DETERMINATION OF INDICATORS OF ECOLOGICAL CHANGE

Second Annual Progress Report

Project Year 2000-2001 (FY01)

SEMP Project CS-1114A-99

University of Florida – Purdue University

William DeBusk, P.I.
Wendy Graham
Jennifer Jacobs
Andrew Ogram
Deborah Miller
Joseph Prenger
Suresh Rao
Ramesh Reddy
George Tanner

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INTRODUCTION

Our research seeks to develop suitable indicators of ecosystem integrity and impending ecological change resulting from both natural variation and anthropogenic activities. We will use a multidisciplinary and multi-scale approach, which will result in robust techniques for ecosystem monitoring and evaluation. Results of the study will enhance the ability to minimize, mitigate or remove major negative environmental impacts on DoD's ability to conduct the military mission. Through the proposed research plan, we will address the SEMP objective of identifying indicators that signal ecological change in intensively and/or lightly used ecological systems on military installations. These indicators will provide early indications of change associated with (1) natural ecosystem variability and (2) military activities, including training and testing, as well as other land management practices. Early indications of change, and an understanding of the likely causes, will improve installation managers' ability to manage activities that are shown to be damaging, and prevent long-term, negative effects.

The concept of ecosystem integrity, or "health", in the context of the military installation, encompasses not only the sustainability of the "natural" biota in the system, but also the sustainability of human activities at the installation, namely the military mission. Thus, changes in ecological condition are of great concern to both resource managers and military trainers. A suite of variables is needed to measure changes in ecological condition. Two types of indicators that may be useful are (1) variables that inform managers about ecosystem status and (2) variables that signal impending change. In many cases, these indicators may be the same. Both types are needed, but variables that serve as early warnings of impending changes outside the natural range of variation, and variables that are shown to be related to activities affecting the military mission, may be especially valuable.

TECHNICAL OBJECTIVE

We will evaluate a suite of parameters related to properties and processes in the understory vegetation, soil and surface hydrology as potentially sensitive indicators of ecosystem integrity and ecological response to natural and anthropogenic factors. In general, the soil hydrologic and biogeochemical parameters to be examined relate to changes in soil physical and chemical characteristics, and the response of soil microbial population and plant communities. To the greatest extent possible, cause and effect relationships will be developed between environmental changes, due to both natural variability and anthropogenic perturbation, and soil and vegetation responses, primarily as they relate to nutrient storage, nutrient turnover and population dynamics.

Our basic premise is that soil serves as the central ecosystem component that links the quality of the terrestrial habitats (by influencing the vegetation and its stability) and the aquatic habitats (via control of soil erosion and overland runoff). Thus, a careful study of soil parameters and processes and linking them to impacts on terrestrial/aquatic habitats is the basis for our experimental approach. Furthermore, we aim to establish a sound scientific basis for the empirical parameters that might be used as ecological indicators.

Our proposed research and monitoring plan will address the following objectives:

- Identify physical, chemical and biological variables (properties and processes) associated with soil, surface hydrology and vegetation that may be used as indicators of ecological change.

- Evaluate potential ecological indicators based on sensitivity, selectivity, ease of measurement and cost effectiveness.
- Select indicators that most effectively 1) show a high correlation with a certain state in a specific ecosystem, 2) provide early warning of impending change and 3) differentiate between natural ecological variation and anthropogenic negative impacts.
- Determine the likely range of natural variation for indicator variables, and compare with the range of values under anthropogenic, especially mission-related, influences.

PROJECT MILESTONES (FY2001)

The following are milestones for FY2001, as listed in the FY2001 Execution Plan, for the University of Florida-Purdue University research team:

Task	Due Date	Status
Complete first year of Phase II sampling	9/2001	Completed

FY2001 RESULTS AND SUMMARY

A summary of accomplishments for FY 2001 are presented below, for soil biogeochemistry, vegetation, and hydrologic components.

1) SOIL BIOGEOCHEMISTRY

Methods

The Phase 1 objectives were to characterize the distributions (range, central tendency) of indicator variables at a regional scale and to determine the response of variables to impacts related to military training and other land uses and management practices. Sampling for Phase 1 of the soil biogeochemistry component was completed during FY2000. Analysis of Phase 1 data was performed during FY2001.

Phase I sampling and monitoring was conducted within 6 watersheds of order 3 or 4, which had been proposed and/or selected as ECMI long-term monitoring units. These watersheds, associated with Sally Branch, Bonham, Halloca, Randall, Wolf and Shell Creeks, represent a wide range of military and non-military land uses and anthropogenic disturbance regimes (type and intensity of disturbance).

Phase 2 sampling was conducted during FY2001; sampling and data analysis are ongoing, and will continue during FY2002. Analysis was completed for soil samples collected during December 2000 for a comparative study of soil and vegetation-based indicators in both wetland and upland regions of highly-disturbed (D-15 compartment) and minimally-disturbed (D-4) areas. Soil cores were taken at 21 points along a 400 m transect in each upland site (high and low disturbance) and at 18 points along 3 transects across each wetland site. Each soil sample consisted of a composite of five 20-cm deep subsamples taken by 1-inch diameter soil probe within a 1 m^2 quadrat. Riparian wetland transects, 80 m in length, were located on either side of the stream (paired transects) and sampled at 20 m intervals. Wetland soils were sampled to a depth of 10 cm, using a 6.5-cm diameter polycarbonate corer. Each sample represented a composite of three subsamples taken within a 1 m^2 quadrat. The transect-based sampling layout facilitates both comparison of indicator response in high and low disturbance areas and, simultaneously, an evaluation of local, within-site variability. The soil characteristics and properties being evaluated for this study are total C, N and P, pH, organic matter, exchangeable NH_4^+, potentially mineralizable N, microbial biomass C and N, soil respiration, Mehlich 1 and 3 extractable P, HCl and ammonium oxalate extractable P, Fe and Al, and microbial enzyme activity (acid phosphatase, beta glucosidase and dehydrogenase).

Additional soil and vegetation monitoring transects were established at 4 upland and 3 wetland sites in D12, D13 and O3 during June 2001. The upland transects, all of which are underlain by Troup loamy fine sands, were 200 m total length, and were sampled for soil biogeochemical characterization at 20 m intervals. Sampling procedures were modified slightly for wetland sites during this sampling event, i.e., the sampling depth was decreased from 10 to 5 cm. It was concluded that sampling only the upper 5 cm of wetland soils provided greater sensitivity and resolution for comparing soil biogeochemical processes among sites. To accommodate this change, the previously sampled wetland transects were resampled using a soil depth of 5 cm.

Upland transects were sampled in areas of high military disturbance (Rowan Hill – D12), low disturbance (D13), and planted pines (2 stands in O3 – ca. 5 years and 12 years). Wetland transects were sampled in watersheds with low (D13) and moderate military impact (D12), and a watershed dominated by managed timber land. Soils sampled along the upland and wetland transects were analyzed for total and extractable nutrients and microbial activity, as previously indicated.

Results

Soil biogeochemical properties

The 300 Phase 1 sites were categorized as low, moderate or severe disturbance, based on visual assessment of vegetation and soil disturbance in the immediate vicinity (ca. 0.1 ha area surrounding the sampling point). Such an initial characterization, albeit a rough estimate, of site disturbance was considered to be necessary component of the evaluation process for soil variables as potential indicators of ecological condition.

A summary comparison of soil total carbon (TC) and microbial biomass C (expressed as a proportion of total C {MBC:TC}) among low-, moderate- and severe-disturbance sites grouped by landscape position (uplands and bottomlands / wetlands) is presented in Fig. 1. These data support field observations that the primary manifestation of intensive military training, with respect to soil quality, is soil erosion in uplands and associated sedimentation in wetlands. Loss of topsoil in disturbed upland sites has resulted in decreased soil organic matter content, shown here as total C. While much of the soil organic matter lost from upland sites is apparently flushed into streams, a significant proportion of the mineral or inorganic component, primarily silt and clay, but also sand in extreme cases, tends to settle out in downslope and downstream wetlands. Thus, a decrease in organic content of disturbed wetland soils occurs as a result of "dilution" by inorganic soil material. In general, for both wetlands and uplands, soil chemical and biological parameters typically correlated with soil organic matter also tend to decrease with increasing site disturbance.

Among the soil parameters that typically decrease with increasing site disturbance is soil microbial biomass C (data not shown), which is primarily a function of decreasing soil organic matter. However, when MBC is expressed as a proportion of total soil C, the MBC:TC tends to increase with increasing levels of soil disturbance. We believe that this phenomenon relates to the relative availability of organic C to heterotrophic microorganisms in the soil. It appears that the loss of "stable" soil organic matter, e.g. humus, near the soil surface through topsoil erosion in uplands or sedimentation in wetlands results in a higher proportion of freshly-deposited organic material, e.g. leaf fragments, in the soil organic matter pool, thus stimulating microbial growth within the organic material. The availability of nutrients such as N, P or K may also be a factor, but this has not been clearly indicated by our data thus far. The relationships between soil organic matter and microbial biomass, activity and diversity will be examined in greater detail, along with implications to soil quality and ecological stability (and change), during FY 2002.

Phase 2 data, which is relatively site-specific compared to Phase 1 data, revealed similar trends in soil C and microbial biomass in response to site disturbance (Figs. 2 and 3). Analysis of within-site spatial and temporal variability along upland and wetlands transects will continue during FY2002, and will be reported in subsequent reports.

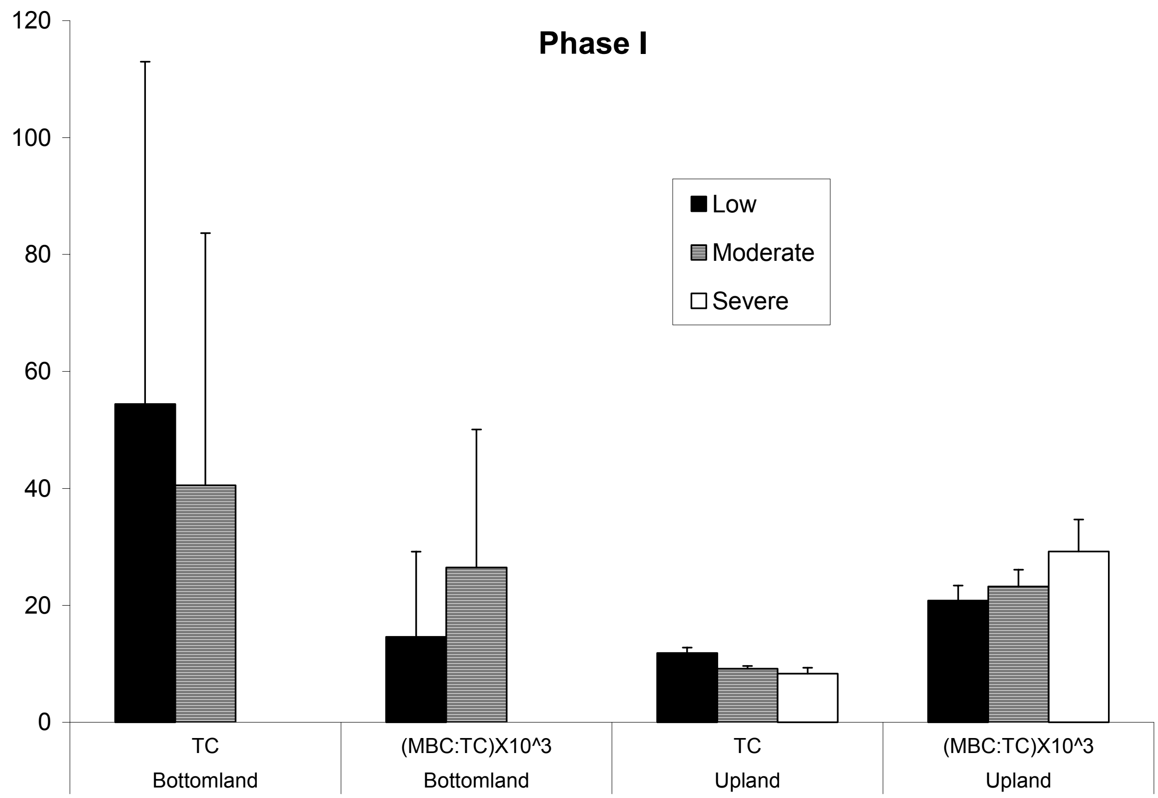


Figure 1. Summary of Phase 1 soil analysis (300 sites) for total carbon and microbial biomass C (as proportion of total soil C) at low-, moderate- and severe-disturbance sites in uplands and bottomlands (wetlands). Data points are mean values, with standard deviation denoted by error bars. All wetland sites sampled during Phase 1 were classified as either "low" or "moderate" disturbance, hence there is no "severe" class shown for wetlands.

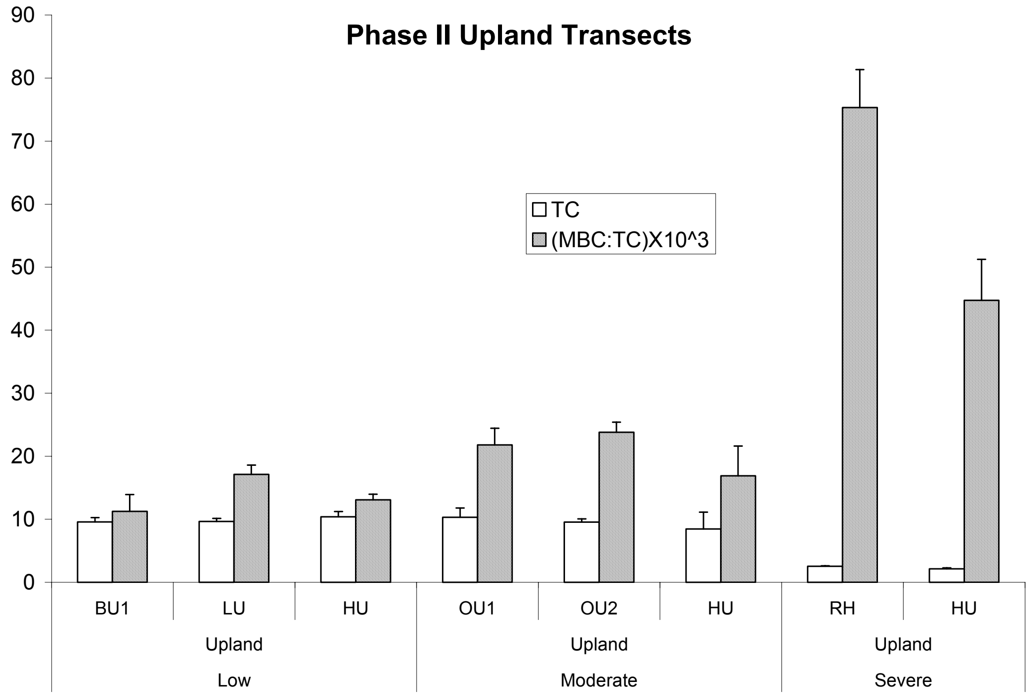


Figure 2. Summary of Phase 2 (transects) soil analysis for total C and microbial biomass C (proportion of total soil C) at low-, moderate- and severe-disturbance sites in uplands. Data points are mean values, with standard deviation denoted by error bars.

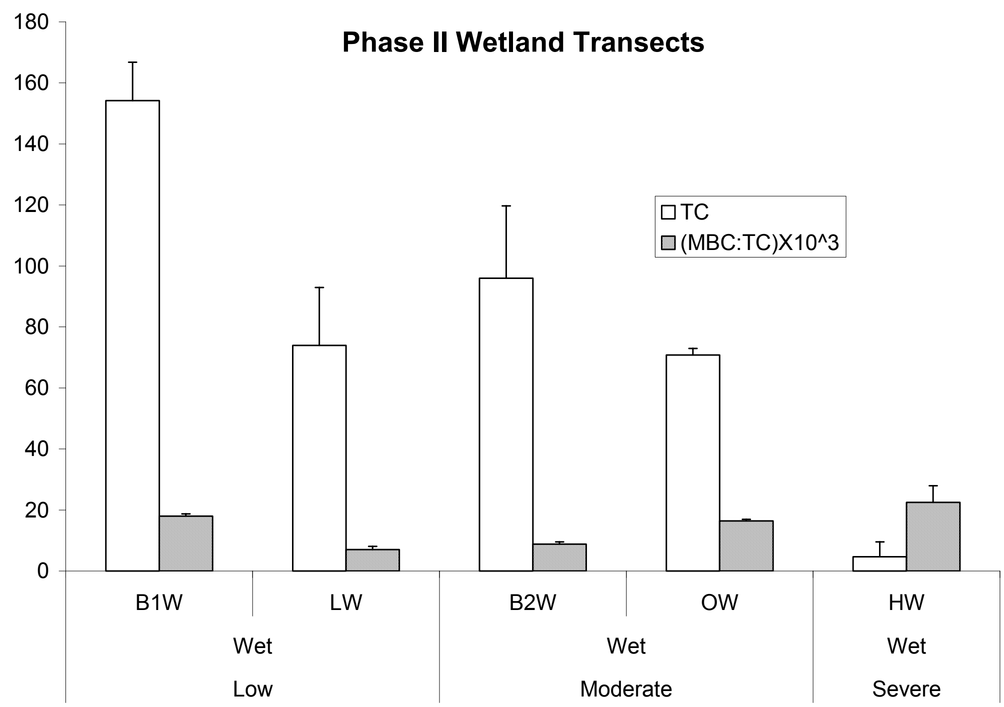


Figure 3. Summary of Phase 2 (transects) soil analysis for total C and microbial biomass C (proportion of total soil C) at low-, moderate- and severe-disturbance sites in wetlands. Data points are mean values, with standard deviation denoted by error bars.

Multivariate analyses

Multivariate statistical analyses were performed on the Phase 1 soil biogeochemical data set, using the most-commonly analyzed parameters: pH, organic matter content, total phosphorus, water extractable P, oxalate extractable P, Mehlich-1 P, microbial P, total carbon, total nitrogen, water extractable C, microbial C, exchangeable ammonium, microbial N, Mehlich-1 Fe, Al, Ca, Mg and K, oxalate extractable Fe and Al. All parameters except for pH were log-transformed prior to analysis, due to the log-normal distributions of these variables.

Cannonical Discriminant Analysis was used as a visualization technique to reduce the dimensionality of the multivariate data set while maximizing the separation between specific categories of data. This was accomplished by developing a smaller set of cannonical variables (which are a weighted linear sum of the original variables), that preserve the maximum variability of the original data set that can be attributed particular data classes. For the Phase 1 soil biogeochemistry data set Cannonical Discriminant Analysis was conducted to provide maximum discrimination among pre-determined site disturbance classes (low, moderate and severe). Results in Fig. 4 show that the canonical variable 1 provides relatively good separation among sites designated as low and moderate, while canonical variable 2 primarily provides separation of severe-disturbance sites from those with low to moderate disturbance. Thus, canonical variable 1 represents a simple combination of soil biogeochemical characteristics that may provide a useful indicator of ecological change, especially where differences or changes in site condition are not easily discernable by observation.

Discriminant Function Analysis is a procedure for classifying observations into two or more groups on the basis of one or more quantitative measurements. To develop the discriminant function, prior knowledge of the classes from which each observation is taken is required, unlike cluster analysis. Quadratic discriminant function analysis was conducted on the Phase 1 soil biogeochemistry data set. The degree to which the a priori site disturbance classification is supported by the soils data is shown in Table 2 as the proportion of the sites assigned to each disturbance class (low, moderate and severe) that fall into the assigned class, based on discriminant function analysis, as compared to the other 2 disturbance classes. Results indicate that the Phase 1 soil biogeochemistry data "predict", to a large extent the degree of site disturbance.

Table 2. Results of discriminant function analysis of Phase 1 soil biogeochemistry data. Values in "low", "moderate" and "severe" columns indicate frequency of statistical grouping of sites in each class, for each pre-determined disturbance group (rows).

From Disturbance	Low	Moderate	Severe	Total
Low	89	16	3	108
Moderate	15	68	5	88
Severe	2	11	13	26

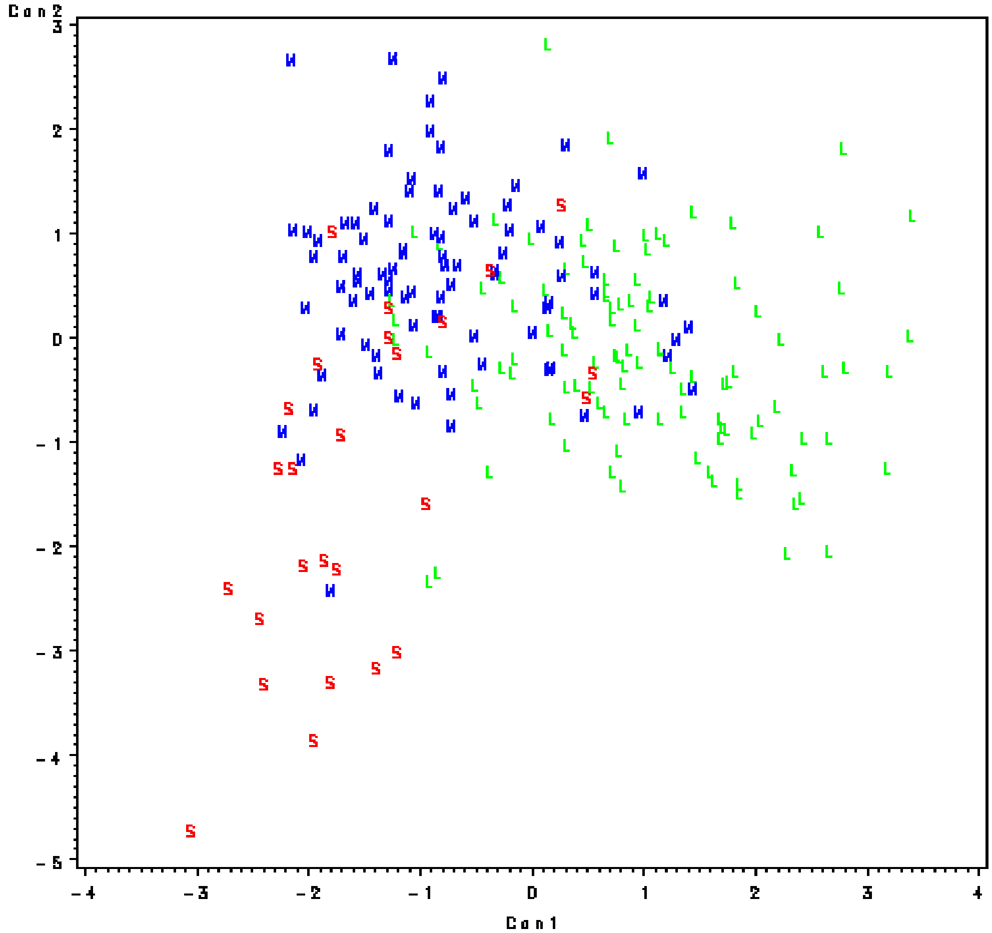


Figure 4. Plot of canonical variables 1 vs 2 for Phase 1 soil biogeochemical parameters. Data are grouped by level of site disturbance, based on visual assessment in the field: low (L), moderate (M) and severe (S).

<u>Soil microbial diversity</u>

The compositions and structures of methanotrophic bacteria were evaluated as indicators of impact along transects taken from uplands and wetlands. The primary tool used to compare the compositions of these assemblages is terminal restriction fragment polymorphism analysis (T-RFLP), a method to fingerprint the 16S rRNA gene belonging to methanotrophs. This method allows visualization of different genotypes of methanotrophs as peaks in an electropherogram, similar to different analytes being visualized as different peaks in a gas chromatogram. Most T-RFLP data are simply analyzed by comparing the presence or absence of a peak (or genotype) between samples. We attempted to extend the meaning of t-RFLP data by including the relative peak sizes as representative of the relative concentrations of the different genotypes in different samples. The validity of this assumption was checked in studies conducted early in 2001.

Most of the activity during the last quarter was to analyze data by various analytical and statistical approaches to determine the most appropriate indicators. Comparison of Shannon diversity indices for high and low impact soils indicated a significantly higher methanotroph T-RFLP diversity for low impact upland

Table 2. Shannon diversity indices of four different transects

	Wetland	Upland
High impact	0.40	0.23
Low impact	0.48	0.54*

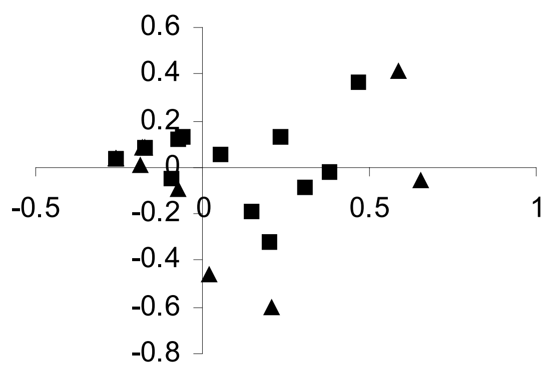
* Significantly different (P < 0.05)

than high impact uplands Table 2. Impact of various types is generally thought to decrease biological diversity. No significant difference was observed in diversity between high and low impact wetland samples, however.

Principal Components Analysis (PCA) (Fig. 5) did not discriminate between high and low impact samples (Fig. 5A); however, low impact wetland samples clustered together, as did high impact wetland samples (Fig. 5B).

In summary, a combination of statistical methods were necessary to identify differences between low and high impact regions of wetland and upland sites. A simple comparison of diversity indices discriminated between high and low impact uplands, whereas PCA was required to differentiate wetland samples on the basis of impact.

A



B

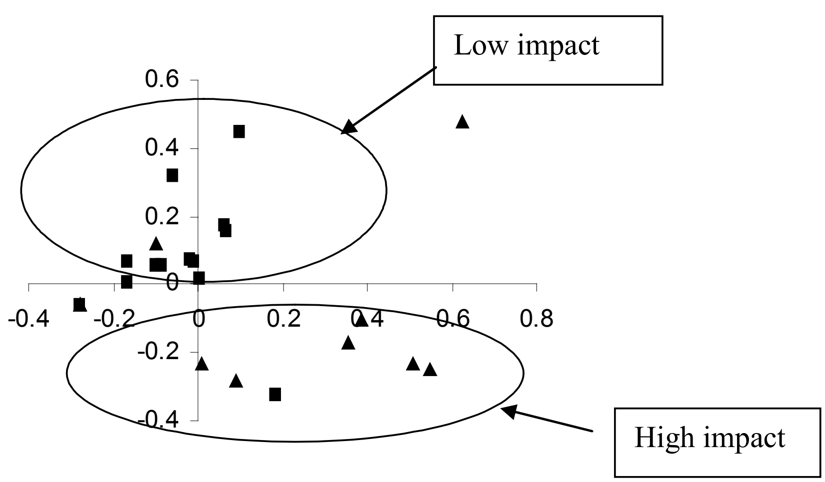


Figure 5. PCA discrimination of four soils based on methanotroph assemblage composition. a) upland samples; b) wetland samples. Close square (■), low impact sample; close triangle (▲), high impact samples. X-axis PCI, Y-axis, PCII.

2) VEGETATION

Vegetation Parameters Associated with Disturbance

Activities

Structural and compositional parameters of the vegetation were measured in the summer and fall of 2000 at the same sampling sites as selected by the soil characterization team across second and third order watersheds within six watersheds: Halloca, Randall, Sally Branch, Bonham, Shell and Wolf Creek. Understory woody plants canopy cover (< 2-m tall) along three 5-m transects and overstory canopy cover (densiometer) were measured at all locations (n= 273). Understory composition and cover and biomass, including litter were measured within three 1-m^2 at the triplicate soil testing sites within the watersheds (n= 56).

Various environmental parameters were measured at all sites by the soil characterization team including: site position (upland, slope, or bottom), soil texture (sand, loam, sand/loam, clay, sand/clay, or organic), and disturbance (low, moderate, or severe). However, very few bottom sampling points had severe disturbance; most moderately and severely disturbed sites were at slope and upland positions. Disturbances resulted from both military training and logging activities.

Mrs. Jessica Archer was hired as a graduate student research assistant on the project. Her thesis research will focus on understory vegetation composition and soil compaction responses to site disturbances associated with timber thinning operations. A chronosequence of thinned sites covering the past 30 years' was established from the forest operations records maintained by the Ft. Benning natural resources working group. Sixteen pine stands in each of two soil types, sandy and loamy, will be selected for a total of 32 sites. Within each soil type, 4 sites will be selected from each of the following categories representing time since last clearcut: 0-3 years, 8-10 years, 18-20 years and >25 years. The stands that are >25 years will also have had one thinning. Data collection on these sites will begin in the Fall of 2001.

Canonical correspondence analysis (CCA) was used as an ordination technique to determine the relationship between the species cover values and the environmental variables. Analyses were performed both on the absolute vegetation cover and relative cover. Graphical displays of the biplots on the matrix of environmental scores and species cover wee used to reveal patterns and relationships among the two sets of data.

Results and Discussion

A total of 113 woody species were encountered in the field; a small portion of these could not be identified to species, so they were given a number until definite identification can be obtained (Table 3). Inspection of the biplot generated by CCA of relative woody plant cover with environmental variables indicates a separation of low (Lo) disturbance sites from moderate (Mod) and severe (Sev) sites, but no marked separation between moderate and severe disturbance sites (Fig. 6). Severe disturbance was most closely associated with upland (Up), sandy clay (Sc) soils. Increased overstory canopy cover as estimated by densiometer measurements (densiom.) were associated with low disturbance sites. These associations have some statistical strength given the signifacance of the first eigenvalue (Table 4), however, the lack of a major decrease of the sequential eigenvalues from Axis 1 through Axis 4 indicates a lack of close association among the variables.

Severe disturbance sites were areas of active heavy military equipment training (tanks and Bradley personnel carriers). Within this classification there was a gradient of disturbance from a condition of virtual absence of woody plants to a condition of scattered larger trees (PILL, QUAR, PILO) and remnant shrubs and vines that could withstand, or be spread by, repeated vehicular trampling (OPUN, IPOM, VAC2, VIBRU, CRET) (see Fig. 6). Relative cover of RUBU and RHCO may be an important indicator of a shift from Mod to Sev conditions. These two species are prolific seed producers, enhancing their ability to colonize disturbed sites, and they appear to withstand physical disturbance once established.

We did not sample many bottom (Bot) sites that had had severe disturbance. The few sites of such classification, however, were downstream and close to road crossing. Erosional fans were evident along with some mortality of overstory trees. Consequently, most bottom sites were classified as low disturbance. Organic soils were rare and were at sites of impounded water. i.e., beaver ponds. It is possible that beaver ponds should be classified as Sev disturbance sites from an ecological viewpoint.

A total of 110 herbaceous species were encountered while sampling (Table 5). Some of these species were not identifiable to species due to immaturity, thus they were given a number. Hopefully, we will be able to identify them to species once we find them in flower and fruit. Given that a very limited number of herbaceous species were encountered within the bottom sites, CCA analysis between species cover and environmental variables was conducted for just the slope and upland sites where the vast majority of species occurred. Inspection of the biplot indicates the obvious separation of sever disturbance from moderate and low levels of disturbance along a gradient from high litter cover (Lo and Mod) to an absence of litter cover (Sev). The separation between Lo and Mod disturbance categories, however, was not distinctive, hence a possible explanation for a lack of statistical significance for the first eigenvalue of the analysis (Table 4). Inspection of the minimal degree of difference among the third and fouth eigenvalues also indicates a general a lack of structure among the relationships. Therefore, this analysis should be viewed as an indication of a possible trend among the variables. This result possibly is related to the relatively low sample size of the analysis (n= 36).

Litter cover varies with short-term forest management regimens, e.g., burning schedules. Litter cover will be related to basal area of overstory trees and basal area and density of understory plants, both woody and herbaceous

Given the limitations of the weak statistical strength of the analysis, there appears to be a relationship between the cover of a subset of the herbaceous species and sites of severe disturbance (Fig. 7). Those herbaceous species most closely associated with severely disturbed sites were: DICI, DITE, STBI, GR4, ARPU, OPHU,HADI, and PANO. Solid stands of PANO occurred on sites that had been severely disturbed in the past; this species probably was planted to reduce erosion from the sites.

Table 3. Codes for woody species encountered.

Codes	Scientific Name	Codes	Scientific Name
AMBE, FAGR	Fagus grandifolia	QUBJ	Quercus marilandica
AMBEA	Callicarpa americana	QUBL	Quercus velutina
ANIS	Illicium floridanum (or parviflorum)	QUHE	Quercus hemisphaerica
ARAR	Aralia spirosa	QULA	Quercus laurifolia
ARARB	Aronia arbutifolia	QUMA	Quercus margaretta
ASHE	Fraxinus pennsylvanica	QUPO	Quercus stellata
AZAL	Rhododendron sp.	QUSE	Quercus sp
BLBE	Carpinus caroliniana	QUSR	Quercus falcata
BLCH	Prunus serotina	QUTU	Quercus laevis
BLGU, NYSY	Nyssa sylvatica	QUWA	Quercus nigra
CAPH	Cephalanthus	QUWH	Quercus alba
CATA	Catalpa bignonioides	REBU	Cercis canadensis
CHIN	Quercus muehlenbergeii	REMA	Acer rubrum
CLAL, CLEAL	Clethra alnifolia	RETI	Cyrilla racemiflora
COBE	Coralbeads	RHCO	Rhus copallina
CRET	Crataegus sp.	RHOD	Symplocos tinctoria
CUGL	Cudwigia glandulosa	RIBI	Betula nigra
CYRA, TYTY	Cyrilla racemiflora	ROCA	Rosa carolina
DEBA	Decumaria barbara	RUBU	Rubus sp.
DESM	Desmodium sp.	SABA	Sabal sp.
DOGW	Cornus florida	SASS	Sassafras albidum
GADU	Gaylussacia dumosa	SBMA	Magnolia virginiana
GAFR	Gaylussacia frondosa	SEFR	Sebastiania fruticosa
HICK	Carya sp.	SH10	Shrub 10
HOBE	Ostrya virginiana	SH11	Shrub 11
HOSU	Lonicera sempervirens or japonica	SH15	Shrub 15
HYHY	Hypericum hypericoides	SH2	Shrub 2
HYQU	Hydrangea quercifolia	SHSS	Shrub seedling
ILCO	Ilex coriacea	SMIL	Smilax sp.
ILDE	Ilex decidua	STAM, STAME	Styrax americanum
ILGL	Ilex glabra	STGR	Styrax grandiflorium
ILOP	Ilex opaca	SUBE	Celtis
IPOM, MOGL	Ipomea sp.	SWGU	Liquidambar styraciflua
ITEA	Itea virginica	TR3	Tree 3
KUDZ	Pueraria lobata	TR6	Tree 6
LISI	Ligustrum sinense	TRCR	Campsis radicans
LOJA	Lonicera japonica	TRSE	Tree seedling
LYON	Lyonia sp.	TUPO	Liriodendron tulipifera
MAGR	Magnolia grandiflora	UN2	Unknown 2
MYCE	Myrica cerifera	UN8	Unknown 8
MYHE	Myrica heterophylla	UNIL	Ilex sp.
MYRI	Myrica sp.	UNSE	Unknown seedling
OABJ	Quercus incana	UNTR	Unknown tree
OPUN	Opuntia sp.	UT1	Unknown tree 1
OXAR	Oxydendrum arboreum	VAAR	Vaccinium arborum
PAPA	Asimina parviflora	VAC2	Vaccinium sp.
PEBO	Persea borbonia	VAEL	Vaccinium elliotii
PERS	Diospyros virginiana	VAMY	Vaccinium myrsinites
PEVI	Ampelopsis arborea	VAST, VASTA	Vaccinium stamineum
PILL	Pinus palustris	VIBRU, VIBU, VIRU	Viburnum rufidulum
PILO, PITA	Pinus taeda	VICR	Parthenocissus quinquefolia
PISH	Pinus echinata	VIN3	Vine 3
POIV	Toxicodendron radicans	VIROT	Vitus rotundifolia
POOA	Toxicodendron pubescens	WIEL	Ulmus alata
PRAN	Prunus angustifolia	WIHA	Hamamelis virginiana
PRUM	Prunus umbellata	YEJE	Gelsemium sempervirens
QUAR	Quercus arkansana	YUCC	Yucca filamentosa

Table 4. Canonical correlation analysis eigenvalues for woody plant species relative cover correlated with environmental variables at all sites and herbaceous species absolute cover correlated with environmental variables at upland and slope sites.

	Axis 1[a]	Axis 2	Axis 3	Axis 4
Woody spp	0.52 (*)	0.21	0.18	0.16
Herbaceous spp.	0.56 (ns)	0.48	0.34	0.28

[a] Test of significance of first eigenvalue: *= <0.05, ns= not significant.

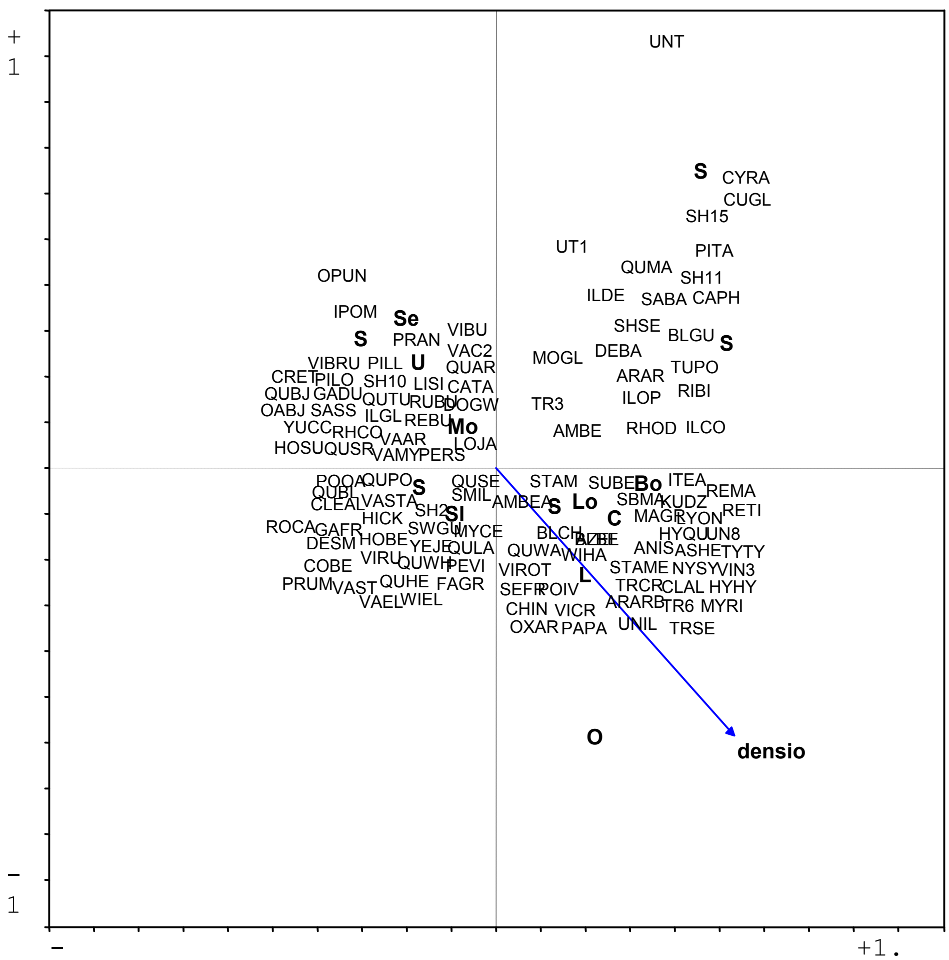


Figure 6. CCA biplot for woody species relative cover and environmental variables.

Table 5. Codes for herbaceous species encountered.

Code	Scientific Name
AGTE	Agalinas tencifolia
ANsC	Andropogon sp. (cover)
ANsD	Andropogon sp. (density)
ANTE	Andropogon ternarius
ANVIc	Andropogon virginicus (cover)
ANVId	Andropogon virginicus (density)
ANRU	Anthaenantia rufa
ARPU	Aristida purpurescens
ARTU	Aristida tuberculosa
ARGA	Arundinaria galgantium
AS1	Aster 1
AS2	Aster 2
AS3	Aster 3
AS4	Aster 4
AS5	Aster 5
AS6	Aster 6
ASDU	Aster dumosus
ASLA	Aster laterifloris
ASTO	Aster tortifolias
BRER	Brachyelytrum erectum
BUCI	Bulbostylis ciliatifolia
CAS	Cassia sp.
CES	Cenchrus sp.
CHLA	Chasmanthium laxum
CIAR	Cinna arundinacea
CRST	Cnidoscolus stimulosus
COER	Commelina erecta
COMA	Coreopsis major
COMS	Coreopsis major var. stellata
COS	Coriopsis sp.
CRGL	Croton glandulosus
DEPA	Desmodium paniculatum
DES	Desmodium sp.
DICI	Digitaria ciliaris
DITE	Diodia teres
ELCA	Elephantopus carolineanus
ELTO	Elephantopus tomentopus
ERS	Erianthus sp.
EGS	Erigonium sp.
ERHI	Erigrostis hirsuta
EUAL	Eupatorium altissimum
EUCA	Eupatorium capillifolium
EUJU	Eupatorium jucundum (Ageratina jucunda)
EUPU	Euphorbia pubentissima
FE1	Fern 1
FO1	Forb 1
FO10	Forb 10
FO2	Forb 2
FO3	Forb 3
FO4	Forb 4
FO5	Forb 5
FO6	Forb 6
FO7	Forb 7
FO8	Forb 8
FO9	Forb 9
GAVO	Galactia volubilis
GACI	Galium circaezans
GAUR, GAFI	Gaura filiper
GR1	Grass 1
GR2	Grass 2
GR3	Grass 3
GR4	Grass 4
HADI	Haplopappus dirasicatus
HEAR	Hexastylis arifolia (Asarum arifolium)
HYGE	Hypericum gentioides
LEVI	Leersia virginica
LECU	Lespedeza cuneata
LEHI	Lespedeza hirta
LIEL	Liatris elegans
LITE	Liatris tencifolia
LIS	Liatrus sp.
LISQ	Liatrus squarrulosa
ONSE	Onoclea sensibilis
OPHU	Opuntia humifusa
OSCI	Osmunda cinnomomea
OSRE	Osmunda regalis
PACHc	Panicum chamaelanche cover
PACHd	Panicum chamaelanche density
PACLc	Panicum clandestinum cover
PACLd	Panicum clandestinum density
PANO	Paspalum notatum
PASE	Paspalum setaceum
PITY	Pityopsis
POPR	Polypremum procumbens
POS	Potentilla sp.
PTAQ	Pterydium aquilinum var. pseudocaudatum
RAGW	Ragweed
RHMI	Rhynchosia minima
RHMC	Rhynchospora microcephala
SCSCc	Schizacherium scoperium cover
SCSCd	Schizacherium scoperium density
SCMI	Schrankia microphylla
SCL	Scleria bottom
SE1	Sedge 1
SE2	Sedge 2
SE3	Sedge 3
SEPE	Segmaria pectinata
SOOD	Solidago odora
SOS	Solidago sp.
SONU	Sorgastrum nutans
SPMO	Sphagnum moss
SPJUc	Sporobolus junceus cover
SPJUd	Sporobolus junceus density
STBI	Stylosanthes biflora
TEFL	Tephrosia florida
TEVI	Tephrosia virginiana
TRS	Tradescantia sp.
TRFL	Tridens flavus
TRAM	Triplasis americana
UN	Unknown
VEAN	Vernonia angustifolia
WOOB	Woodsia obtusa
WOAR	Woodwardia areolata
XYDI	Xyrus difformis

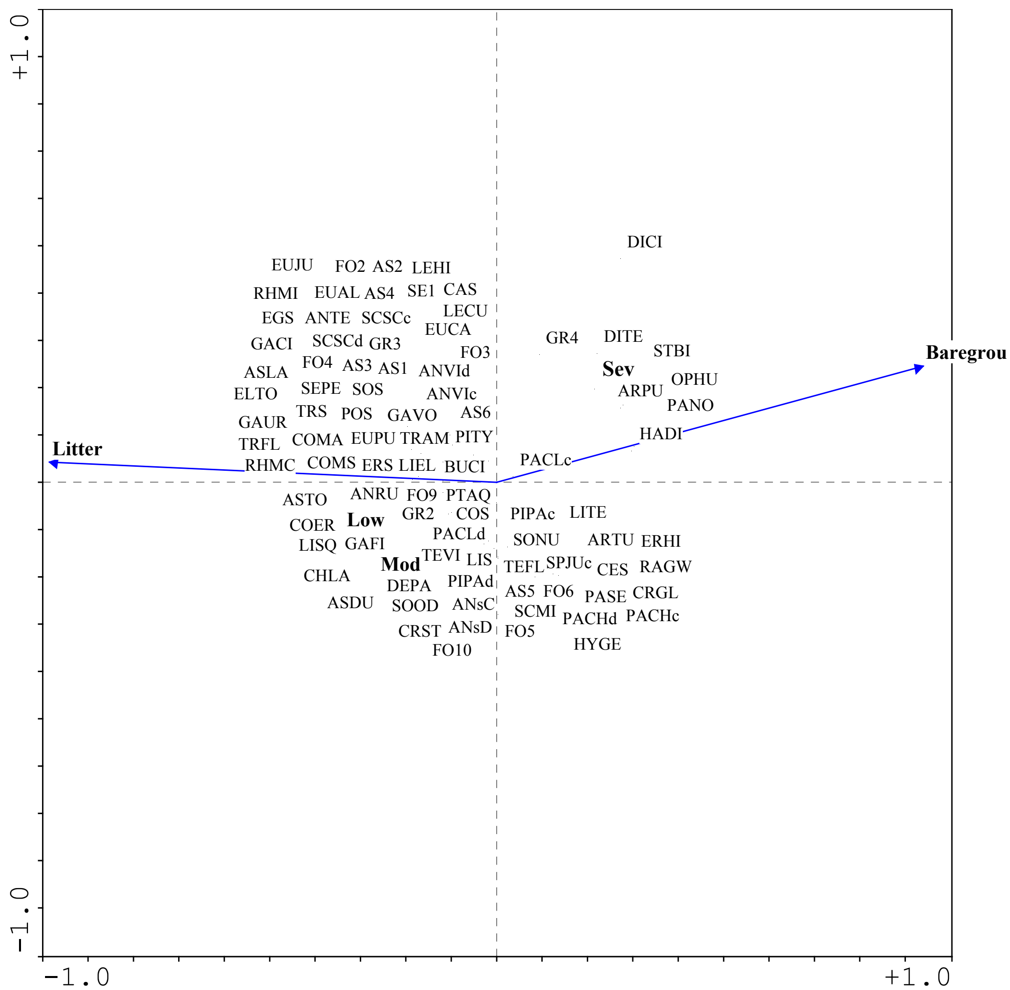


Figure 7. CCA biplot for herbaceous species absolute cover and environmental variables.

3) WATERSHED HYDROLOGY

Technical Approach:

<u>Water Content Sampling:</u>

Soil moisture is being measured and logged at several distributed locations and along specific transects in the "Bonham-1" subwatershed, a relatively low-impact catchment in D13 (Fig. 8).

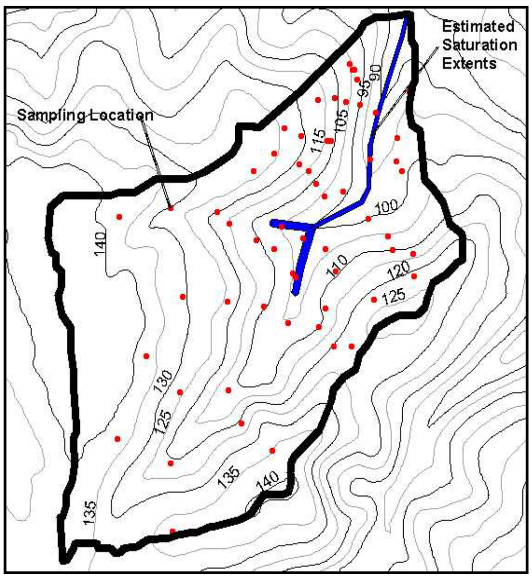
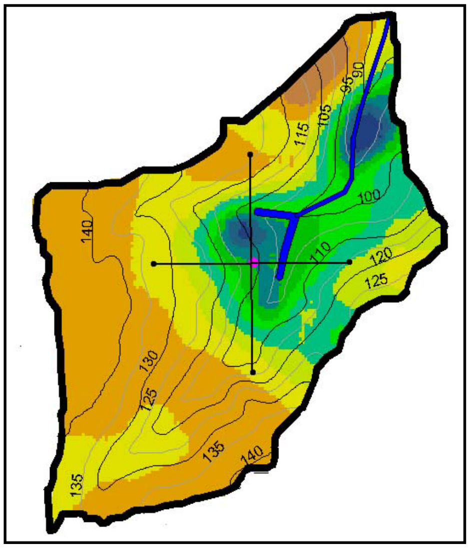


Figure 8. 70 Sampling locations in D13 catchment of Bonham-1 watershed – August 8, 2001.

Monitoring how distributed storage changes both spatially and temporally will take place. The measurements will be used to estimate the total water storage and spatial moments of water content within the catchment (Fig. 9). The estimation will be computed using an unbiased (e.g. kriging) geostatistical model. The soil moisture data will also be compared to stream gage recordings to examine how distributed storage dynamics affect in-stream responses.



Spatial Moment Summary

	w/o Stream Zone	w/ Stream Zone
Total Water (m3)	38,896	42,880
Centroid - x (m)	710,313	710,330
Centroid - y (m)	3,588,465	3,588,488
Centroid - z (in)	13	13
stddev - x (m)	251	247
stddev - y (m)	274	276
stddev - z (in)	9	9
Total Volume (m3)	580,710	
Average Water Content	0.067	0.074

Figure 9. Integrated water content in upper 30-inches, D13 Bonham-1 watershed - August 8, 2001. Shown on the plot are also the spatial mean water content (red point) and standard deviation about the mean (black lines).

<u>Sediment:</u>

Sediment sampling along established erosion channels in the Cannons and Rowan Hill areas (D12) may be continued to determine the effects of upland disturbance on downstream impacts. Sampling is conducted along longitudinal transects in the channel. Transects are also taken normal to the channel in sediment fans and other depositional areas. At each location, incremental depth samples are collected and the depth to channel bottom recorded. In the lab, samples are analyzed to find relationships in particle size distribution with channel location (Fig. 10). The particle-size analysis, along with sediment depth measurements will be used to hypothesize the effects of upland activity on the depositional history.

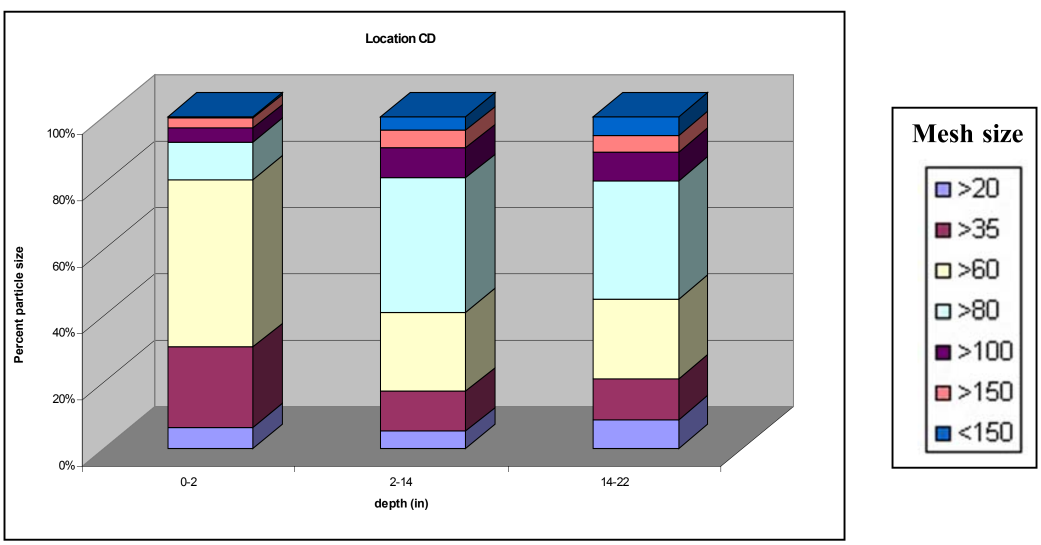


Figure 10. Example of percent particle-size distribution with depth – Cannons (D12), August 8, 2001.

Progress To Date:

Water Content:
Distributed soil moisture sampling was contented both in June 2001 and August 2001. Analysis shows a relatively dry upland soils with increasing water content on the hill slopes. The majority of the water storage is confined to the areas immediately adjacent to the stream channel. More data is needed to observe water redistribution activity under different climate and seasonal situations as well as a more detailed characterization of moisture dynamics in riparian areas. Soil moisture measurements will also be extended to other watersheds as well as impacted areas for comparison purposes.

Sediment Sampling:
Three major erosion channels and corresponding depositional fans were sampled once in June 2001 and again in August 2001. Preliminary analysis is helping to better direct sampling strategies to reveal primary source areas of upland sediments and the process of depositional fan formation.

Watershed Hydrologic Budget

- The Randall Creek stream flow measurement site was moved due to no flow conditions. A staff gage and a pressure transducer was installed for the stage measurement. The stage measurements in Bonham-1, and Bonham-2 Creeks continued. Duplicate measurements of rainfall in Bonham-1 watershed continued.
- Period 1 of 4 for the throughfall study was completed. Initial results show a distinct signature among the 5 vegetation types categories into five different groups: wetland, pine plantation, hard wood, mixed, and pine for throughfall study. The spatially distributed model hydrological input model development is nearly complete. The model includes a Gash throughfall model coupled to a GIS system which uses landuse coverages. Routine clogging of tipping bucket gages in the wetlands site has reduced the quantity and quality of data collected at the site.
- Rainfall data collected from January 2000 to June 2001 in the Bonham-1 Creek was evaluated and organized. A preliminary QA/QC evaluation of the hydrolab data was conducted. The data shows some irregularities. Based on these findings several of the hydrolabs will be serviced.
- Measurements of stream discharge were conducted every three weeks from June to September.
- Preliminary hydrologic modeling efforts in Bonham-2 were conducted using TOPMODEL. The model parameters needed to run TOPMODEL in DOS platform were calculated. The model was run and showed reasonable results.