Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics

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FY01 Annual Report

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Introduction

Background

Land at Fort Benning must sustain the military training mission. A second land management goal is sustainable upland forests, including longleaf pine (*Pinus palustris*) forest, which provides economic benefits and supports the endangered red-cockaded woodpecker (*Picoides borealis*). Current land use for military training at Fort Benning involves light disturbance by foot and light vehicle traffic through heavy disturbance by repeated heavy vehicle traffic. Site-specific management of uplands entails thinning and burning to promote longleaf pine savanna.

At some intensity and frequency, disturbances due to land use may no longer be sustainable. That is, the ecosystem does not recover or continue its desired trajectory following disturbance; it may lose nutrients, become dominated by early successional or invasive species, or fail to regenerate key species. Land managers at Fort Benning need information to determine what combinations of military training and longleaf pine forest management exceed thresholds beyond which upland ecosystems are not sustainable.

Objective

The broad objective of our research is to evaluate the ecological effects of military training and forest management for longleaf pine at Fort Benning, to determine if there are thresholds beyond which upland ecosystems cannot sustain the combined effects of thinning, burning, and military training disturbances.

Approach

We are taking an experimental approach to test the hypothesis that underlying soil type partly determines nutrient cycling, species diversity, and vegetation dynamics on a site, and influences thresholds for sustainability of land use disturbances. We are comparing cycling of a key element, nitrogen, as well as species diversity and vegetation dynamics of sites on clayey and sandy soils subjected to different forest management scenarios (burned on 2 yr cycle, burned on 4 yr cycle, thinned, unthinned) and to either heavier (open to tracked vehicles) or lighter (primarily infantry) military use.

Field research sites (32 400 m x 400 m sites) were established during FY00 in upland forest areas that had been burned during spring, 2000. Half the sites (16) are on sandy soil; half are on clayey soil. Half the sites (8) on each soil type are in areas with heavier military use; half are in areas with lighter use. Half the sites (4) in each soil type/ military use combination will be burned on a 2 yr cycle in spring, 2002; half will have burning delayed until spring 2004. Each combination of soil type/military use/burning includes two sites that were recently thinned and two that are unthinned.

Summary of Research Activities and Results for FY01

Research efforts during FY01 concentrated on 1) characterizing the environment, "disturbance," and vegetation in each site and 2) establishing field procedures to monitor and compare N cycling, environment, and vegetation response to the land management treatments.

Site baseline characterization

Results of the baseline vegetation, environment, and "disturbance" surveys in each site during summer 2000 have been analyzed and are summarized in a manuscript (Dilustro, J., B. Collins, L. Duncan, and R. Sharitz. *Soil texture, vegetation, and land use intensity of Fort Benning Sandhills sites*) to be submitted to a journal during early FY02. We characterized soil texture and land use disturbance among the 32, 400 m x 400 m sites, and asked if canopy and ground layer vegetation (species composition and richness, basal area, abundance) differ among sites on the basis of soil texture or land use.

Trees were surveyed using the point quarter method and ground layer vegetation was surveyed by line-intercept at 25 points in a 100 m x 100 m plot in each site. Soil texture was determined from nine samples in each site. Land use intensity was assessed by line intercept of disturbance features along two 300 m transects in each 400 m x 400 m site.

Soil clay content of the 32 sites ranges from 2 % in a sandy site to 48 % in a clayey site; sand content ranges from 32 % in a clayey site to 91 % in a sandy site. Clayey sites generally have greater variation in percent clay and sand among and within sites. There is significant interaction between land use and soil texture, with a gradient of soil texture (% clay) from clayey sites within light training areas, to sandy sites in heavier training areas (Fig. 1).

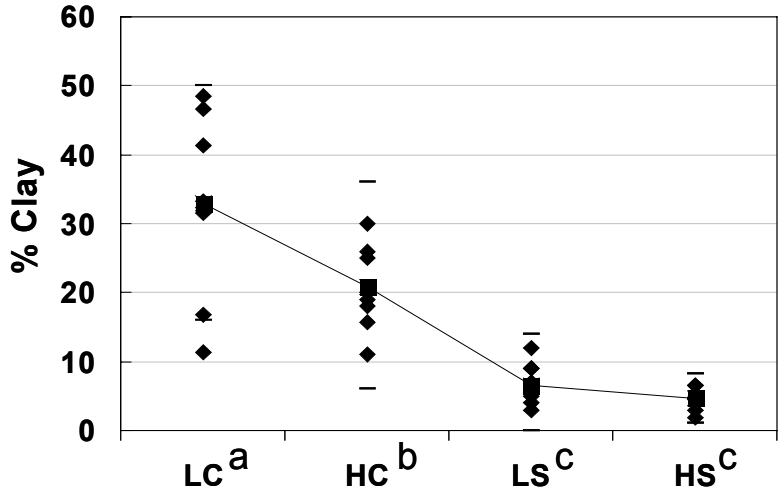

Fig. 1. Clay content (%) of sites with lighter (L) or heavier (H) land use and sandy (S) or clayey (C) soil. Shown are the category mean (circles) and standard deviation (line), and mean of each site (stars) within the category. Category means with the same letter do not differ significantly.

Disturbance features in the research sites include those due to natural disturbance (e.g., treefalls), forestry practices (e.g., skidders), and military use (e.g., tank tracks), or some combination of these (e.g., mounds that could have been left by treefalls, harvesting, or military use). Road-like features, including active and remnant trails, roads, and vehicle tracks or trails are the most frequent and abundant disturbance feature. Among sites, landuse (forestry or military training-generated) or natural disturbance features occupied from 7 % to 50 % of sample transect length; half the sites were at least 19 % disturbed, and 3/4 of the sites were at least 30 % disturbed. Sites within soil texture/landuse categories differ in amount of disturbance (ANOVA df=3; ms=19822; F=6.19; p=0.002; Fig. 2). Clayey sites in heavy military use areas (HC sites) have greater length of sampling transects in disturbance features (Fig. 2).

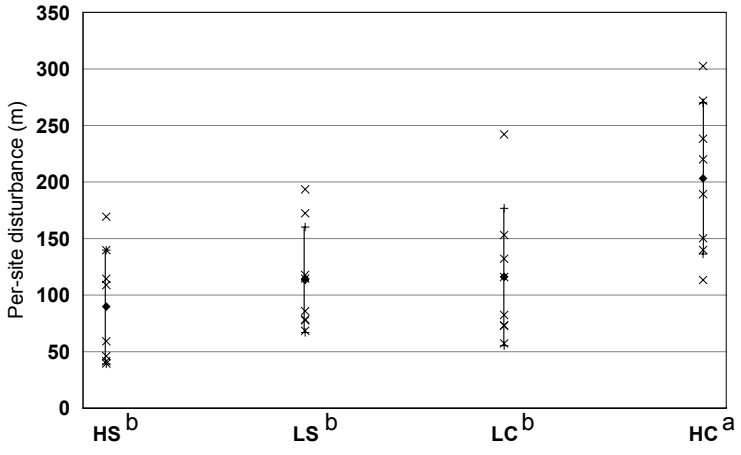

Fig. 2. Amount of disturbance (m of line “disturbed” per 600 m sampled) in sites classified as heavier (H) or lighter (L) disturbance and clayey (C) or sandy (S) soil. Shown are category

means (diamonds) and standard deviations (lines), and totals for sites (x) in each category. Category means with the same letter do not differ significantly.

Remnant and active roads and trails at Fort Benning

Common plants in the ground layer vegetation of all sites include *Liquidambar styraciflua* (sweetgum) sprouts/seedlings, Poaceae (grasses other than *Andropogon* spp.), *Andropogon* spp. (broomsedge), and *Heterotheca graminifolia*. Pines, including *P. taeda* (loblolly), *P. echinata* (shortleaf), and *P. palustris* (longleaf), dominate the canopy of most sites. The proportion of pine in the canopy varies among sites from 12 % to 99.9 %. Four of the 32 sites, with < 30 % pine in the canopy are "hardwood sites" dominated by oaks (*Quercus falcata* [southern red oak] and *Q. nigra* [water oak]). Differences in ground layer and canopy composition among sites scale by disturbance intensity; differences in canopy composition also reflect the proportion of pine. Species richness of ground layer vegetation differs among soil texture/landuse categories; there is a richness gradient from heavily disturbed sites with clayey soil, through lightly disturbed sites, to heavily disturbed sites with sandy soil (Fig. 3).

Examples of pine and hardwood sites at Fort Benning. The upper-left site has abundant sweetgum. The lower-right site is A15, which has light military use, but burns frequently and is compositionally closer to sites with heavy military use.

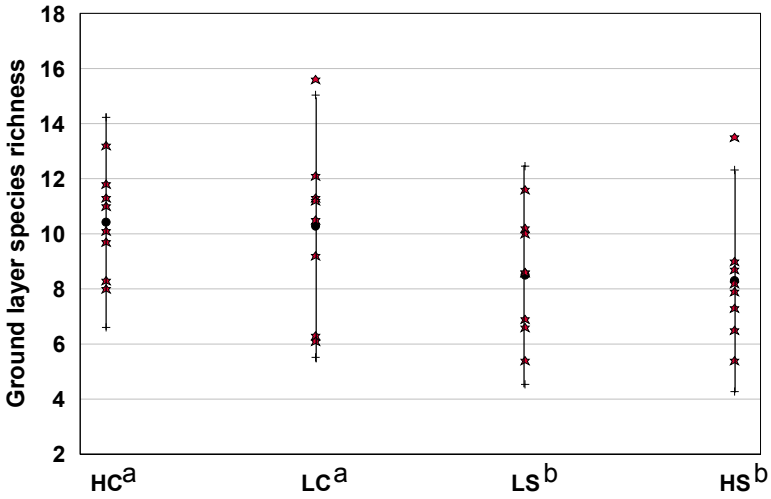

Fig. 3. Ground layer richness (number of species per point) in sites categorized by heavier (H) or lighter (L) military use and clayey (C) or sandy (S) soil. Shown are the mean (circle), standard deviation (line), and site means (stars) within each use/soil category.

Results of the baseline surveys of the 32 upland oak-hickory-pine forest research sites suggest they range from sandhills scrub oak-pine vegetation to shortleaf pine-hardwood or oak-hickory dominated forests, with greater species diversity in the understory of clayey sites. Disturbances associated with mechanized military training and forestry

practices have favored pine dominance, and maintained open-site, successional or fire-tolerant species in the understory.

Results of the vegetation, disturbance, and soil texture surveys in summer, 2000, also revealed that three of the 32 sites selected in spring, 2000, were put into the wrong soil texture (sandy vs. clayey) or military disturbance (lighter vs. heavier) category, or had vegetation that was different from all other sites. We identified three "replacement" sites, and conducted baseline surveys in each during summer, 2001, to ensure the new sites are compatible with our experimental design.

Field procedures

Research efforts during 2001 concentrated on installing equipment or establishing procedures to compare the environment, vegetation, and nitrogen dynamics among sites in response to the land use treatments and soil texture categories. All sites were in the second post-burn season; 2 yr burn sites will be burned in spring 2002; 4 yr burn sites will have burning delayed until spring 2004. Research activities included resurveying ground layer vegetation in all sites, surveying woody seedlings and marking seedlings to monitor survival, planting seedlings to monitor their growth and mortality, installing temperature and soil moisture monitoring equipment in each site, installing and monitoring litter traps in each site, implementing an aboveground decomposition study, and initiating soil nitrogen studies.

Vegetation

Oak and pine seedlings were planted in 4 yr burn sites during January/February, and censused for survival and growth in early June. Pine seedlings had high mortality (from 54 to 83 %, Fig. 4), while oak seedlings ranged from 0 to 10 % mortality (Fig. 4). For seedlings that survived, nine week growth rates were generally higher for the oak seedlings (1.6 to 13.8 cm/plant). As expected, the longleaf pine seedlings had low growth rates (0.4 to 3.4 cm/plant, Fig. 4).

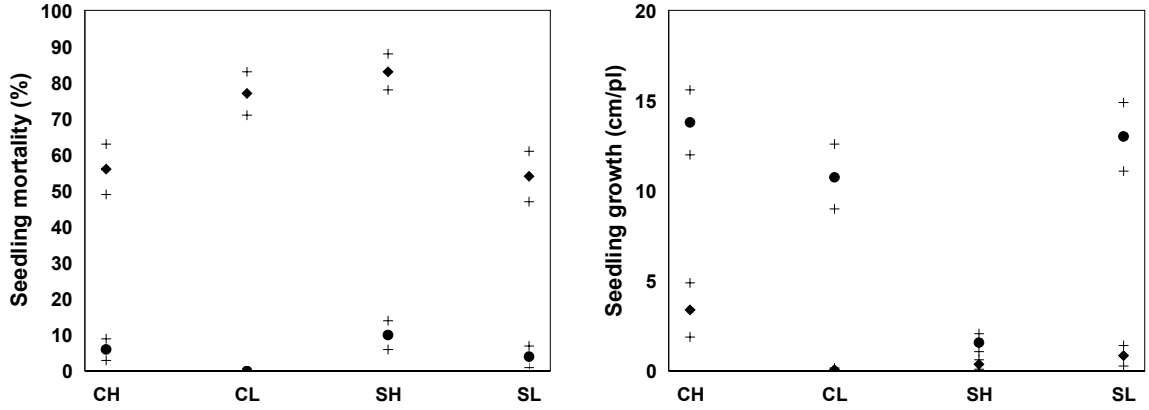

Fig. 4. Preliminary data on mortality and growth of oak (circles) and pine (diamonds) seedlings after nine weeks in clayey (C) and sandy (S) sites with heavier (H) or lighter (L) military training. Shown are the mean ± 1 standard error for each category of sites.

A planted pine seedling

Litter traps (256) were constructed and eight traps were installed in each of the 32 sites in March. During late May / early June the seed/litter traps were sampled and the litter was sorted into seeds, foliage and miscellaneous woody debris. These initial results show similar litterfall rates among sites, with inputs ranging from 0.46 to 0.51 $g^2/m^2/day$. Traps were sampled again in September, and a peak litterfall harvest is planned for late fall (early FY02).

Litter traps in a pine site.

Groundlayer vegetation was re-surveyed in all sites in summer, 2001, following the methods for the baseline vegetation survey conducted in summer, 2000. In addition, woody seedlings were surveyed at each of the 25 sampling points in each site to assess post-fire regeneration. Up to 50 oak and pine seedlings were marked in each site to monitor survival and growth of natural regeneration. Results of the vegetation and seedling surveys are currently being analyzed.

Environment and nitrogen dynamics

Environmental measures are being taken in each site as needed to enhance weather station information from ECMI stations. To assess temperature, four continuously logging soil temperature sensors (ibuttons) were installed in each of the 32 sites during spring, 2001. Air temperature also is being continuously logged in each site. Four soil moisture access tubes were installed in each site for in-field measurement of volumetric soil moisture. Initial information shows that volumetric soil moisture increases with clay

content. In September, volumetric soil moisture ranged from 39 % in sites with light military use and clayey soil, through 26 % in heavily used clayey soil sites and 17.6 % in lightly used sites with sandy soil, to 10.4 % in heavily used sites with sandy soil.

Procedures were established during FY01 to monitor nitrogen dynamics and ecosystem attributes that potentially affect N and C dynamics. Litter samples, collected periodically from the litter traps in each site, will be analyzed to evaluate carbon and nitrogen inputs into the sites. At 8 points in each of the 32 sites the mass of the forest floor was estimated by collecting 491 cm^2 samples (256 total) of the pooled Oi, Oe, and Oa layers from each plot in May. Samples were dried at 70C. The samples will be analyzed to determine the total amounts of carbon and nitrogen in the forest floor. Below each sample a 7 x 16-cm soil core was collected and sieved for roots; this soil is being used to measure soil mineralization over an 84 day incubation period. The initial extraction and a 42-day extraction have been completed; the 84-day extraction is currently being analyzed. In the initial extractions, NO_3 (0.1 μg N g^{-1} soil) was highest in sandy sites with heavy military use, suggesting a potential for nitrogen loss in these sites.

An aboveground decomposition study is underway with 896 litter decomposition bags constructed and arrayed in 16 of the 32 study sites. The study was initiated in April, 2001, and will continue for the duration of the project. Sets of samples are being harvested periodically to determine mass loss. The first two sets of samples have been harvested and mass remaining for the initial 4-week and 16-week periods has been analyzed. After 16 weeks, mass remaining varied among site landuse/soil texture categories from 86.8 to 88.6 percent (Fig 5). Later harvests will test the effect of litter elevation on decay in an attempt to simulate the effect of differing understory composition on litter decay rates. The complete dataset will also be used to model decay rates for these upland pine/oak forests.

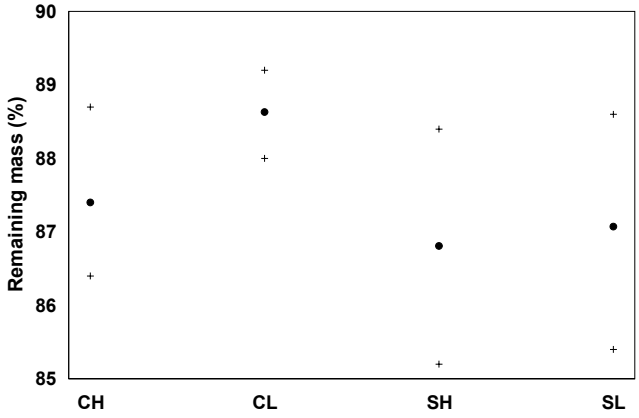

Fig. 5. Litter mass remaining after 16 weeks in sites with sandy (S) or clayey (C) soil and heavier (H) or lighter (L) military training use. Shown are means (●) ± 1 standard error.

Important Findings and Conclusions

Results of the baseline vegetation, soil texture, and disturbance surveys conducted in the first post-burn season during summer, 2000, suggest plant species diversity and composition on the 32 research sites are influenced by soil texture and the intensity of land use disturbance, respectively. These upland oak-hickory-pine forests range from sandhills scrub oak-pine vegetation to shortleaf pine-hardwoods or oak-hickory dominated forests, with greater species diversity in the understory of clayey sites. Disturbances associated with mechanized military training and forestry practices have favored pine dominance, and maintained open-site, successional or fire-tolerant species in the understory.

Initial and preliminary results suggest soil texture influences soil moisture and, potentially, nitrogen cycling. Initial samples from soil moisture tubes show soil moisture increases with clay content; sites with light military use and clayey soil had the greatest volumetric soil moisture in a September sample. Preliminary results from soil mineralization studies suggest the potential for nitrogen loss in sandy sites with heavy military use.

During the FY01 growing season, the sites were in the second post-burn season. Half (16 of the 32 sites) will be burned in early 2002; the other half will have burning delayed until 2004. Field procedures and equipment are now in place to compare the combined effects of the burning cycle and military land use on nitrogen dynamics and vegetation between sites on clayey and sandy soil, to determine if thresholds for sustaining these land use disturbances differ with soil texture.

Products

Collins, B. Land use and disturbance on DOE and DoD sites. Westinghouse Environmental Advisory Committee Meeting. SRS, 8 November, 2000.

Collins, B., J. Dilustro, L. Duncan, R. Sharitz, J V. McArthur, C. Romanek, J. Seaman, D. Imm, M. Cadenasso, and P. White. Thresholds of disturbance: land management effects on vegetation and nitrogen dynamics. SERDP Annual Technical Symposium, Arlington, VA. 28-30 November, 2000.

Dilustro, J. , B. Collins, L. Duncan, R. Sharitz, J V. McArthur, C. Romanek, and J. Seaman. 2001. Thresholds of disturbance: land management effects on vegetation and nitrogen dynamics. Southeastern Biology 48(2):80.

Partners Along the Fall-Line: Sandhills Ecology and Ecosystem Management Workshop. SREL Conference Center, March, 2001.

Dilustro, J. , B. Collins, L. Duncan, R. Sharitz, J V. McArthur, C. Romanek, and J. Seaman. Thresholds of disturbance: land management effects on vegetation and nitrogen dynamics. Ecological Society of America, August, 2001.

Dilustro, J., B. Collins, L. Duncan, and R. Sharitz. Soil texture, vegetation, and land use intensity of Fort Benning Sandhills sites. In preparation for J. Torrey Botanical Society.