

Influence of Silvicultural Practices on Understory Disturbance Regimes, Microsites, and Plants

David S. Buckley and Jordan M. Marshall

Associate Professor and Graduate Research Assistant, respectively, University of Tennessee Agricultural Experiment Station, Department of Forestry, Wildlife and Fisheries, 274 Ellington Plant Sciences Building, Knoxville, TN 37996-4563. dbuckley@utk.edu.

Acknowledgements

The authors wish to thank Ray Albright, Richard Evans, Jennifer Franklin, Brien Ostby, J. Mark Young, and Jake Weltzin for lending their ideas and assistance during this research. This work was made possible through McIntire-Stennis funds.

Abstract

Many silvicultural practices represent controlled disturbances that influence the overall disturbance regime in managed forests, as well as understory microsites and plants. We investigated the response of Japanese stilt grass, a shade-tolerant, invasive, exotic species, to microsites created by partial harvesting in winter 2005 in oak-hickory forest in East Tennessee. Microsites were classified into six types within three harvest units in close proximity to existing Japanese stilt grass populations. Japanese stilt grass was sown in replicate plots within each microsite type in spring 2005, and subsequent growth was measured in October 2005. Canopy cover, light, moisture, litter depth, and compaction were also measured in each plot. Preliminary results suggest that increased light, the loss of litter, and other factors may interact to increase height growth in microsites such as multiple-pass haul roads, and that fine-scale information on microsite factors influenced by disturbance is important for revealing mechanisms underlying exotic invasions.

Key Words

Disturbance Microsites Japanese stilt grass

Introduction

The overall disturbance regime experienced by forest species depends on the spatial scale, frequency, intensity, spatial pattern, and type of each potential disturbance. Disturbance regimes in forests under active management are often hybrid regimes comprised of elements of the natural disturbance regime combined with elements resulting from various human disturbances, including the implementation of silvicultural practices. Many silvicultural practices designed to influence the composition, abundance, distribution, and growth of forest species involve the application of planned and controlled disturbances such as cutting, prescribed fire, and herbicide application. Due to the potentially powerful effects of silvicultural practices on the full spectrum of forest species and other ecosystem characteristics, a great deal of interest exists in the comparability of natural disturbance regimes and the hybrid disturbance regimes in forests managed with silvicultural practices (Perry and Amaranthus 1997; Reich et al. 2001; Simberloff 2001; Baker et al. 2004; *also see Palik in these proceedings*).

Components of natural disturbance regimes such as the scale, frequency, and intensity of natural disturbances tend to be more easily emulated through silviculture than types and spatial patterns of disturbance, particularly at fine spatial scales. Spatial scales of natural disturbances can be simulated by choosing appropriate sizes of harvest and management units, natural frequencies can be approximated by setting rotation lengths and treatment schedules, and natural intensities can be emulated by adjusting methods of cutting, prescribed burning, or herbicide application. Types and patterns of disturbance, on the other hand, can differ substantially between natural disturbance regimes and the hybrid regimes in stands under active management. Although it is possible to emulate large-scale spatial patterns of natural disturbance by setting appropriate boundaries and locations for treatment areas, limited information and research (e.g., Franklin et al. 1997; Palik et al. 1997) exists on methods for adjusting fine-scale patterns of disturbance, such as the particular felling pattern used within a partially harvested area. Perhaps the most challenging contrasts between natural disturbances and silvicultural practices occur with respect to the specific types of disturbance experienced by forest species. For example, the biological legacies (Franklin et al. 1997) which remain after an individual tree is windthrown or struck by lightning are quite distinct from those following the harvest of a single stem, and there are few analogous natural processes that result in the magnitude and patterns of soil compaction created by logging machines.

The need for additional information on the impact of the different disturbance regimes in actively managed forests and unmanaged baselines provided the impetus for a five-year study established in 1994 by Crow et al. (2002), and additional studies involving similar comparisons of managed and unmanaged forests (e.g., Goodburn and Lorimer 1999; Scheller and Mladenoff 2002). The primary objective of the Crow et al. (2002) study was to compare biological diversity in northern hardwood stands actively managed with even- and uneven-aged methods with biological diversity in unmanaged northern hardwood baselines comprised of unmanaged second growth and unmanaged old growth. Elements of biodiversity investigated included overstory and understory structure, microclimate, species richness and composition, and nutrient dynamics. Major findings of the Crow et al. (2002) study included greater structural complexity in unmanaged old growth than managed forests, similar species richness in overstory vegetation between managed and unmanaged forests, and a marked difference in the richness and

composition of herb-layer species between managed and unmanaged forests. Herb-layer species richness was greater in managed than unmanaged stands, but this greater richness was the result of adding several exotic species in addition to native species.

Skid trails and haul roads in the managed stands investigated in the Crow et al. (2002) study were clearly hotspots for increased species richness and exotic plant species, which led to a 1998 follow-up study (Buckley et al. 2003) with the objectives of: 1) documenting the proportions of managed stands comprised of haul roads, skid trails, and forest patches with no soil disturbance, 2) characterizing the growth conditions in each of these microsites, and 3) comparing the richness and composition of trees, shrubs, and herbs between these types of understory microsite. Results of this follow-up study suggested that disturbances resulting from the establishment and use of skid trails and haul roads created novel combinations of microsite factors, which had substantial impacts on plant species richness and composition in the understory. Haul road microsites had significantly greater species richness than skid trails and forest without soil disturbance, but 13% and 23% of the species in haul roads were exotic and wetland species, respectively. These wetland species were native to the area, but not normally found in the understory of unmanaged northern hardwood stands.

The study conducted by Crow et al. (2002), similar studies involving stand-level comparisons, and the Buckley et al. (2003) study involving comparisons at the level of patches within stands provide evidence that disturbances resulting from the implementation of silvicultural practices can produce changes in understory plant richness and composition. These studies, however, were not designed to reveal the specific mechanisms underlying the changes in understory vegetation observed. In the case of invasive exotic plants, an understanding of what basic factors related to the disturbance regime either facilitate or hinder the invasion of managed forests by exotic plant species is critical. Fine-scale information on factors underlying the susceptibility of forests to invasion must be obtained in order to predict when invasion of an exotic species is likely, and what modifications to silvicultural practices may be useful for reducing the likelihood of invasion.

In 2005, the authors established a study designed to reveal what basic factors influence the susceptibility of managed, upland, oak-hickory forests to invasion by Japanese stilt grass (*Microstegium vimineum* (Trin.) A. Camus). Japanese stilt grass is an annual, invasive, exotic grass species native to Asia (Sur 1985; Osada 1989), and is ranked as very tolerant of shade (Winter et al. 1982). This species forms dense mats and spreads through prolific seed production (Winter et al. 1982). In the U.S., Japanese stilt grass was first collected in the vicinity of Knoxville, Tennessee around 1919, and more recent range estimates include nearly all of the southern states from Kentucky and Virginia south to Florida, and west to Texas (Fairbrothers and Gray 1972; Hunt and Zaremba 1992; Miller 2003). Japanese stilt grass is ranked as a high-priority invasive species by the USDA Forest Service and Tennessee Exotic Pest Plant Council (TNEPPC 2001; USFS 2001; Miller et al. 2004), and anecdotal evidence gathered from private and public managers suggests large populations of this species are either becoming established or are being noticed for the first time in forests across the state of Tennessee.

The level of shade tolerance of Japanese stilt grass has generated substantial concern related to the potential ability of this species to invade closed forests and displace native species, and this

concern has stimulated several studies on the life history, ecology, and control of this species (Fairbrothers and Gray 1972; Winter et al. 1982; Barden 1987, 1996; Redman 1995; Horton and Neufeld 1998; Williams 1998; Gibson et al. 2002; Miller 2003; Cole and Weltzin 2004, 2005). Experimental evidence of the displacement of native species by Japanese stilt grass is limited, but a strong negative relationship between biomass production of this species and first-year height growth of planted high-quality oak seedlings was recently described by Oswalt et al. (2004). To our knowledge, there have been no studies specific to the effects of the different types of disturbance and microsites resulting from silvicultural practices on the susceptibility of forest stands under active management to invasion by this species. As a result, the objectives of this study were to: 1) identify and classify understory microsites created by cutting, log skidding, and hauling in selectively harvested oak-hickory forest, 2) quantify canopy cover, light, litter depth, soil moisture, and soil compaction conditions within these microsites, and 3) document the response of Japanese stilt grass sown in replicated plots located within each type of microsite identified under objective 1.

Methods

Study areas consisted of three harvest units within an oak-hickory forest on the University of Tennessee Forest Resources Research and Education Center at Oak Ridge, Tennessee. Selective harvests of each unit occurred in February 2005. Transects for identifying and classifying primary microsite types in each unit were established 10 meters apart and parallel to the long axis of each of the three harvest units on 21-23 March 2005. Transect lengths were variable in order to conform to the shape and size of the harvesting blocks. Along each transect, all types of soil disturbance related to harvesting, as well as undisturbed areas, were recorded by category.

Microsites were classified as a one-pass compacted track without litter, one-pass compacted track with litter, one-pass compacted log skid, multiple-pass compacted, multiple-pass loosened, and microsites without soil disturbance. One-pass compacted tracks without litter were microsites created by a single pass of a bulldozer, in which litter and other forest floor materials were removed from the tracks. One-pass compacted tracks with litter were similar to the previous category, except that litter persisted within the track marks. Compacted log skids were linear areas between bulldozer tracks that the ends of logs passed over during skidding. Small vegetation and litter were generally removed and pushed aside by the logs skidded within these microsites. Multiple-pass compacted and multiple-pass loosened microsites were created by repeated passes of a rubber-tired skidder, bulldozer, or both, and had little or no vegetation or litter. Microsites labeled as multiple-pass compacted fell within the area compacted repeatedly by skidder tires and bulldozer tracks, whereas multiple-pass loosened microsites were located on the edges of multiple-pass areas where tracks or tires pushed soil up along the sides of ruts. The position and length of each transect covered by each category of disturbed area and undisturbed areas were recorded along each transect for subsequent establishment of plots representative of each microsite type.

Five occurrences of each disturbed microsite, as well as the undisturbed microsites, were randomly selected within each harvest unit to receive a 0.25 m² (0.56 m diameter) circular plot. Japanese stilt grass seed was collected 20 October 2004 from a large population which had become established at the Ijam's Nature Center in Knox County, Tennessee. After air-drying at

room temperature, seeds were separated randomly into lots of 100 and were placed in 4° C cold storage over the winter. One hundred Japanese stilt grass seeds were sown within each 0.25 m² plot on 29 March, 30 March, and 6 April 2005.

Mean litter depth was calculated for each plot from measurements taken with a metric ruler in the center of each quadrant of the 0.25 m² circular plot area. Soil compaction was measured in the center of each 0.25 m² plot with a soil penetrometer (Lang Inc., Gulf Shores, AL) on 3 March and 28 April 2005. Soil moisture and photosynthetically active radiation (PAR), were measured mid-month May-October 2005. Soil moisture was measured to 15 cm depth in the center of each plot with a Trase Time Domain Reflectometry (TDR) probe (Soilmoisture Corp., Santa Barbara CA). Soil moisture was measured in all sown plots within a single day each month. PAR was measured with an AccuPAR Linear Ceptometer (Decagon Devices Inc., Pullman, WA) held at both the mean height of Japanese stilt grass stems and at 1 m. Additional measurements of PAR were obtained in the open during each measurement period to allow calculation of percent full PAR. Percent canopy cover was measured once over each plot center with a digital plant canopy imager (CID Inc., Camas, WA). Heights of the tallest and shortest Japanese stilt grass stems in each plot were measured with a metric ruler in October 2005.

Differences between microsite types in Japanese stilt grass height and all microsite variables were investigated with one-way ANOVA and Tukey's Honestly Significant Difference (HSD) procedure with $\alpha = 0.05$. Analyses of additional measures of Japanese stilt grass performance are currently ongoing, and the use of multiple regression is planned to develop predictive models relating different elements of Japanese stilt grass performance to measured microsite variables.

Results

Percent canopy cover was significantly lower in the multiple-pass compacted and multiple-pass loosened microsites than in the remaining microsites (Figure 1).

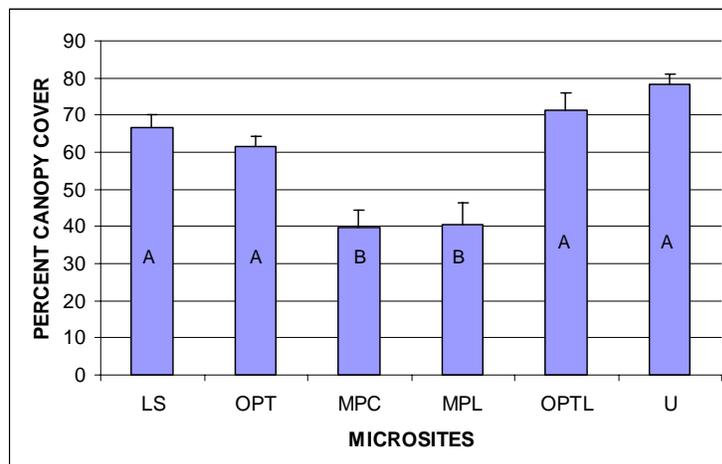


Figure 1. Mean percent canopy cover by microsite type. LS = compacted log skid, OPT = one-pass compacted track without litter, MPC = multiple-pass compacted, MPL = multiple-pass loosened, OPTL = one-pass compacted track with litter, U = microsites without soil disturbance. Means with the same letters are not significantly different at the $\alpha = 0.05$ level, and error bars represent one standard error.

The greatest percentages of full PAR occurred in the multiple-pass compacted and multiple-pass loosened microsites, with significantly greater percent full PAR in the multiple-pass loosened microsite than in the one-pass track, one-pass track with litter, and undisturbed microsites (Figure 2).

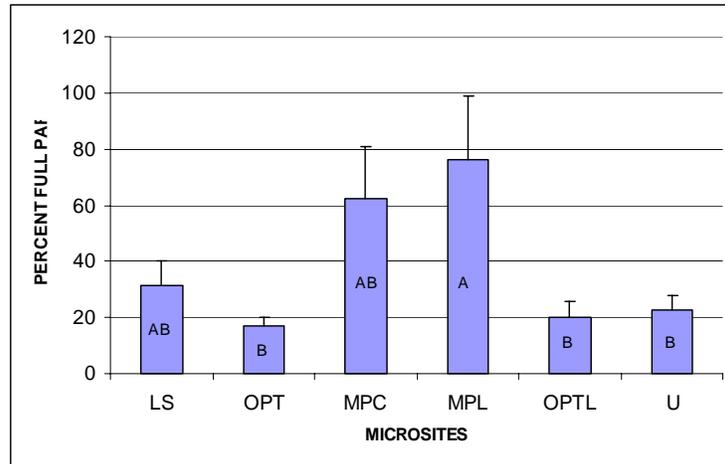


Figure 2. Mean percent full PAR by microsite type. Microsite codes, significance, and error bars as in Figure 1.

Mean litter depths were significantly greater in one-pass compacted tracks with litter and undisturbed microsites than in all other microsites (Figure 3).

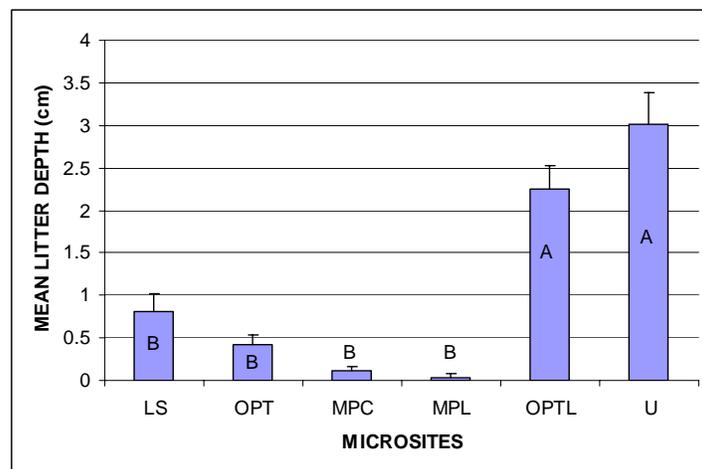


Figure 3. Mean litter depth by microsite type. Microsite codes, significance, and error bars as in Figure 1.

Mean compaction was significantly greater in compacted log skids and multiple-pass compacted microsites than in undisturbed microsites (Figure 4). Compaction in multiple-pass loosened areas was significantly less than in undisturbed microsites (Figure 4).

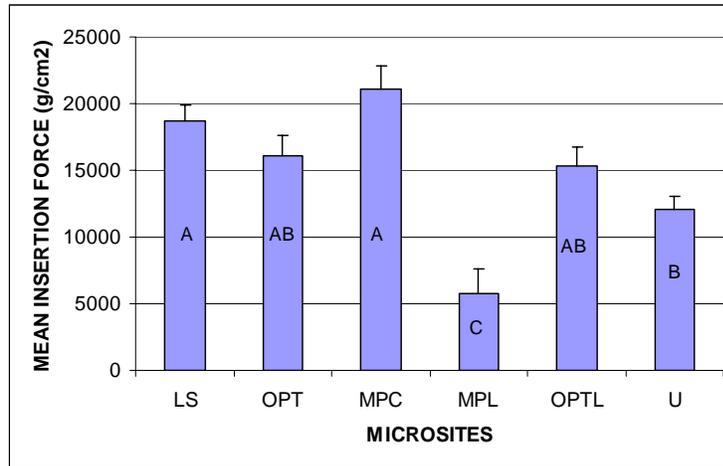


Figure 4. Mean compaction by microsite type. Microsite codes, significance, and error bars as in Figure 1.

Mean percent soil moisture was significantly greater in the one-pass compacted track microsites than in the multiple-pass loosened and undisturbed microsites (Figure 5).

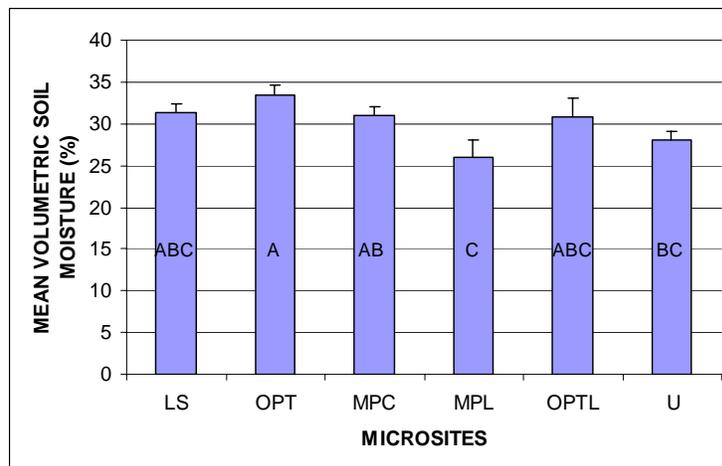


Figure 5. Mean percent soil moisture by microsite type. Microsite codes, significance, and error bars as in Figure 1.

At approximately 60 cm, median height of Japanese stilt grass was greatest in the one-pass compacted tracks without litter and multiple-pass compacted microsites, and significantly greater in these microsites than in the one-pass track with litter and undisturbed microsites (Figure 6).

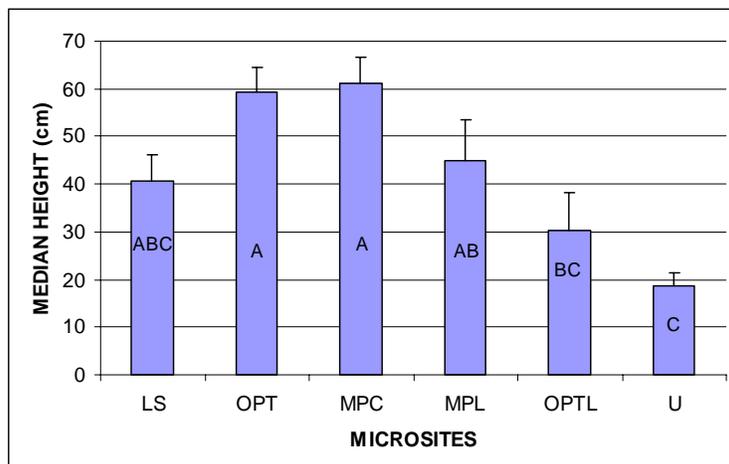


Figure 6. Median height of Japanese stilt grass by microsite type in October 2005. Microsite codes, significance, and error bars as in Figure 1.

Discussion and Preliminary Conclusions

Significantly lower levels of canopy cover and increases in PAR in multiple-pass compacted and multiple-pass loosened microsites were likely due to the location of multiple-pass roads in areas with fewer trees, and the felling of trees in these areas to provide additional room for logging equipment. Although litter depths were greatly reduced, compacted log skid, one-pass track without litter, and the multiple-pass microsites did contain small amounts of litter. Differences were not always statistically significant, but the greater mean levels of compaction in microsites impacted by the operation of logging equipment (except for the multiple-pass loosened microsites) were expected. The greatest contrast in compaction clearly occurred between the multiple-pass compacted and multiple-pass loosened microsites, which were often located in close proximity. Fewer differences in soil moisture occurred between microsites than might be expected based on the differences observed in litter depth and compaction. Reduced percent soil moisture in multiple-pass loosened microsites may have been due to a combination of little or no litter cover in these microsites, the slightly greater elevation of these microsites relative to the adjacent terrain, and low compaction.

The pattern of greatest Japanese stilt grass height growth in one-pass compacted track without litter and multiple-pass compacted microsites did not correspond directly to patterns in PAR, litter depth, compaction, or soil moisture across microsites. Thus, results of these analyses do not suggest that a single overriding factor such as PAR can be used to predict height growth of Japanese stilt grass. It is important to note, however, that mean values of microsite variables by microsite type may not provide an accurate picture of the combinations of levels of microsite factors that either maximize or minimize Japanese stilt grass performance. Subsequent multiple regression analysis utilizing measurements of microsite variables in the immediate vicinity of individual plots is expected to shed additional light on combinations of microsite variables and interactions between these variables that are important.

Additional overall conclusions that can be drawn at this time are that several distinct and unique combinations of light, litter depth, compaction, and soil moisture can occur *within* patches

disturbed by the implementation of silvicultural practices, and that levels of these factors can vary substantially at the scale of a few centimeters. It can also be argued that fine-scale information on specific microsite factors will be necessary to reveal mechanisms underlying the susceptibility of actively managed forest to invasion by exotic species, and for predicting what silvicultural scenarios are likely to lead to significant problems involving these species.

Literature Cited

- BAKER, S.C., A.M.M. RICHARDSON, O.D. SEEMAN, and L.A. BARMUTA. 2004. Does clearfell, burn and sow silviculture mimic the effect of wildfire? A field study and review using litter beetles. *Forest Ecology and Management* 199:433-448.
- BARDEN, L.S. 1987. Invasion of *Microstegium vimineum* (Poaceae), an exotic, annual, shade-tolerant, C₄, grass, into a North Carolina Floodplain. *American Midland Naturalist* 118:40-45.
- _____. 1996. The linear relation between stand yield and integrated light in a shade-adapted annual grass. *Bulletin of the Torrey Botanical Club* 123:122-125.
- BUCKLEY, D.S., T.R. CROW, E.A. NAUERTZ, and K.E. SCHULZ. 2003. Influence of skid trails and haul roads on understory plant richness and composition in managed forest landscapes in Upper Michigan, USA. *Forest Ecology and Management* 175:509-520.
- COLE, P.G., and J.F. WELTZIN. 2004. Environmental correlates of the distribution and abundance of *Microstegium vimineum*, in East Tennessee. *Southeastern Naturalist* 3:545-562.
- _____. 2005. Light limitation creates patchy distribution of an invasive grass in eastern deciduous forests. *Biological Invasions* 7:477-488.
- CROW, T.R., D.S. BUCKLEY, E.A. NAUERTZ, and J.C. ZASADA. 2002. Effects of management on the composition and structure of northern hardwood forests in Upper Michigan. *Forest Science* 48: 129-145.
- FAIRBROTHERS, D.E., and J.R. GRAY. 1972. *Microstegium vimineum* (Trin.) A. Camus (Gramineae) in the United States. *Bulletin of the Torrey Botanical Club* 99:97-100.
- FRANKLIN, J.F., D.R. BERG, D.A. THORNBURGH, and J.C. TAPPEINER. 1997. Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. Pp. 111-139 in KOHM, K.A., and J.F. FRANKLIN (eds.). *Creating a forestry for the 21st Century*. Washington, DC: Island Press.
- GIBSON, D.J., G. SPYREAS, and J. BENEDICT. 2002. Life history of *Microstegium vimineum* (Poaceae), an invasive grass in southern Illinois. *Journal of the Torrey Botanical Society* 129:207-219.

- GOODBURN, J.M., and C.G. LORIMER. 1999. Population structure in old-growth and managed northern hardwoods: an examination of the balanced diameter distribution concept. *Forest Ecology and Management* 118:11-29.
- HORTON, J.L., and H.S. NEUFELD. 1998. Photosynthetic responses of *Microstegium vimineum* (Trin.) A. Camus, a shade-tolerant, C4 grass, to variable light environments. *Oecologia* 114:11-19.
- HUNT, D.M., and R.E. ZAREMBA. 1992. The northeastward spread of *Microstegium vimineum* (Poaceae) into New York and adjacent states. *Rhodora* 94:167-170.
- MILLER, J.H. 2003. *Nonnative invasive plants of southern forests: a field guide for identification and control*. USDA Forest Service Southern Research Station Revised General Technical Report SRS-62.
- MILLER, J.H., E.B. CHAMBLISS, and C.T. BARGERON. 2004. Invasive Plants of the Thirteen Southern States. <http://www.invasive.org/seweeds.cfm> [12/21/04].
- OSADA, T. 1989. *Illustrated Grasses of Japan*. Tokyo: Heibonsha Ltd, Publishers.
- OSWALT, C.M., W.K. CLATTERBUCK, S.N. OSWALT, A.E. HOUSTON, and S.E. SCHLARBAUM. 2004. First-year effects of *Microstegium vimineum* (Trin.) and early growing season herbivory on planted high-quality oak (*Quercus* Spp.) seedlings in Tennessee. *Proceedings, 14th Central Hardwood Forest Conference*. USDA Forest Service Northeastern Research Station General Technical Report NE-316 (CD).
- PALIK, B.J., R.J. MITCHELL, G. HOUSEAL, and N. PEDERSON. 1997. Effects of canopy structure on resource availability and seedling responses in a longleaf pine ecosystem. *Canadian Journal of Forestry Research* 27:1458-1464.
- PERRY, D.A., and M.P. AMARANTHUS. 1997. Disturbance, recovery, and stability. Pp. 31-56 in KOHM, K.A., and J.F. FRANKLIN (eds.). *Creating a forestry for the 21st Century*. Washington, DC: Island Press.
- REDMAN, D.E. 1995. Distribution and habitat types for Nepal *Microstegium* [*Microstegium vimineum* (Trin.) Camus] in Maryland and the District of Columbia. *Castanea* 60:270-275.
- REICH, P.B., P. BAKKEN, D. CARLSON, L.E. FRELICH, S.K. FRIEDMAN, and D.F. GRIGAL. 2001. Influence of logging, fire, and forest type on biodiversity and productivity in southern boreal forests. *Ecology* 82: 2731-2748.
- SHELLER, R.M., and D.J. MLADENOFF. 2002. Understory species patterns and diversity in old-growth and managed northern hardwood forests. *Ecological Applications* 12: 1329-1343.

- SIMBERLOFF, D. 2001. Management of boreal forest biodiversity—A view from the outside. *Scandinavian Journal of Forest Research Supplement* 3:105-118.
- SUR, P.R. 1985. A revision of the genus *Microstegium* Nees (Poaceae) in India. *Journal of Economica and Taxonomic Botany* 6:167-176.
- [TNEPPC] TENNESSEE EXOTIC PEST PLANT COUNCIL. 2001. Invasive Exotic Pest Plants in Tennessee. http://www.tneppc.org/Invasive_Exotic_Plant_List/Invasive%20List%20Introduction.htm [12/21/04].
- [USFS] UNITED STATES DEPARTMENT OF AGRICULTURE, FOREST SERVICE, SOUTHERN REGION. 2001. Regional Invasive Exotic Plant Species List. Regional Forester's List and Ranking Structure: Invasive Exotic Plant Species of Management Concern. <http://www.se-eppc.org/fslist.cfm> [12/21/04].
- WILLIAMS, L.D. 1998. Factors Affecting Growth and Reproduction in the Invasive Grass *Microstegium vimineum*. *MS Thesis. Appalachian State University*.
- WINTER, K, M.R. SCHMITT, and G.E. EDWARDS. 1982. *Microstegium vimineum*, a shade adapted C₄ grass. *Plant Science Letters* 24:311-318.