TECHNICAL ASPECTS OF THE FOREST CARBON INVENTORY OF THE UNITED STATES: RECENT PAST AND NEAR FUTURE

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Abstract.—The Forest Inventory and Analysis program of the U.S. Forest Service has explicitly assumed responsibility for providing an inventory of the U.S. forests' carbon stocks and stock change to the U.S. Environmental Protection Agency for numerous years to meet obligations to the United Nations Framework Convention on Climate Change. Recent improvements, plans for the future, and implications regarding use of the U.S. inventory both nationally and at the project scale are discussed.

It appears unlikely that the 112th Congress of the United States will approve incentives for the commoditization of biogenic carbon (C) (i.e., "cap and trade"), so where should the science of forest C accounting head in the near future? Initial versions of the 2012 Farm Bill coupled with the National Forest System Climate Change Performance Scorecard highlight areas of current and future research in C accounting. The Forest Inventory and Analysis (FIA) Program of the U.S. Forest Service has adopted several areas of priority research in the area of carbon: reduction of the uncertainty associated with FIA's C estimates; downscaling of national C estimates to the national forest or mid-level; and refinement of biomass estimation procedures. This represents a substantive course of action to improve the science of C accounting and to meet user demands.

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Over the past year (2011-2012), the major changes to the accounting of U.S. forest C involved adoption of the Component Ratio Method (CRM) approach (Domke et al. 2012) to biomass/C estimation and incorporating standing dead tree measurements in the national inventory (i.e., annual Phase 2) (Woodall 2012). Incorporating standing dead tree measurements greatly improved the sensitivity of the national inventory to stand-level dynamics (Woodall et al. 2012a). FIA is encouraged that incorporating a national downed dead wood inventory (Woodall et al. 2008) in the 2012 National Greenhouse Gas Inventory (NGHGI) may impart the same positive effect. In 2013 and beyond, it is hoped that many aspects of the FIA national inventory of forest health indicators (Woodall et al. 2011) may refine C estimation. Sometimes the casting of a forest health indicator in a different light can greatly inform the estimation of a C stock such as found with components of the forest floor (Woodall et al. 2012c). This process of "stepping through" each forest C pool with the objective to increase estimate precision and linking the estimates to recently derived empirical information (i.e., Phase 3 inventory) is a tremendous benefit to C and biomass accounting.

Refined C stock estimates at the national scale may benefit the NGHGI, but can this be downscaled to our national forests and other comparable

scales? Estimates of National Forest System C stocks (Heath et al. 2011) are now a requirement of climate change scorecard reporting for national forests in the United States. Because an intention of the scorecard is to understand and consider the effects of management activities on carbon budgets at the scale of a national forest, the uncertainty (sometimes > 5 percent sampling error) associated with a "downscaled" NGHGI may not appropriately inform such management activities. Ongoing research into "downscaling" NGHGI to inform mid-level activities (Wilson et al. in review, Coulston et al. this proceedings) may improve the statistical power (Westfall et al., in review) to detect management/disturbance effects on C budgets. Whereas the techniques used to develop the NGHGI satisfy requirements under United Nations Framework Convention on Climate Change (U.S. EPA 2012), new areas of research are needed to downscale NGHGI to empower land managers interested in mitigating climate change.

As renewable biomass is an emerging topic in regards to energy and economic development (Woodall et al. 2012b), the draft 2012 Farm Bill language requests more information on the supply of renewable forest biomass in the United States. In addition to C accounting, it should be recognized that forest C accountants are also biomass experts. The FIA program has already initiated a national effort to improve the modeling of individual tree biomass/C attributes (Coulston et al. this proceedings). This same drive should be reflected in non-live tree pools. Refining the estimations of standing dead tree, downed dead, and understory components should benefit more comprehensive biomass assessments. Domke et al. (2011) found that biomass estimates could be improved by refining the decay reductions and structural deductions for standing dead trees. Such a research approach across the many diverse pools associated with C accounting will benefit renewable biomass estimation.

Finally, all of these technical improvements do not occur in isolation within the FIA program. State and university partners in concert with an array of federal partners (e.g., USGS and NASA) are critical to the development and application of C/biomass accounting. Only through partnership can FIA's refined approaches to C/biomass monitoring be leveraged to meet the expectations of our diverse user community.

LITERATURE CITED

Domke, G.M.; Woodall, C.W.; Smith, J.E. 2011. **Accounting for density reduction and structural loss in standing dead trees: implications for forest biomass and carbon stock estimates in the United States.** Carbon Balance and Management. 6: 14. doi:10.1186/1750-0680-6-14

Domke, G.M.; Woodall, C.W.; Smith, J.E.; Westfall, J.A.; McRoberts, R.E. 2012. **Consequences of alternative tree-level biomass estimation procedures on U.S. forest carbon stock estimates.** Forest Ecology and Management. 270: 108-116.

Heath, L.S.; Smith, J.E.; Woodall, C.W.; Azuma, D.L.; Waddell, K.L. 2011. **Carbon stocks on forestland of the United States, with emphasis on USDA Forest Service ownership.** Ecosphere. 2(1): article 6. 21 p.

U.S. Environmental Protection Agency [U.S. EPA]. 2012a. **Land use, land-use change, and forestry.** Chapter 7. In: Inventory of U.S. greenhouse gas emissions and sinks: 1990-2010. #430-R-12-001. Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency [U.S. EPA]. 2012b. **Methodology for estimating net carbon stock changes in forest land remaining forest lands.** Annex 3.12. In: Inventory of U.S. greenhouse gas emissions and sinks: 1990-2010. #430-R-12-001. Washington, DC: U.S. Environmental Protection Agency.

Westfall, J.A.; Woodall, C.W.; Hatfield, M.A. In review. **If forest carbon flux made a sound would we be able to hear it? A statistical power analysis of woody carbon stocks in forests of the Great Lakes, U.S.A.**

Wilson, B.T.; Woodall, C.W.; Griffith, D. In review. **From plots to the Nation: imputing forest carbon stock estimates from inventory plots to a nationally continuous coverage.**

Woodall, C.W. 2012. **Where did the U.S. forest biomass/carbon go?** Journal of Forestry. 110: 113-114.

Woodall, C.W.; Amacher, M.C.; Bechtold, W.A.; Coulston, J.W.; Jovan, S.; Perry, C.H.; Randolph, K.C.; Schulz, B.K.; Smith, G.C.; Tkacz, B.; Will-Wolf, S. 2011. **Status and future of the forest health indicators program of the United States.** Environmental Monitoring and Assessment. 177: 419-436.

Woodall, C.W.; Domke, G.M.; MacFarlane, D.W.; Oswalt, C.M. 2012a. **Comparing field- and model-based standing dead tree carbon stock estimates across forests of the United States.** Forestry. 85: 125-133.

Woodall, C.W.; Heath, L.S.; Smith, J.E. 2008. **National inventories of dead and downed forest carbon stocks in the United States: opportunities and challenges.** Forest Ecology and Management. 256: 221-228.

Woodall, C.W.; Ince, P.J.; Skog, K.E.; Aguilar, F.X.; Keegan, C.E.; Sorenson, C.B.; Hodges, D.G.; Smith, W.B. 2012b. **An overview of the forest products sector downturn in the US.** Forest Products Journal. 61: 595-603.

Woodall, C.W.; Perry, C.H.; Westfall, J.A. 2012c. **An empirical assessment of forest floor carbon stock components across the United States.** Forest Ecology and Management. 269: 1-9.