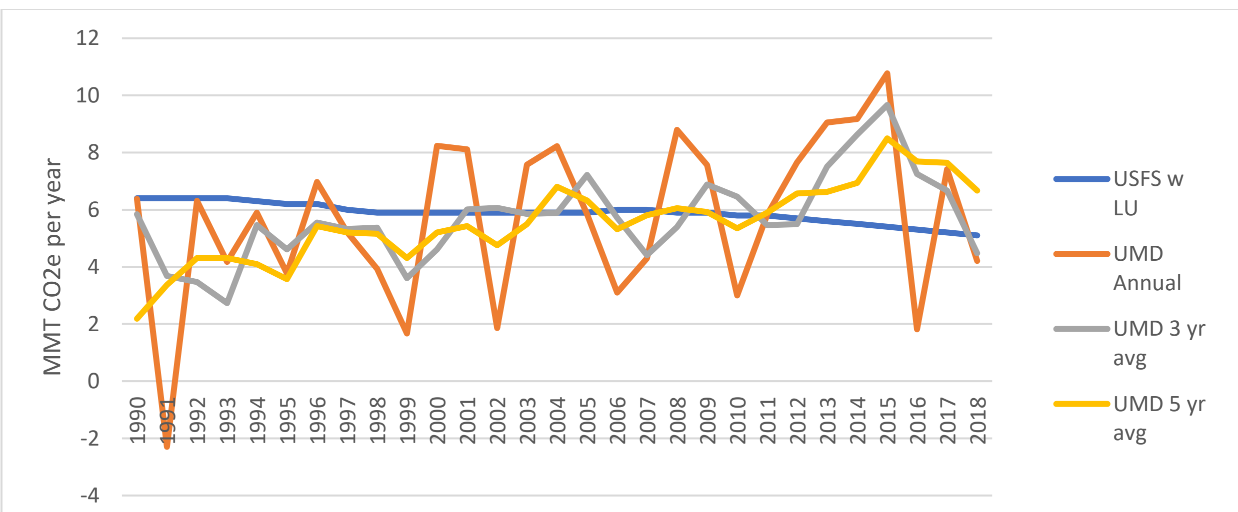

Figure 1. Comparing USFS and UMD Maryland Forest Carbon Sink, 1990-2018

Table 1 Summarizing Results of USFS and UMD Forest Carbon Sink, 1990-2018

	UMD Annual	UMD 5 yr avg	UMD 3 yr avg	USFS[10]
sum 1990-2018 (MMT CO2e)	164.523	160.924	165.293	170.700
average 1990-2018 (MMT CO2e per year	5.673	5.549	5.700	5.886

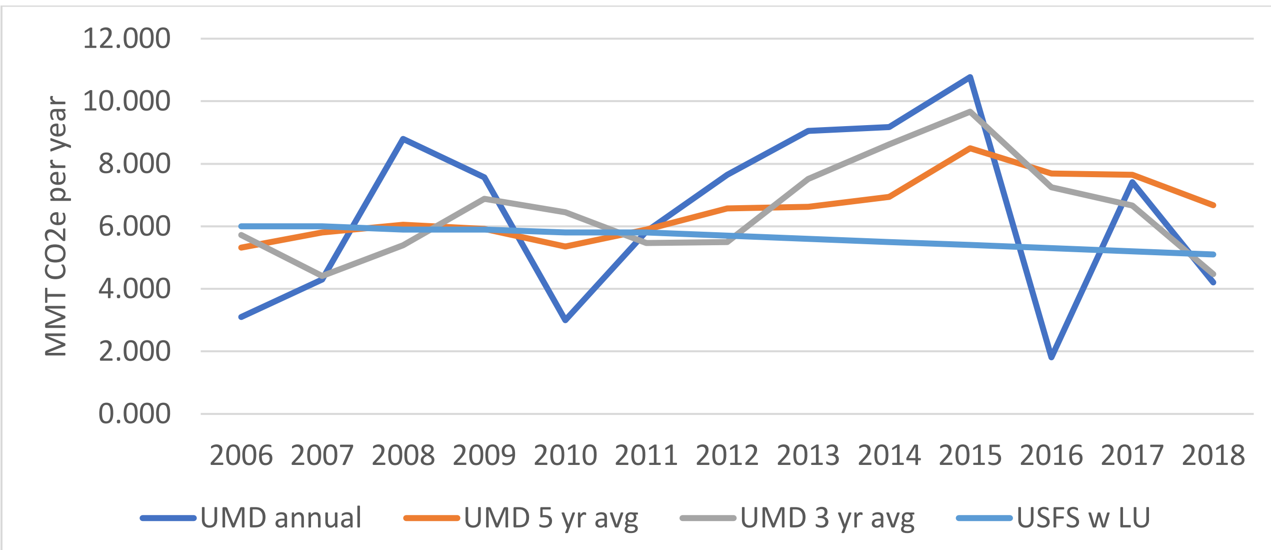

Figure 2. Comparing USFS and UMD Maryland Forest Carbon Sink, 2006-2018

Table 2. Summarizing Results of USFS and UMD Forest Carbon Sink, 2006-2018

	UMD Annual	UMD 5 yr avg	UMD 3 yr avg	USFS Inventory
Sum, 2006-2018 (MMT CO2e)	82.656	84.975	84.019	73.200
Difference 2006-2018	1.105	1.355	-1.245	-0.900

[10] The USFS produces separate estimates for carbon sequestration from forests and "settlement trees", we added these estimates to compare to the UMD inventory.

(MMT CO2e)				
Average 2006-2018 (MMT CO2e per year)	6.358	6.537	6.463	5.631

Conclusion

Averaged over time, the UMD and USFS methods produce very similar numbers for the Maryland forest carbon sink (only 3.5% difference over the 28 years of inventory analyzed here), a result that gives confidence to the accuracy of these estimates. However, when measuring year-to-year change, there are significant differences, primarily due to the frequency and resolution at which information is incorporated into the estimates (most data updated yearly at an annual resolution with the UMD model, 5-year rolling average with a multi-year delay for the USFS model). The UMD approach also provides wall-wall coverage, as opposed to sample-based estimate, and ability to backdate estimates. The 2018 UMD estimate is 45% less and the 2018 USFS estimate 50% less than the value in Maryland's 2017 GHG inventory so making this change will make it more difficult for the State to meet its percent reduction and net zero climate goals. However, numbers on paper do not reduce sea level rise or dangerous heat days so it is important to make this improvement and adjust targets to reflect the latest scientific understanding of this important part of Maryland's inventory. The science of monitoring forest carbon fluxes is challenging and continuing to improve. This result will certainly not be the final estimate of Maryland's forest carbon sink as models continue to improve and new data become available, but this work addresses two big concerns with the prior estimate of forest carbon. The first concern was that the estimate from the 2009 State Inventory Tool is no longer consistent with current estimates, and the second was that there was not methodological consistency in the EPA SIT tool for estimating a consistent baseline with which to compare new estimates. Any future estimates produced by any source will need to adopt the dual approach of scientific rigor combined with inventory compatibility and need.

Produced by

Project Team- US Climate Alliance "High-Resolution Annual Forest Carbon Monitoring Utilizing Remote Sensing"

University of Maryland: George Hurtt, Carlos Silva, Rachel Lamb, Lei Ma, Quan Shen

World Resources Institute: Alexander Rudee, Haley Leslie-Bole

Maryland Department of Natural Resources: Elliott Campbell, Rachel Marks