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

CS-1114E-00

FY02 Annual Report

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Introduction

Background

Land at Fort Benning must sustain the military training mission. Current land use for training involves lighter disturbance by foot and light vehicle traffic through heavier disturbance by repeated heavy vehicle traffic. A second land management goal is sustainable upland forests. These mixed-pine-hardwood forests are on ridgetops and upper slopes on sandy and clayey soils. They are managed through thinning and prescribed burning to promote longleaf pine (*Pinus palustris*) forest, which provides economic benefits and supports the endangered red-cockaded woodpecker (*Picoides borealis*).

Some combinations of military and forestry land use may not be sustainable. The forest cannot recover or continue its desired trajectory; it may lose nutrients or fail to regenerate key species. Land managers at Fort Benning need information to determine what combinations of military training and 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 at Fort Benning, to determine if there are thresholds beyond which upland mixed-pine-oak forests 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 sustainable land use. 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, and unthinned) and to either heavier (open to tracked vehicles) or lighter (primarily dismounted 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 were 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 FY02

Research efforts during FY02 concentrated on 1) completing the baseline 'pre-burn' characterization of each site and 2) collecting field data to compare biogeochemical cycling and vegetation between 2-yr and 4-yr burn sites on sandy and clayey soils in heavier and lighter military training compartments.

Site baseline characterization

Results of baseline vegetation, environment, and "disturbance" surveys in each site during summer 2000 are now published in a journal article (Dilustro, J., B. Collins, L. Duncan, and R. Sharitz. 2002. *Soil texture, vegetation, and land use intensity of Fort Benning Sandhills sites*. Journal of the Torrey Botanical Society 128:289-297). The 32 upland forest research sites include sandhills scrub oak-pine forests, shortleaf pine-hardwoods, loblolly pine-hardwoods, longleaf pine-hardwoods, and oak-hickory forests. Species diversity is greater in the understory of clayey sites.

The vegetation and nitrogen cycling characteristics of each research site potentially reflect past land use. Results of the 2001 surveys revealed that 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 (Dilustro et al., 2002). In FY02, additional data were analyzed to determine if vegetation reflects the number of times a site has burned over the last 20 yr. Fig. 1 is an overlay of the burn history of each site, gleaned from the digitized 'fire' maps, onto a multi-dimensional scaling ordination (MDS) of canopy vegetation. In this figure, sites that are closer together have more similar canopy composition; symbol color represents fire history. Sites dominated by hardwoods (H) have burned less frequently (blue to light reddish colors = 2 – 4 fires over the last 20 yr) and are in lighter military training compartments. Sites with significant amounts of longleaf pine in the canopy tend to have burned more frequently (reddish colors = 4 – 6 fires) or are in heavier military training compartments (solid symbols).

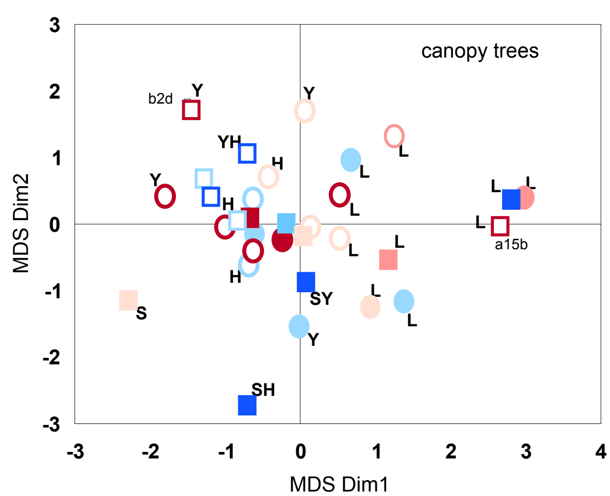


Fig. 1. Overlay of site burn history and MDS ordination of canopy trees. Sites are arrayed by similarity of vegetation composition; more similar sites are closer together. Letters represent the dominant canopy species: L = longleaf pine; Y = loblolly pine; H = hardwood species; S =

shortleaf pine. Solid symbols are sites in heavier military training compartments; open symbols are sites in lighter military training compartments. Symbol color reflects the frequency of fires over the last 20 yr and ranges from dark blue (≤ 2 fires) through dark red (6 fires).

Analyses using ground layer vegetation (Fig. 2) reveal that most sites with unique ground layer vegetation have burned frequently (≥ 4 times). However, ground layer composition differs among these sites. Seedlings of a disturbance-tolerant canopy tree species – sweet gum – dominate three sites that have burned frequently; one site is a mix of species; and a15, which has burned yearly over the last three years, is dominated by grasses and bracken fern.

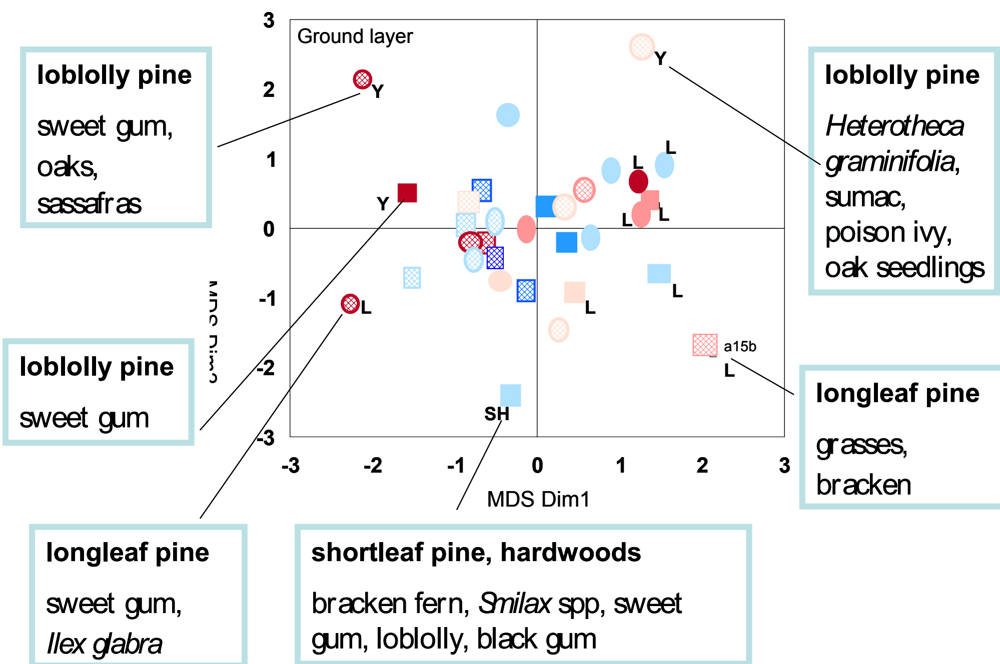


Fig. 2. Overlay of site burn history and MDS ordination of ground layer vegetation. Sites are arrayed by similarity of vegetation composition; more similar sites are closer together. Letters represent the dominant canopy species: L = longleaf pine; Y = loblolly pine; H = hardwood species; S = shortleaf pine. Solid symbols are sites in heavier military training compartments; open symbols are sites in lighter military training compartments. Symbol color reflects the frequency of fires over the last 20 yr and ranges from dark blue (≤ 2 fires) through dark red (6 fires). Text boxes give dominant canopy (bold type) and ground layer vegetation.

Field and laboratory assays of the soil characteristics and nitrogen cycling among the sites were conducted and summarized during FY02. Depth of the soil A layer and mass of the pooled organic layer were determined in all sites to characterize soil conditions. Deeper A horizon (cm) in sandy and clayey sites with lighter military use possibly reflects less erosion or compaction on these sites (Fig. 3). Preliminary analyses indicate depth of the A horizon may be a good indicator of landuse. Organic layer dry mass (g/m2) was greatest in low military use sites with clayey soil (Fig. 3). These sites also have the highest canopy tree density.

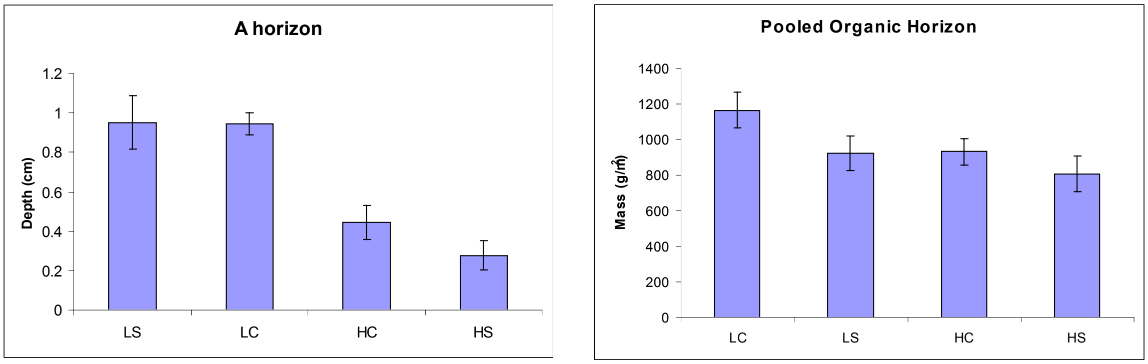


Fig. 3. Depth of the soil A horizon and mass of the pooled organic layer in sandy (S) and clayey (C) sites with heavier (H) or lighter (L) military use.

Laboratory mineralization incubations of soil samples (9/site) taken from all sites showed opposite patterns among the military use/soil texture categories. Extractable NH_4-N (µg N/g soil) was greater in sites with clayey soil and lighter military use (CL), while NO_3-N was greater in sites with sandy soils and heavier military use (SH) (Fig. 4). To determine if loss of the organic layer affects N supply to mineral soil or flux through the soil, lysimeter pots were installed in two heavier military use sites with sandy soil and two with clayey soil. Sites with sandy soil (D14A, F1C) had highest N loses (Fig. 5). Removing the O layer lowers the supply of NO_3 leaching through the soil by 50 % and greatly reduces NH_4 transport through the soil column. These results suggest sandy soils may be less buffered for disturbances that remove the litter layer.

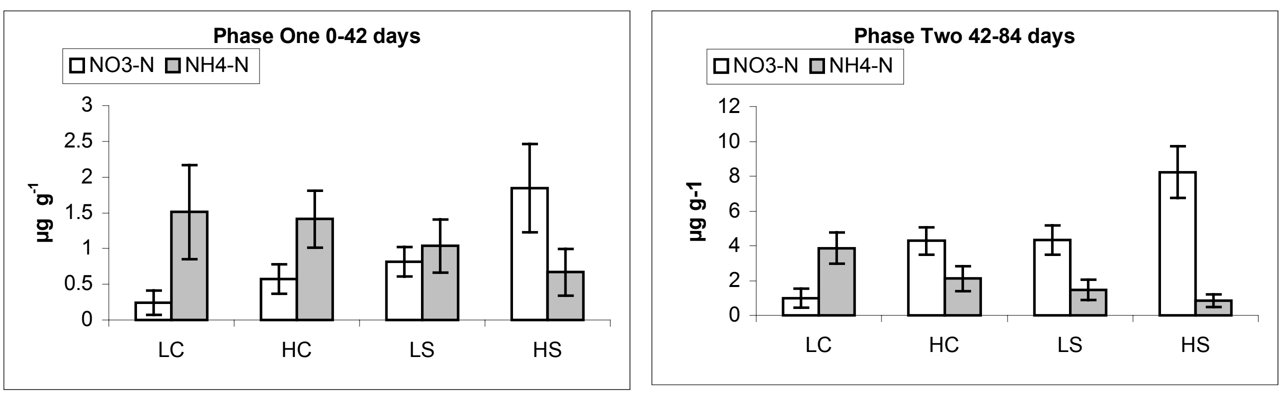
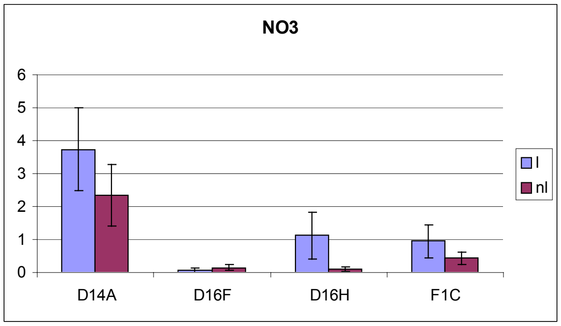


Fig. 4. NH_4-N and NO_3-N (µg N/g soil) production during and Phase1 (0-42 days) and Phase 2 (42-84 days) laboratory incubation of soil samples from clayey (C) and sandy (S) sites in lighter (L) or heavier (H) military military training compartments.



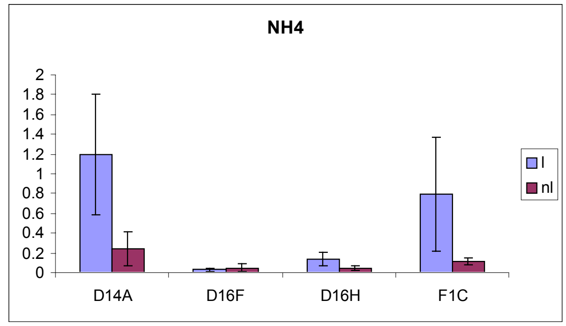


Fig. 5. NH_4-N and NO_3-N (ppm) in lysimeter pots with the soil organic layer removed (no I) or intact (I) located in sites with sandy (D14A, F1C) or clayey (D16F, D16H) soil.

Plant root simulator (PRS) probes were installed and left in place for 14 days in four heavier military use sites (two with clayey soil and two with sandy soil) to assess nitrogen availability to plants. More nitrogen is available to plants, particularly as ammonium, in sites with sandy soil (Table 1). This could relate to the greater N capital on these sites, as illustrated by the greater % N in the organic layer.

Site	Trt	O layer mass (g/m^2)	O layer C:N	O layer % N	% clay	PRS probes NH_4	PRS probes NO_3
D14A	HS	1605	35	.876	4.6	2.61 (0.90)	9.54 (2.32)
F1C	HS	906	55.8	.739	7.4	2.25 (1.09)	0.57 (0.20)
D16F	HC	944	53.9	.688	27.2	0.62 (0.37)	0.19 (0.09)
D16H	HC	787	52.1	.653	19.2	0.95 (0.56)	0.39 (0.08)

Table 1. NH_4-N and NO_3-N (µg N/10 cm^2/14 days) uptake by probes that simulate plant roots placed in sites with sandy (D14A, F1C) and clayey (D16F, D16H) soil.

Taken together, results of the baseline soil studies indicate clayey sites tend to produce greater quantities of NH_4; however, lower uptake rates support the idea that this NH_4 may be bound by clays and less available to plants or microbes. In contrast to clayey sites, sandy sites have greater NO_3 production, which could buffer disturbance effects or lead to greater losses via leaching on these sites. The lysimeter pot results indicate greater leaching of both NO_3 and NH_4 from sandy soils. These sites also may show more immediate and drastic nitrogen loss in response to disturbances that remove the litter layer.

Fire effects

Environment

Soil temperature at 1 and 10 cm below ground was logged at minute intervals during the prescribed burning of the 2-yr burn sites. Fig. 6 shows a distinct, but modest and relatively short-lived, temperature effect at 1 cm depth as fire moved through a site (two sites are shown). This depth is in the region of microbial and root activity. Data for 10 cm depth sensors are still being evaluated, but we anticipate few detectable signals at that depth.

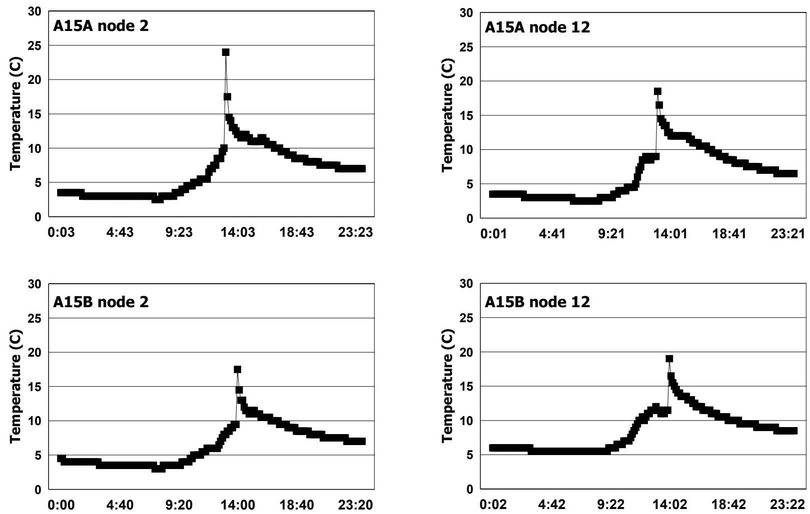


Fig.6. Temperature (^{o}C, Y-axis) 1 cm below soil surface taken at 1-minute intervals in four locations within research site A15B during prescribed burning for the 2-yr burn treatment.

Soil characteristics and nitrogen cycling

Mass of the soil organic layer was compared between the preburn (2001) and postburn (2002) seasons to determine loss due to prescribed burns on the 16 2-yr burn sites. Fig. 7 shows that sites with greatest pooled organic layer mass in 2001 lost the most mass to combustion.

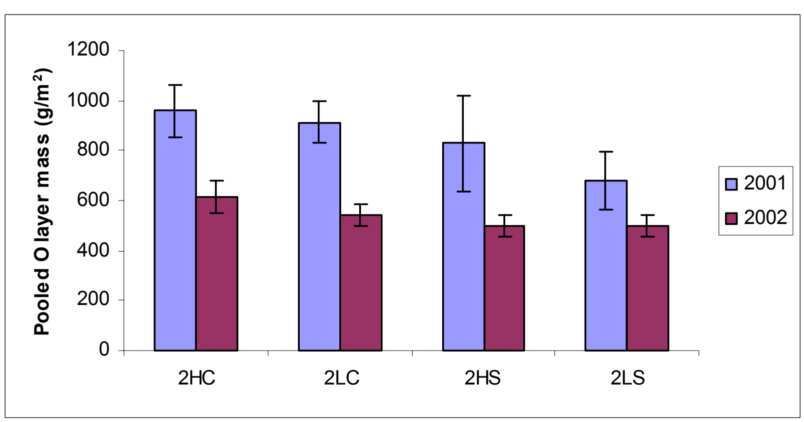


Fig. 7. Mass of the pooled soil organic layer in summer before (2001) and after (2002) prescribed burns for the 2-yr burn treatment.

Soil samples were taken before and after burning in each 2-yr burn site and analyzed for extractable nitrogen. A small pulse of available nitrogen often occurs following prescribed burns. The samples, which did not include the soil organic layer or A-horizon, revealed that extractable NH_4+ NO_3 was either unchanged or more available following prescribed burns (Fig. 8). We are currently analyzing longer term nitrogen availability following the burns.

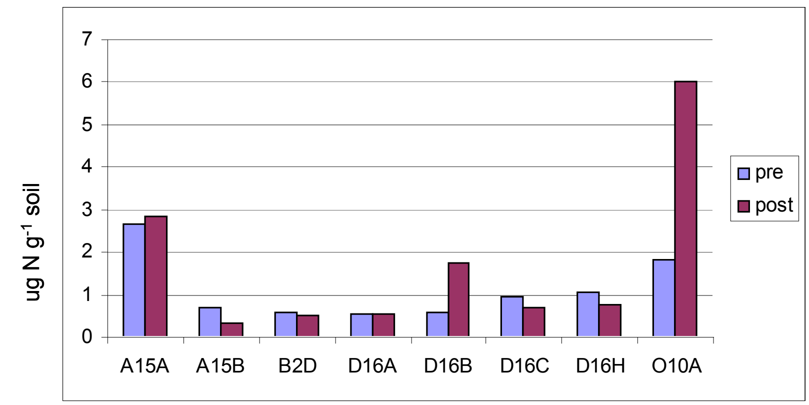


Fig. 8. Extractable soil nitrogen before and after prescribed fire in the 2-yr burn treatment sites.

Vegetation

Seeds of southern red oak (*Quercus falcata*) were placed in two burned and two unburned sites to determine if fire influences seed predation, which could potentially limit regeneration of this common canopy tree. Half the acorns in each site were "protected" from predation by larger mammals by wire mesh exclosures that included a small door to allow small mammal access. Acorn removal was checked four times. Between 75 % and 95 % of the 30 acorns in each site were removed, and all the "protected" acorns were removed in the two unburned (B4) sites (Fig. 9). Burning does not increase seed predation on southern red oak; however, seed predation could limit regeneration of this species on burned and unburned sites.

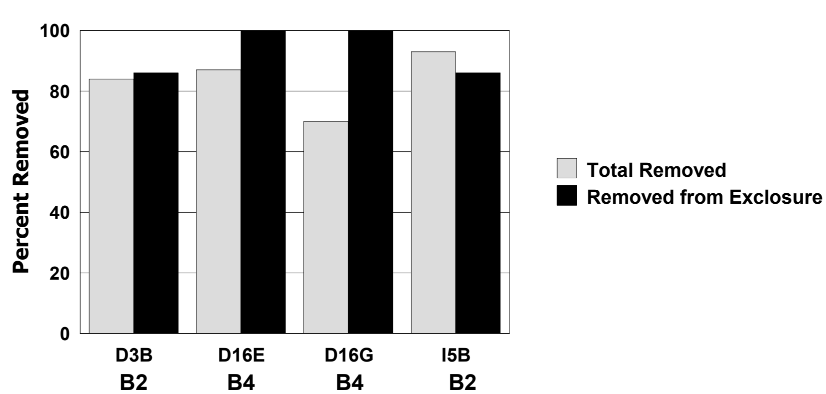


Fig. 9. Percent of southern red oak acorns removed by seed predators on burned (B2) and unburned (B4) sites.

To determine if fire could affect regeneration of canopy tree species by influencing survival of seedlings, oak seedlings (and sprouts) and pine seedlings that had naturally established were tagged in each site in 2001. Mortality of these seedlings was censused in 2002 after the prescribed 2-yr burn treatments (Fig.10). Seedlings/sprout mortality was greater in burned than unburned sites, primarily due to pine seedling mortality. Pine seedling mortality also was greater in lighter compared to heavier military use sites. Mortality of the tagged oak seedlings/sprouts was low (0 – 20%) and did not differ between burn treatments or military use categories. In general, burning leads to loss of established seedlings, and, at some fire frequency, the interval between fires may be too short for seedlings to accumulate in sufficient numbers to regenerate canopy species.

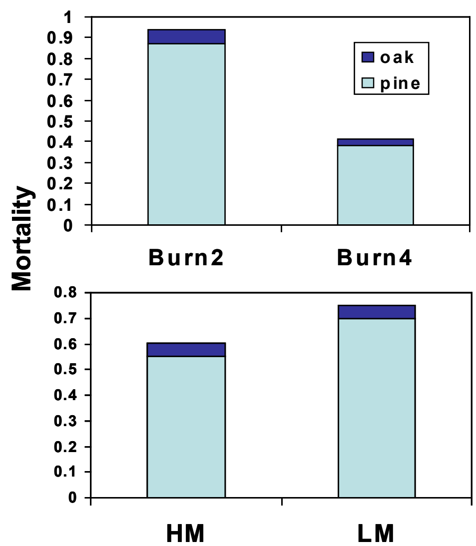


Fig. 10. Mortality of oak and pine seedlings after one year in burned (Burn2) and unburned (Burn4) sites and in sites with heavier (HM) or lighter (LM) military training.

Fire removes ground layer vegetation and can promote establishment nitrogen-fixing legumes. We compared plant biomass, relative importance of legumes, and density of nitrogen-fixing legume root nodules between 2-yr and 4-yr burn sites (Fig. 11). Burning caused a decrease in biomass of woody species, but led to an increase in fern, forb, grass, and legume biomass. The fire removed woody species, including woody seedlings that likely collect in intervals between fires. Burning also led to an increase in root biomass, which agrees with the trend for aboveground herbaceous vegetation

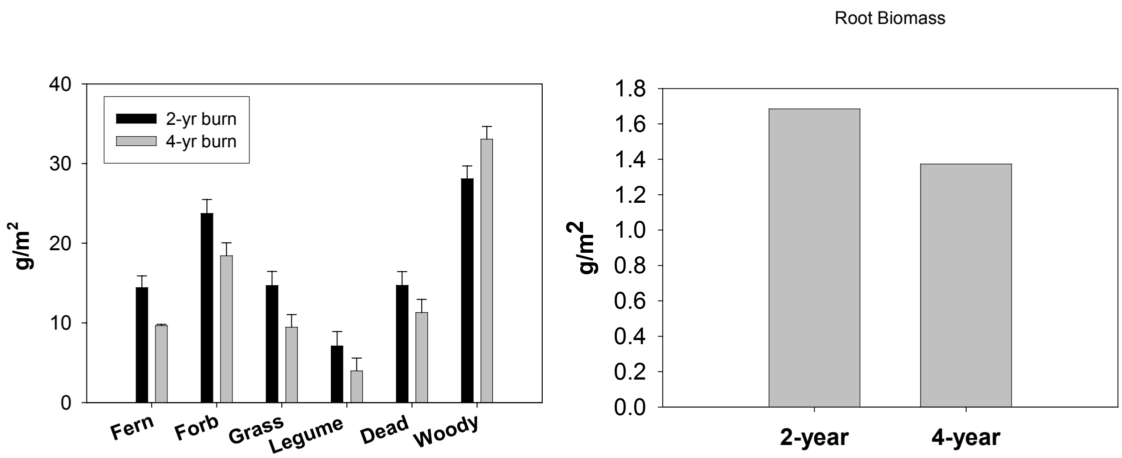


Fig. 11. Biomass of ground layer vegetation (including standing dead plants) and roots in unburned (4-yr) sites and after prescribed burns (2-yr sites).

Fire and land use over the landscape create habitat patches and edges that have been shown to influence animals, including many bird species. We conducted point counts in 2-yr (2002) and 4-yr (2000) burn sites in heavier (H) and lighter (L) training compartments during May 2002 to determine if occurrence of selected bird species was influenced by burning or military training. We selected 8 bird species that might be expected to respond to disturbance, that include resident and Neotropical migratory species, and that are easy to identify aurally. Selected species included Bachman's Sparrow (BACS), Brown-headed Cowbird (BHCB), Eastern Wood Pewee (EAWP), Indigo Bunting (INBU), Northern Bobwhite (NOBO), Northern Cardinal (NOCA), Prairie Warbler (PRAW), and Yellow-breasted Chat (YBCH). Further statistical analysis is needed, but frequency of occurrence (% points where species detected) indicates some species might be influenced by disturbance intensity (BACS, NOBO, YBCH) and others are more equally distributed across treatments (INBU, NOCA, PRAW).

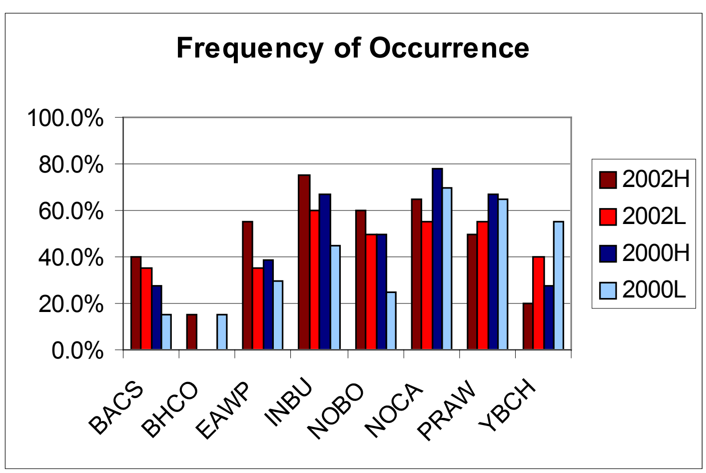


Fig. 12. Frequency of occurrence of selected bur species in burned (2-yr burn; 2002) and unburned (4-yr burn; 2000) sites with heavier (H) and lighter (L) military training.

Important Findings and Conclusions

Our baseline analyses indicate that pine (longleaf) canopy has been sustained in sites with heavier military use or a history of more frequent fires over the past 20 yr. The ground layer of frequently burned sites differs among sites, but is generally dominated by open-site species. Nitrogen cycling reflects soil texture. Sites with sandy soil have greater nitrate production, but this does not translate to more productive vegetation. Compared to clayey sites, sandy sites may show more immediate and drastic N loss in response to disturbances, but may have a higher threshold of sustainability because other factors, such as plant uptake, drive vegetation response.

Comparisons between the unburned (4-yr) sites and the newly burned (2-yr) sites revealed that fire causes an immediate, short-term increase in soil temperature at 1 cm. Burning results in organic layer loss roughly in proportion to pre-fire condition, but extractable soil ammonium and nitrate were either unchanged or more available after fire. Burning can reduce the number of naturally established seedlings/sprouts, especially pine species, and can remove woody biomass, including tree seedlings that may accumulate between burns. However, fire can lead to an increase in aboveground biomass of herbaceous vegetation, including nitrogen-fixing legumes. These preliminary results suggest that fires more frequent that some threshold could eventually result in unsustainable woody biomass and limit regeneration of mixed-pine-hardwood forests, especially on low-productivity sites, if woody species do not recover or accumulate between burns.

Products

Collins B., J.J. Dilustro, L. Duncan and R. Sharitz Soil texture, land use intensity, and vegetation of Fort Benning sandhills sites. 2001. SERDP Partners in Environmental Technology Technical Symposium and Workshop. Washington D.C.

Collins, Beverly. 2002. Symposium: A regional perspective – partnerships for ecosystem research and management in the Southeast. ASB Meeting, Boone, North Carolina, April. Southeastern Biology 49:213.

Dilustro, J. J., B.S. Collins, L.K. Duncan and R. R. Sharitz. 2002. Soil texture, land use intensity, and vegetation of Fort Benning upland forest sites. ASB Meeting. Boone, North Carolina, April. Southeastern Biology 49:160.

Dilustro, J. J., B. S. Collins, L. K. Duncan and R.R. Sharitz. 2002. Soil texture, nitrogen mineralization and vegetation of Fort Benning upland forest sites. ESA Meeting. Tucson, Arizona. August.

Dilustro J.J., Collins B., L. Duncan and R. Sharitz. 2002. Soil Texture, land use intensity, and vegetation of Ft Benning upland forest sites. Journal of the Torrey Botanical Society 129:289-297.