Dead Wood Relative to Slope Severity in Mesic Loess Bluff Hardwood Forests

Daniel J. Twedt, U.S. Geological Survey, Patuxent Wildlife Research Center, 2524 South Frontage Road, Vicksburg, MS 39180; dtwedt@usgs.gov

Abstract

To aid in identification of land within Vicksburg National Military Park that was subjected to forest restoration during the 1930s, I evaluated the hypothesized relationships between maximum live tree diameter or dead wood (standing and down) and severity of slope. Disproportionate mortality among early-successional, pioneer tree species suggested maturation of pioneer upland hardwood forests. As such, input and decomposition of dead wood have likely approached equilibrium. Thus, I did not detect a useful predictive relationship between dead wood (standing or down) or maximum diameter of live trees and severity of slope. Lack of relationships between slope and large diameter trees or volume of dead wood resulted in an inability to evaluate former land use based on these parameters.

Introduction

The Mississippi Valley Loess Plains physiographic region extends about 750 km along the eastern edge of the Mississippi Valley (Figure 1; Omernik 1987). This region is distinguished by deep (15–60 m) fertile soils comprised of silt-sized sediments, likely of eolian origin. The loess bluffs along the western edge of this region (Figure 1) are well-drained but prone to severe erosion, such that locally abundant rainfall has produced a severely dissected, rugged topography of great relief on a diminutive scale (Caplenor 1968).

Although historically vegetated by mesic hardwood forests, the primeval climax forests have been largely lost (Delcourt and Delcourt 1974). Post-European settlement, nearly all areas have been subjected to timber harvest, many of which were subsequently converted to agriculture. The extant hardwood forest continues to be impacted by erosion, exurban encroachment, conversion to pine forest, and invasion of exotic plants. Even so, some pockets of 'old-growth' forest remain, particularly in areas with steep-sided gullies that are not suitable for cultivation, and where timber harvest is difficult (Davis 2003). Throughout this loess plain, some areas converted to agriculture have been abandoned, often spurred by severity of erosion, and subsequently returned to hardwood forest (Taylor 2010). Within Vicksburg National Military Park, at the western fringe of the loess bluffs (Figure 2), active forest restoration via tree planting was undertaken by the Civilian Conservation Corps during the 1930s to combat excessive erosion (NPS 2009). Although

Citation: Weber, Samantha, ed. 2012. *Rethinking Protected Areas in a Changing World: Proceedings of the 2011 George Wright Society Biennial Conference on Parks, Protected Areas, and Cultural Sites.* Hancock, Michigan: The George Wright Society.

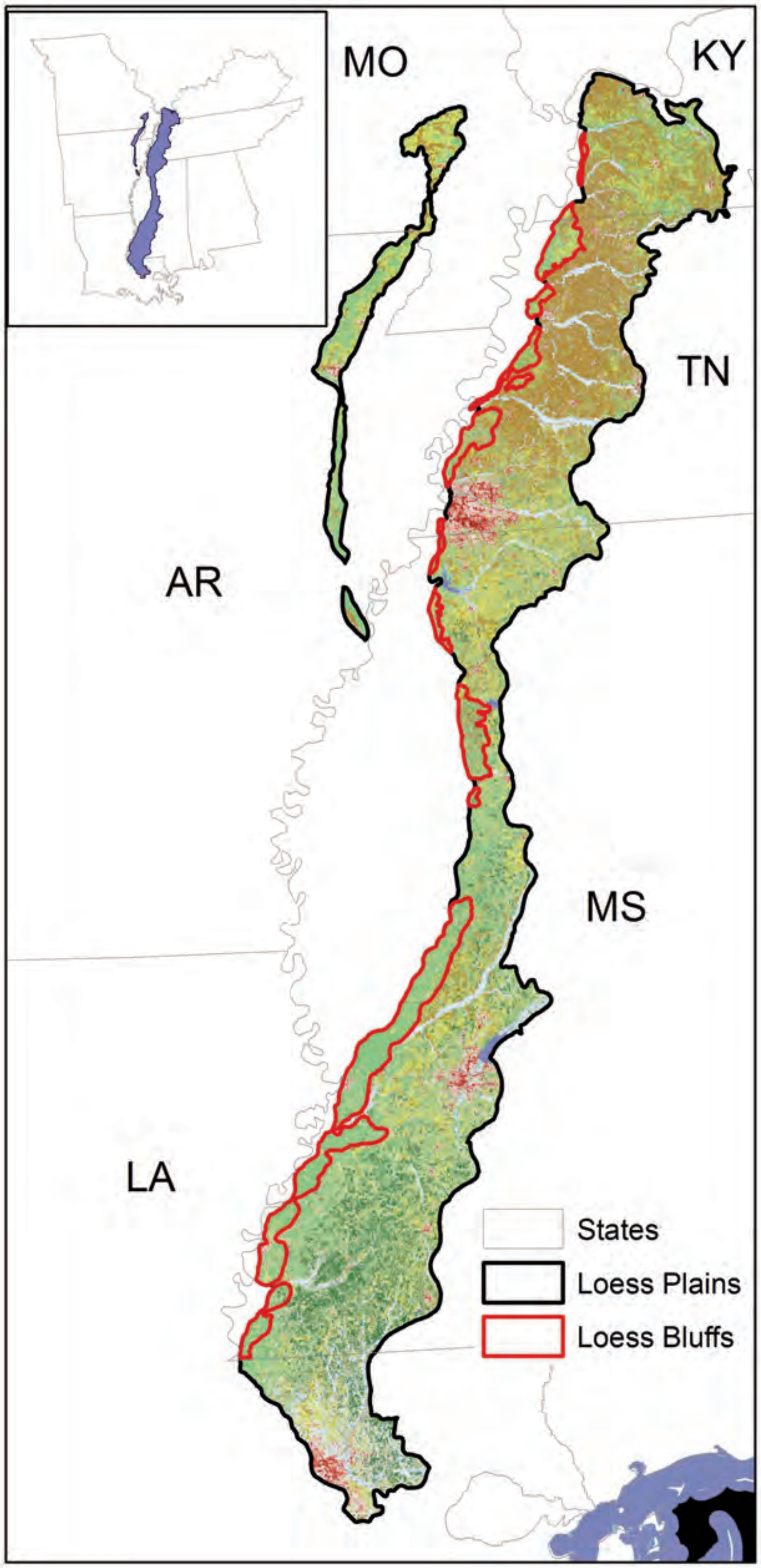

Figure 1. Mississippi Valley Loess Plain ecological region (Level III; Omerik 1987) and Loess Bluffs (Level IV) along the western edge of the eco-region.

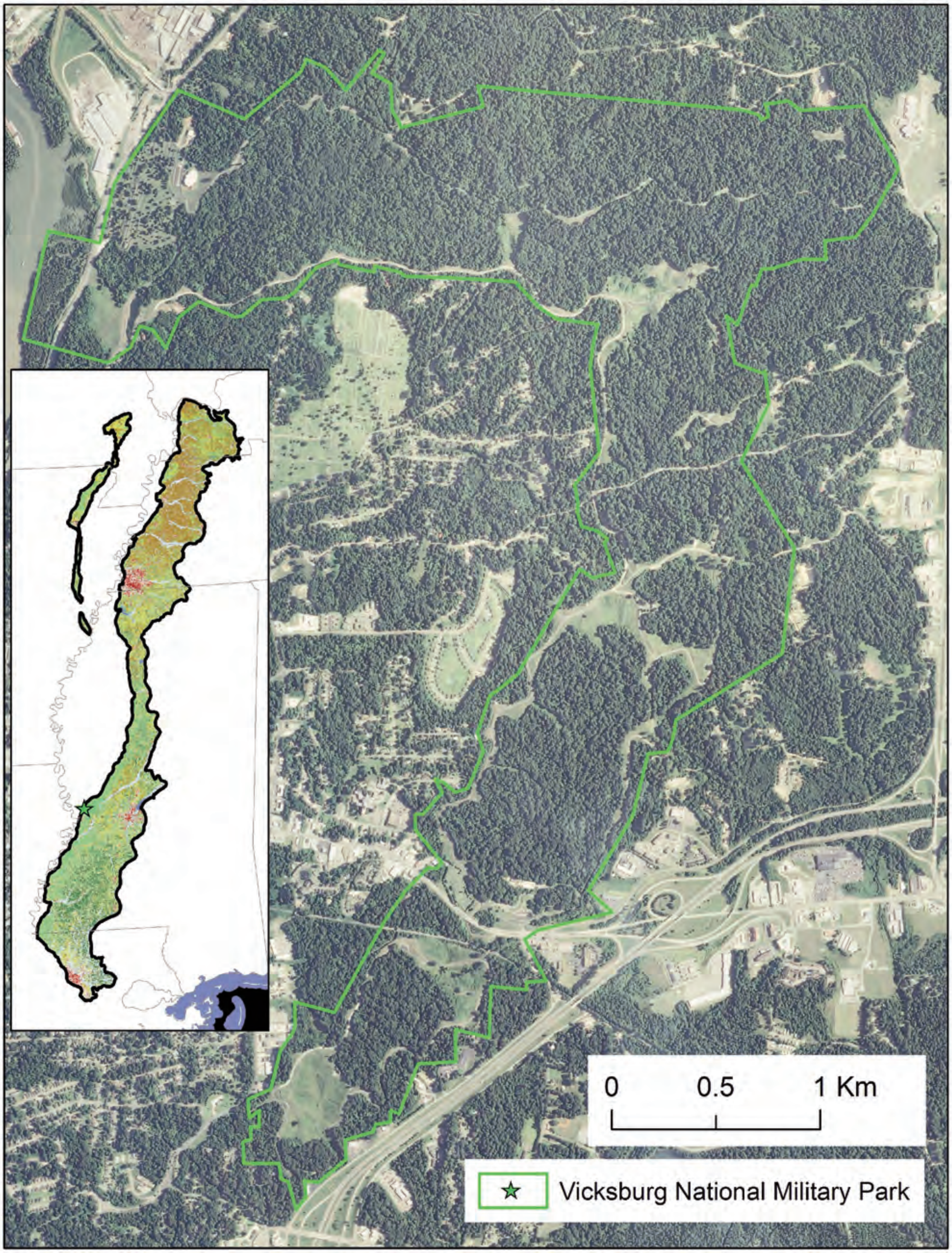

Figure 2. Forest and non-forest land cover within Vicksburg National Military Park depicted on 2010 U.S. Department of Agriculture, National Agriculture Imagery Program (NAIP) aerial photograph.

historical records are sparse, these forest restorations were not undertaken to restore antebellum forest compositions, and likely introduced selected species disproportionate to their natural occurrence.

The primary management objective of Vicksburg National Military Park is to preserve and commemorate the historic Civil War battlefield. As such, despite ubiquitous pre-settlement forest vegetation, transformation of forest land cover to open land cover, as was present during Civil War military campaigns, is being undertaken to maintain the park's cultural landscape (NPS 2009). However, the entire battlefield is not slated for landscape transformation, but rather specific locales that enhance interpretation of battlefield conditions, and that provide visitors with suitable viewscapes that portray historic campaigns. Thus, one of the key recommendations of the park's Cultural Landscape Report was to remove woodland so as to approximate historic patterns of open landcover within areas of key military engagement (NPS 2009). Identification of these areas would benefit from knowledge of the history of Civilian Conservation Corps (CCC) tree planting so as to determine the exact locations of forest restoration projects and their scope. As such, identification of site plans, photographs, or written descriptions confirming the nature, location, and extent of plantings would be valuable (NPS 2009).

Unfortunately, historical records that document forest restoration within this park are incomplete. Therefore, I sought to exploit a hypothesized linkage between severity of slope and propensity to retain forest cover (Davis 2003) to evaluate the usefulness of the ecological record for identifying areas that historically were denuded of forest cover. For example, Sturtevant et al. (1997) found that coarse woody debris in boreal forests accumulated asymptotically until decomposition rates began to equal input rates, at circa 80 years post disturbance. This 80-year time horizon roughly corresponds with the time elapsed since the aforementioned 1930s tree planting by the CCC.

To characterize the historical distribution of forest clearing within Vicksburg National Military Park, I evaluated the relationship between steepness of slope and maximum diameter of live trees, density and volume of standing dead trees (a.k.a., snags), volume of down dead wood (DDW), and total volume of dead wood (down or standing). My hypotheses were that areas with steeper slopes would not have been deforested, and would therefore have larger diameter trees and a greater volume of dead wood than areas with more moderate slopes. Secondarily, I hypothesized that snag density would be less on steeper slopes due to greater soil erosion at these sites, which destabilizes root systems of standing dead trees.

Study area

Vicksburg National Military Park is about 7,300 hectares nearly entirely within the Mississippi Valley Loess Plains (Figure 2). Forest land cover comprised about 80% of the area: non-forest cover was maintained through periodic mowing or burning (Figure 2; Somershoe et al. 2006). Forest cover was predominately mixed mesophytic hardwoods. Sweetgum (*Liquidambar sytraci - flua*), water oak (*Quercus nigra*), elms (*Ulmus* spp.) and sugarberry (*Celtis laevigata*) were common canopy species, but composition and survival of naturally colonizing species generally reflected topography. For example, large tulip poplar (*Liriodendron tulipifera*) were present in moist ravines, whereas dominant cherrybark oak (*Q. pagoda*) and chinquapin oak (*Q. muehlenbergii*) were common on slopes and ridges (Table 1).

Methods

At 150 random locations in Vicksburg National Military Park, during 2008 through 2010, I assessed species, diameter at breast height (dbh), basal area (BA), and height (m) of live woody vegetation and snags (≥10 cm dbh) using 1-m^2 Basal Area Factor (BAF) prism plots (Avery and Burkhart 2002). Similarly, species (if discernable), mid-point diameter, and length (m) of dead down wood (≥6 cm mid-point diameter) were assessed within 1-m^2 BAF plots (Bebber and Thomas 2003). Volume of dead down wood was calculated as the product of basal area (BA) and length (Harmon and Sexton 1996). Snag volume was the product of BA and height, adjusted for tree taper, using a form factor of 0.91 (Hilt 1980). Within superimposed 10 m radius fixed area plots, I quantified snag density and maximum diameter of live trees. I used an inclinometer to determine slope (degrees) in each cardinal direction, from plot center to 10 m (plot edge): maximum slope was the greatest absolute (+) slope, whereas mean slope was the average absolute slope among the 4 quadrants. Rarely, dramatic topographic relief within 10 m was not identified by inclination from plot center to 10 m radii. I used linear regressions to examine relationships between measured forest variables and severity of slope.

Results

I censured data from 30 plots that were primarily non-forested, because mowing or burning restricted accumulation of down dead wood. On the other 120 plots where forest predominated, density of snags per hectare (ha) was 38.5 ± 4.4 (SE; range = 0–255), volume (m^3/ha) of dead down wood was 43.1 ± 3.2 (range = 0–242), and total volume of deadwood (DDW + snags) was 63.1 ± 3.7 (range = 0–249). Maximum diameter (cm) of live trees within 10 m was 61.2 ± 2.3 (range = 17–132). Mean slope was 10.4 ± 0.6 degrees (range = 1–41), with maximum slope of 18.6 ± 0.9 degrees (range = 2–56).

Linear regressions failed to detect any significant relationship between severity (mean or maximum steepness) of slope and maximum tree diameter ($F \leq 1.58$, $p \geq 0.21$, $R^2_{adj} \leq 0.01$), volume of down dead wood ($F \leq 2.96$, $p \geq 0.088$, $R^2_{adj} \leq 0.02$), density of snags ($F \leq 2.83$, $p \geq 0.095$, $R^2_{adj} \leq 0.02$) or volume of snags ($F \leq 1.98$, $p \geq 0.162$, $R^2_{adj} \leq 0.01$). Total volume of dead wood (DDW + snags) was positively related to mean slope ($F = 4.36$, $p = 0.04$), but the relationship was poor ($R^2_{adj} = 0.03$; Figure 3). Quadratic regression for volume of dead wood improved model fit ($F = 5.43$, $p < 0.01$), but the relationship to mean slope remained poor ($R^2_{adj} = 0.07$).

Discussion

Within the mesic hardwood forests of Vicksburg National Military Park, severity of slope appears to be a poor predictor of deadwood volume. Thus use of deadwood volume to predict areas of forest restoration is not justified. I suspect that the approximately 80 years since forest restoration was undertaken has provided sufficient time for establishment of equilibrium in rates of deadwood input and decomposition within newly established forests. Therefore, forests in areas that were not cleared have similar accumulation of deadwood as forest areas that were historically cleared. Alternatively, deforestation during the Civil War era may have been so widespread that most of what is now Vicksburg National Military Park was open land. If so, our sampling regime may have been insufficient to capture those few areas of relictual native forest.

The 52 species of trees greater than or equal to 10 cm dbh identified within surveyed plots confirmed the mixed mesophytic nature of forests within this park (Table 1). Although diverse in species composition, succession and maturation of restored forests within Vicksburg National Military Park was evidenced by the high proportion of standing dead trees that were 'pioneer' tree species, such as *Juniperus virginiana*, *Robinia pseudo-acacia*, *Gleditsia triacanthos*, *Sassafras albidum*, and *Salix nigra* (Table 1). Conversely, the paucity of *Magnolia grandiflora* (n = 6), *Fagus grandifolia* (n = 2), *Ilex opaca* (n = 0), and *Q. alba* (n = 2) within sample plots suggests these forests are not representative of primeval loess bluff forest as described by Delcourt and Delcourt (1974). Thus, the current forests within Vicksburg National Military Park should likely be characterized as an old pioneer forest, because although the forest is relatively young, the pioneer species therein are relatively old (Runkle 1996).

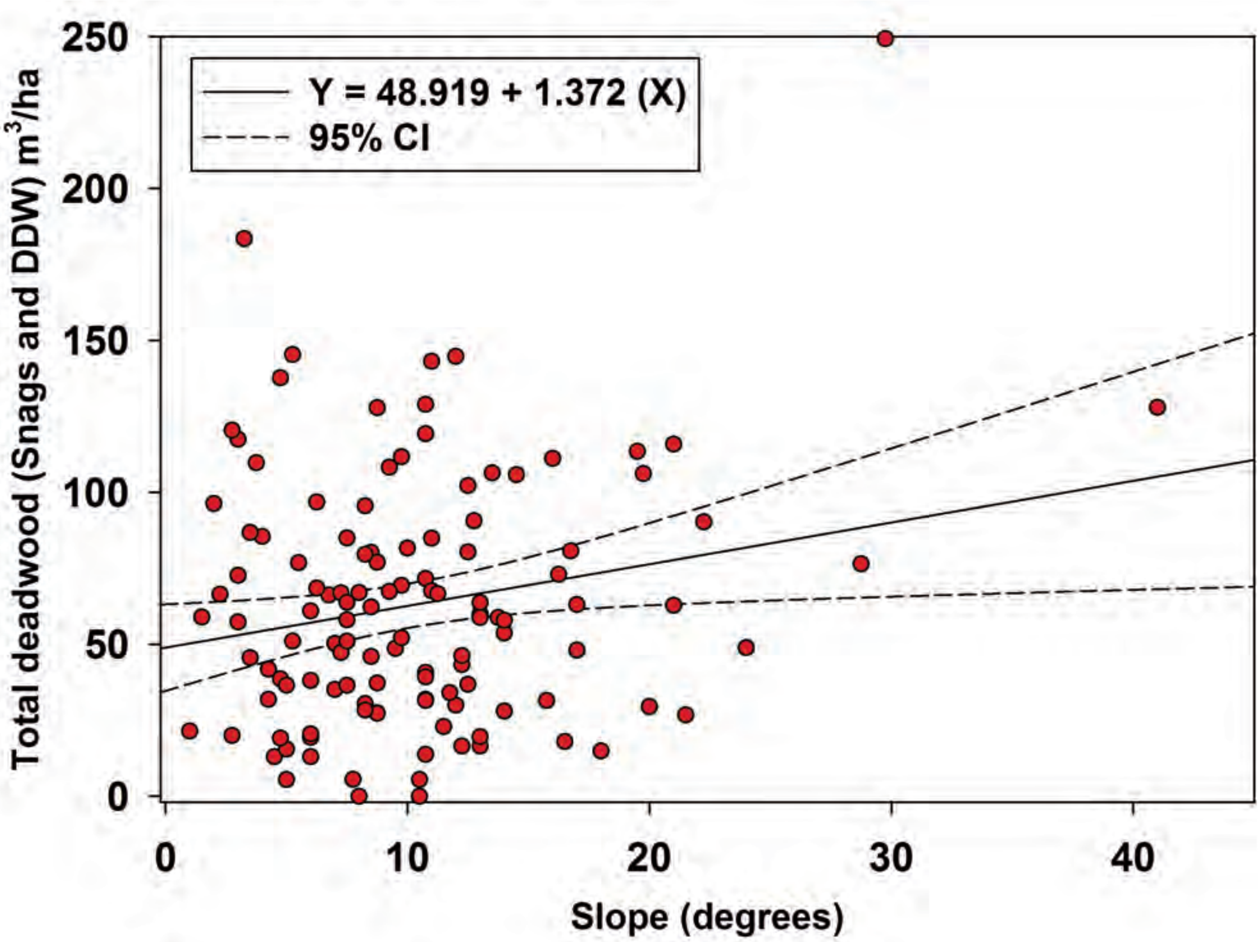

Figure 3. Poor (R^2_{adj} = 0.03) relationship of total volume of dead wood (standing and down) and severity of slope assessed at 120 random forested locations within Vicksburg National Military Park, 2008 to 2010.

Desired forest conditions for priority wildlife species within bottomland hardwood forests are describes as having coarse woody debris (>25 cm diameter) volume that exceeds 14 m^3/ha, and standing dead or stressed trees >25 cm dbh should exceed 15 stems/ha, or >0.9 m^2 BA/ha (Wilson et al. 2007). Although these desired forest conditions were proposed for bottomland forests, evaluation of data from the mesic bluff forests within Vicksburg National Military Park suggests that standing and down dead wood exceed recommended conditions. That is, after limiting to snags and DDW >25 cm diameter, density (15.6 ± 2.4 snags/ha) and basal area (1.5 ± 0.1 m^2/ha) of snags exceed recommended forest conditions. Similarly, the 22.8 ± 2.2 m^3/ha volume of coarse woody debris >25 cm diameter exceeded desired forest conditions.

Conclusions

Disproportionate mortality among early-successional tree species suggests maturation and senescence of pioneer upland hardwood forests within Vicksburg National Military Park. As such, input and decomposition of dead wood are likely approaching equilibrium. Forest maturation and equilibrium of dead wood generation and decomposition likely contributed to my inability to detect a relationship between dead wood and severity of slope. Lack of relationships between slope and large diameter trees or volume of dead wood, resulted in an inability to evaluate former land use based on these parameters.

Table 1. Species, percent basal area of identified[a] trees >10 cm diameter at breast height (%_all), and percent basal area of each species comprised of dead trees (%_species_dead) based on live (n = 3047) and standing dead (n = 237) trees surveyed on 120 forested, 1-m^2 basal area factor prism plots within Vicksburg National Military Park, Mississippi, 2008–2010.

Species[b]	%_all	%_species_dead
Liquidambar styraciflua	15.31	3.73
Quercus nigra	14.14	6.79
Acer negundo	10.53	6.55
Ulmus americana	8.52	7.39
Celtis laevigata	8.25	2.18
Liriodendron tulipifera	4.98	2.41
Quercus pagoda	4.83	3.73
Robinia pseudo-acacia	4.11	30.66
Carya illinoinensis	3.15	7.62
Quercus muehlenbergii	3.12	2.88
Platanus occidentalis	2.07	7.25
Morus rubra	1.83	3.28
Ostrya virginiana	1.71	7.02
Prunus serotina	1.50	10.00
Sassafras albidum	1.38	23.91
Juniperus virginiana	1.20	55.00
Ulmus alata	1.14	13.16
Carya cordiformis	1.11	5.41
Prunus caroliniana	0.99	0.00
Fraxinus americana	0.84	10.71
Quercus velutina	0.69	0.00
Gleditsia triacanthos	0.66	22.73
Tilia caroliniana	0.66	4.55
Cercis canadensis	0.57	0.00
Ligustrum sinense	0.54	0.00
Populus deltoides	0.36	8.33
Broussonetia papyrifera	0.36	0.00
Pinus taeda	0.36	0.00
Acer barbatum	0.33	0.00
Juglans nigra	0.30	0.00
Salix nigra	0.27	44.44

[a] Species of 46 snags could not be identified and are not included in percentages.

[b] 20 additional species accounted for <5% of total basal area within surveyed plots.

Acknowledgments

I thank A. Ayala, E. Ray, M. Schickel, and H. Sullivan for field assistance. I also thank V. Dubowy and M. Segura, NPS, for logistic and operational support. Reference to commercial products does not imply U.S. government endorsement. R. L. Woodman and C. Remington provided editorial suggestions on this manuscript.

References

Avery, E.T., and E.H. Burkhart. 2002. *Forest Measurements.* 5th ed. New York: McGraw-Hill.

Bebber, D.P., and S.C. Thomas. 2003. Prism sweeps for coarse woody debris. *Canadian Journal of Forest Research* 33:1737–1743.

Caplenor, D. 1968. Forest composition on loessal and non-loessal soils in west-central Mississippi. *Ecology* 49:322–331.

Davis, M.B. 2003. Old growth in the East: A survey. Eastern Old-Growth Clearinghouse, Appalachia—Science in the Public Interest. Mount Vernon, KY. www.primalnature.org.

Delcourt, H.R., and P.A. Delcourt. 1974. Primeval magnolia–holly–beech climax in Louisiana. *Ecology* 55:638–644.

Harmon, M.E., and J. Sexton. 1996. Guidelines for measurements of woody detritus in forest ecosystems. Publication Number 20. U.S. LTER Network Office, Univ. of Washington, Seattle.

Hilt, D.E. 1980. Taper-based system for estimating stem volumes of upland oaks. Forest Service Research Paper NE-458. U.S. Department of Agriculture, Northeast Forest Experiment Station, Broomall, PA.

NPS [National Park Service]. 2009. Vicksburg National Military Park Cultural Landscape Report. http://parkplanning.nps.gov/document.cfm?parkID=411&projectID=19204&documentID=27908.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. *Annals of the Association of American Geographers* 77:118–125.

Runkle, J.R. 1996. Central mesophythic forests. In *Eastern old-growth forests*, ed. M.D. Davis, 161–177. Washington, DC: Island Press.

Somershoe, S.G., D.J. Twedt, and B. Reid. 2006. Combining breeding bird survey and distance sampling to estimate density of migrant and breeding birds. *Condor* 108:691–699.

Sturtevant, B.R., J.A. Bissonette, J.N. Long, and D.W. Roberts. 1997. Coarse woody debris as a function of age, stand structure, and disturbance in boreal Newfoundland. *Ecological Applications* 7:702–712.

Taylor, J.L. 2010. Mississippi Valley Loess Plains. U.S. Geological Survey Land Cover Trends Project. http://landcovertrends.usgs.gov/east/eco74Report.html.

Wilson, R., K. Ribbeck, S. King, and D. Twedt, eds. 2007. Restoration, management, and monitoring of forest resources in the Mississippi Alluvial Valley: Recommendations for enhancing wildlife habitat. Forest Resource Conservation Working Group, Lower Mississippi Valley Joint Venture, Vicksburg, MS. www.lmvjv.org/library/DFC%20Report%20to%20LMVJV% -202007.pdf.