ERDC SR-02-2

US Army Corps of Engineers®
Engineer Research and Development Center

Strategic Environmental Reserch and Development Program (SERDP) Ecosystem Management Project (SEMP) FY01 Annual Report

Harold E. Balbach, William D. Goran, Teresa Aden, David L. Price, M. Rose Kress, William F. Debusk, Anthony J. Krzysik, Virgina H. Dale, Charles Garten, Jr., and Beverly Collins

March 2002

Construction Engineering Research Laboratory

Foreword

This study was conducted for the Strategic Environmental Research and Development Program (SERDP) Office under SERDP Work Unit CS-1114, "SERDP Ecosystem Management Project." The technical monitor was Dr. Robert Holst, Program Manager. The Executive Director of SERDP is Mr. Brad Smith.

The work was performed under the direction of the Ecological Processes Branch (CN-N) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Dr. Harold E. Balbach. William D. Goran and Teresa Aden are from CERL. Dr. David L. Price and M. Rose Kress are from the Environmental Laboratory, Engineer Research and Development Center. Dr. William F. DeBusk is from the University of Florida, Gainesville. Dr. Anthony J. Krzysik is from Embry-Riddle Aeronautical University, Prescott, Arizona. Dr. Virginia H. Dale and Charles Garten, Jr., are from Oak Ridge National Laboratory, Oak Ridge, Tennessee, and Dr. Beverly Collins is from the Savannah River Ecology Laboratory, Aiken, South Carolina. The technical editor was Gloria J. Wienke, Information Technology Laboratory. Stephen E. Hodapp is Chief, CEERD-CN-N, and Dr. John T. Bandy is Chief, CEERD-CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Director of CERL is Dr. Alan W. Moore.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL John Morris III, EN and the Director of ERDC is Dr. James R. Houston.

Contents

Put Initial Caps on Rpt Doc Pg after regeneration.

List of Figures

Figures

TAKE “Figure” and periods off after regeneration

1 Introduction

Background

According to numerous memorandums and policies, Department of Defense (DoD) lands and waters are to be managed from an "adaptive ecosystem management" approach. The overriding goal of these policies is twofold: (1) to support sustainable mission use of DoD lands, waters, and airspace, and (2) to restore, sustain, and protect valuable natural and cultural resources occurring on/in the lands and waters.

To practice adaptive ecosystem management, DoD land/water resource managers are asked to inventory and monitor ecosystem resources, processes, and conditions; to understand the relationship between mission operations, management actions, and ecosystem conditions; and to adjust ecosystem management practices and mission usage patterns based on goals, observations, analysis, and previous management actions. In addition, guidance calls for DoD land/water managers to incorporate the best scientific understanding of their ecosystem and mission interactions with ecosystems into their adaptive management practices. The Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP) is a venture to help DoD managers address this challenging guidance.

The SERDP Investment

SERDP is the DoD's major environmental research program, responding to environmental issues, concerns, and formal requirements emerging from all DoD services. SERDP normally translates requirements and issues into Statements of Need (SONs). These SONs are used as solicitations for government agencies, academics, and private sector researchers to submit proposals. With SEMP, the SERDP responded to an enduring need to better understand the complex dynamics between various ecosystems and DoD operations through a managed set of investments that include multiple SON solicitations, a long-term monitoring program, a proactive partnering with DoD installation managers, and the eventual development of a adaptive ecosystem management protocol, based on a continuously improving cycle of ecological observations, data analysis, and management adjustments.

SEMP was initiated in 1998, following a June 1997, SERDP-sponsored workshop of DoD ecosystem managers, academics, and nongovernmental organizations (NGOs), that focused on Landscape Scale Ecosystem Management Research. From this workshop, a series of research themes emerged as fundamental to improving management understanding of ecosystems. The primary themes that emerged from the Workshop included:

- Ecosystem Health or Change Indicators,
- Thresholds of Disturbance,
- Biogeochemical Cycles and Processes, and
- Ecosystem Processes as they relate to multiple temporal and spatial scales.

These themes, which included ecosystem change or status indicators and disturbance thresholds, helped form the SEMP SON solicitations. After the workshop, a team of DoD researchers and conservation policy proponents formed a "working group" to translate these themes into a research program. This team, led by senior staff from the Corps of Engineers' research laboratories (now part of the Engineer Research and Development Center, or ERDC), identified the southeastern United States as the preferred location to initiate an ecosystem management research effort, and then selected the Army installation Fort Benning, in western Georgia and eastern Alabama, as the host location for this research. The team developed an overall plan for this research effort, issued an initial SON, and designed a long-term monitoring program.

Objective

The overall program objective for SEMP is to plan, coordinate, execute, and manage, on behalf of SERDP, an ecosystem management project initiative that focuses on ecosystem science relevant to DoD ecosystem management concerns. This includes:

- Addressing DoD requirements and opportunities in ecosystem research, as identified by the 1997 SERDP Ecosystem Research Workshop;
- Establishing and managing one (or more) long-term ecosystem monitoring sites on DoD facilities for DoD relevant ecosystems research;
- Conducting multiple ecosystem research and monitoring efforts, relevant to DoD requirements and opportunities, at these and/or additional facilities; and Facilitating the integration of results and findings of research into DoD ecosystem management practices.

Status and Approach

SEMP now has five research teams addressing two different SONs (FY [Fiscal Year] 99, "Indicators of Change;" and FY00, "Thresholds of Disturbance") in addition to an ongoing long-term monitoring effort, an emerging analysis effort, and a functioning data repository. A brief summary of the FY01 accomplishments of each of these efforts forms Chapter 2 of this annual report. Each of the teams has progressed on or very close to their proposed schedule of accomplishments during FY01. A discussion of overall program progress is included in Chapter 5. The most significant change would appear to be a shift of perspective in which the more than 20 investigators, representing 12 universities and 4 U.S. Government laboratories, now more fully appreciate that they are part of a larger team, working toward a mutual goal.

The host installation has actively supported and shaped the program, and one key element of the SEMP approach has been to link the Fort Benning Integrated Natural Resources Management Plan (INRMP) with SEMP. All DoD installations are required to develop INRMPs as a means to bring together and reconcile the diverse plans that affect installation natural resources. Many of these plans, including that for Fort Benning, state goals for the future status of environmental elements. These goals become important measures of what ecosystem conditions are desired by installation managers, and may be viewed as the targets for adaptive management.

The SEMP long-term monitoring program has two main purposes: (1) to provide a basic set of background data that can inform various research efforts, and (2) to provide installation managers basic information on overall ecological conditions and trends on the installation. While this monitoring program is not designed to specifically monitor protected species or land restoration projects, monitoring data does provide measures that can be evaluated in terms of trends toward or away from broad ecosystem management goals. In addition, promising observations (or indicators) from the research projects that more specifically address measures of trends to or away from installation goals can be incorporated into the baseline monitoring program. The FY01 progress of the monitoring component faced many physical challenges, primarily that of the near-record drought of 2000-2001, which caused complete loss of flow in 9 of the 10 streams that were being monitored.

One of the goals of SEMP was to provide a landscape level research environment that helped support enduring mission use and ecosystem health. Already, this goal has clearly succeeded, as numerous additional research efforts beyond the SERDP-funded SEMP are underway and/or proposed for the Fort Benning area. Another goal is to share approaches and results with other installations in the region. Such efforts are already underway through the "Partners Along the Fall Line" initiative and the linkages to the multi-agency Southeast Natural Resources Leader's Group.

SEMP is a dynamic process rather than a fully-defined, fixed project, and much hard work is still needed to ensure this SERDP investment brings benefits to DoD land/water resource managers. Efforts are just beginning to bring SEMP data and analysis tools into a common environment, yet this step is critical to gain both local and transferable benefits from SEMP. We are developing information to help determine the sets of approaches and technologies that will benefit other resource managers across the Southeast and regions beyond.

Mode of Technology Transfer

The transfer of the information gained will be through the development of adaptive environmental management relationships. Each of these relationships will integrate the background information, knowledge of ecosystem processes, and installation ecosystem management objectives in such a manner that installation environmental managers may implement management changes to meet the installation goals.

This report, and other SEMP documents will be made accessible through the World Wide Web (WWW) at URL: http://www.cecer.army.mil

This report presents a summary of the FY01 progress of each project. A full-length report for each project can be found within the project information at: https:/www.denix.osd.mil/denix/Public/Library/SEMP/Research/research.html

2 Research Projects

As a result of the initiating workshops described in Chapter 1, statements of need were developed based on the two highest-ranked needs, and proposed projects were solicited and evaluated in two steps. First, three projects relating to the identification of indicators of change were initiated late in FY99. Second, two projects examining thresholds were funded in mid-FY00. A brief, summarized version of the FY01 progress of these five projects follows. In each case, a full-length version of their report is available at the website address given.

Determination of Indicators of Ecological Change (CS-1114A-99)

The principal investigator for this project is Dr. William F. DeBusk from the University of Florida, Gainesville.

Background

This research seeks to develop suitable indicators of ecosystem integrity and impending ecological change resulting from both natural variation and anthropogenic activities. It uses a multi-disciplinary 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, it addresses 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.

Research Plan/Objectives

The 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.

Approach

This research project is employing a multiscale approach, which will result in robust techniques for ecosystem monitoring and evaluation. It is proposed to evaluate a suite of parameters related to properties and processes in the soil, understory vegetation, 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. Quantitative relationships will be developed between environmental change, 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.

Relationships between ecological indicators and environmental and anthropogenic stressors will be evaluated simultaneously over a broad area encompassing a wide range of environmental conditions (low-intensity sampling) and in localized areas of relatively homogeneous environmental conditions (high-intensity sampling). This approach will give us the ability to apply and test indicator-based algorithms across multiple spatial scales, a major consideration in assessing the utility of the indicators for evaluating ecological change.

FY01 Progress

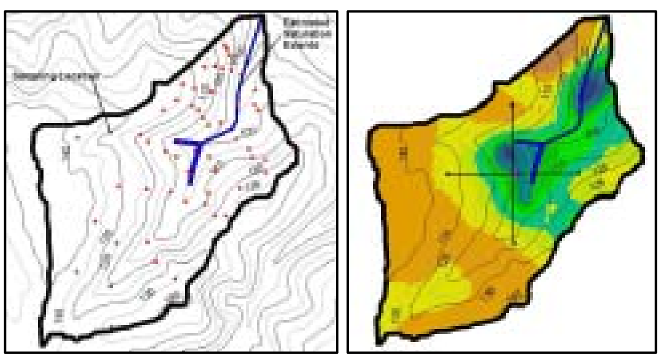
Soil Biogeochemistry. Phase I sampling was conducted within 6 watersheds of order 3 or 4, representing a wide range of type and intensity of disturbance. Analysis of Phase I soil samples was completed during FY01, while Phase 2 sampling and data analysis are ongoing. Analysis was completed for soil samples collected during December 2000 for a comparative study of soil and vegetation-based indicators in both wetland and upland regions of highly disturbed (in compartment D-15) and minimally disturbed (D-4) areas. Additional soil and vegetation monitoring transects were established at four upland and three wetland sites during June 2001, including areas of high military disturbance (Rowan Hill , D-12), low disturbance (D-13), and planted pines (2 stands in O-3, ca. 5 years and 12 years).

Comparison of soil total carbon (TC) and microbial biomass carbon (MBC) among low-, moderate- and severe-disturbance sites support field observations that the primary effect of military training is soil erosion in uplands and associated sedimentation in wetlands. Loss of topsoil has resulted in decreased TC in disturbed upland sites with a concomitant decrease in TC of disturbed wetland soils as a result of “dilution” by inorganic soil material. In general, soil chemical and biological parameters typically correlated with soil organic matter also tend to decrease with increasing site disturbance. MBC expressed as a proportion of total soil C (MBC:TC) tends to increase with increasing levels of soil disturbance, possibly indicating the relative availability of organic C to heterotrophic microorganisms in the soil. We have observed a similar trend for dissolved organic C, expressed as a proportion of total C, suggesting that the fractionation of soil C may reflect intensity of physical soil disturbance. Overall, the parameters related to organic matter and microbial biomass/activity (including microbial respiration and enzyme production), have shown promise as sensitive indicators of soil and vegetation disturbance at Fort Benning, GA.

The compositions and structures of methanotrophic bacterial communities were evaluated as indicators of impact along transects taken from uplands and wetlands using terminal restriction fragment length polymorphism (T-RFLP) analysis. Comparison of Shannon diversity indices for high and low impact soils indicated a significantly higher methanotroph T-RFLP diversity for low impact upland than high impact uplands. Comparison of diversity indices discriminated between high and low impact uplands, whereas principal components analysis (PCA) was required to differentiate wetland samples on the basis of impact.

Vegetation. Structural and compositional parameters of vegetation were measured in the Summer and Fall of 2000 at the Phase I soil sampling sites described above. Canonical correspondence analysis (CCA) was used as an ordination technique to determine the relationship between the species cover values and environmental variables. Analyses were performed both on the absolute vegetation cover and relative cover. Severe disturbance was most closely associated with upland, sandy clay soils. Increased overstory canopy cover as estimated by densiometer measurements was associated with low disturbance sites. Litter cover varies with short-term forest management regimens (e.g., burning schedules), and will be related to basal area of overstory trees and the basal area and density of understory plants, both woody and herbaceous. Given the limitations of the statistical analysis, there appears to be a relationship between the cover of a subset of the herbaceous species and sites of severe disturbance.

Watershed Hydrology. Soil moisture was measured and logged at several distributed locations and along specific transects in the Bonham-1 subwatershed, a relatively low-impact catchment in D-13 (Figure 1, left). The distribution of both spatial and temporal storage changes have been and will continue to be monitored, and these measurements used to estimate the total water storage and spatial moments of water content within the catchment (Figure 1, right). This estimation will use 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. The plot in Figure 1 (left) shows the spatial mean water content (red points) and standard deviation about the mean (black lines).



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 1. Sampling locations (left) and integrated water content in upper 30 inches (right) for D-13 catchment of Bonham-1 watershed on August 8, 2001.

Sediment sampling along erosion channels in the Cannons and Rowan Hill areas (D-12) was conducted along longitudinal transects in the channel and transects normal to the channel in sediment fans and other depositional areas. At each location, incremental depth samples were collected and depth to channel bottom recorded. In the lab, particle size distributions were determined with respect to channel location. Particle-size analysis and sediment depth measurements are used to hypothesize the effects of upland activity on the depositional history. Three major erosion channels and corresponding depositional fans were sampled in June 2001 and August 2001. Preliminary results will be used to better direct sampling strategies in order to reveal primary source areas of upland sediments and the process of depositional fan formation.

Watershed Hydrologic Budget. Stage measurements in Bonham-1 and Bonham-2 Creeks continued; however, the stream flow measurement site in Randall Creek was moved due to no flow conditions. Measurements of stream discharge were conducted every 3 weeks from June to September. Duplicate measurements of rainfall in Bonham-1 watershed continued. Initial results for period 1 of the throughfall study show a distinct signature among the five vegetation types: wetland, pine plantation, hard wood, mixed, and pine. The spatially distributed hydrological input model development is nearly complete, including a Gash throughfall model coupled to a geographic information system (GIS) system which uses landuse coverages.

Publications

Dabral, S., W. D. Graham, and W. F. DeBusk. (in preparation). “Development of soil biogeochemical indicators of ecological condition for military land management.” J. Environ. Qual.

Prenger, J. P., B. L. Skulnick, and W. F. DeBusk (in preparation). “Evaluation of soil organic C storage and cycling as the basis for development of ecological indicators.” J. Environ. Qual. or Biogeochemistry.

Presentations

Jacobs, J. J., S. Bhat, W. D. Graham, P. S. C. Rao, N. Haws, W. F. DeBusk, and J. W. Jawitz. 2001. “Identification of eco-hydrologic indicators of ecological impact: Phase I results from Fort Benning, Georgia watersheds.” Poster presented at Spring 2001 Meeting of the American Geophysical Union, May 29 – June 1, 2001, Boston, MA.

DeBusk, W. F., and J. P. Prenger. 2001. “Wetland soil biogeochemical indicators of ecological condition for military land management.” Poster presented at Annual Meeting of Society of Wetland Scientists, May 28 – June 1, 2001, Chicago, IL.

Address for Full Report

https://www.denix.osd.mil/denix/Public/Library/SEMP/Research/ResearchProjects/RPFY99/determination.html

Development of Ecological Indicators for Land Management (CS-1114B-99)

The principal investigator for this project is Dr. Anthony J. Krzysik, Embry-Riddle Aeronautical University, Prescott, AZ.

Background

Ten Ecological Indicator (EI) systems are being researched to develop and integrate a "Guild System" for assessing disturbance gradients, ecological changes, and thresholds relevant to landuse management decisions, primarily addressing military training environmental impacts. Nine EI systems are applicable to different ecological systems and scales, while the tenth represents the synthesis of the first nine.

Objective

The objective of this research is to develop Ecological Indicator Guilds based on ecosystem-relevant design criteria and multiscale performance and stress-response criteria, for the purpose of monitoring ecological changes directly relevant to biological viability, long-term productivity, and ecological sustainability of military training and testing lands. Three important capabilities of developed ecological indicators are: (1) the ability to assess and monitor multiscale ecosystem stressor effects independent of natural environmental variability and disturbance regimes, (2) their direct applicability to ecoregional contexts, and (3) the developed approaches, analysis, and modeling capabilities could be extended to any global ecoregion.

Approach

Classifications (Guilds) of ecological indicators will be developed to assess and monitor ecological changes and thresholds relevant to land use management decisions. These Guilds will be developed from responses to five different indicator systems measured along ecosystem disturbance gradients in three spatially delineated watershed ecosystems: uplands, riparian, and aquatic-lotic. These indicator systems are:

- ecological test systems,
- ecological multiscale metrics,
- geoindicators,
- ecofunction groups, and
- indicator taxa (and possibly communities).

Ten habitat variables, from the original pool of 78 variables, appear to represent excellent ecological indicators of habitat condition on the basis of their discriminating power in Discriminant Analysis. Principal Components ordinations also strongly indicated that general habitat variables were important in distinguishing disturbance classes. These ten variables are: four expressing variability in general habitat features (canopy cover standard deviation [SD], A-horizon soil depth SD, soil compaction SD, and Bitterlich basal area SD), three ground cover variables (forbs, grasses, legumes), and three general tree density variables (oak density, pine density, and "other species" tree density). These variables in different, but similar, combinations were able to reliably and consistently discriminate among not only the three disturbance classes Low, Medium, and High, but also different combinations of paired comparisons among these three classes. Nonmetric Multidimensional Scaling ordination was effective in quantifying the relationships among the nine research sites on the basis of tree floristics and general classes of ground cover. Tree floristics data clearly ordinated and separated the two watersheds of this study, Bonham Creek and Sally Branch, independent of habitat disturbance class, and clearly defined the two most disturbed sites in the analysis. The value of the ground cover ordination was its effectiveness at ranking the age of controlled burns.

The results of Species Diversity and Fractal Analysis along a disturbance gradient suggested that limited disturbance may be beneficial to ecosystem maintenance and resilience (sustainability) in the Sand Hills. The "Intermediate Disturbance Hypothesis" in ecology similarly suggests that low levels of community disturbance increase species diversity. Overlap, as measured by this analysis, may be a useful indicator of disturbance.

Over 100,000 measurements have been completed to date on 10 selected species of abundant and widespread plants to assess if site disturbance levels contribute to developmental instability. Research sites with higher disturbance levels showed increased fluctuating asymmetry in several parameters for Winged Sumac, Morning Glory, and Tred-Softly (Figure 2). Net photosynthesis declined as disturbance increased, while transpiration and stomatal conductance were significantly higher at the heavily disturbed sites. Variable fluorescence is often used as a measure of stress. The minimum, maximum, and ratio indices of fluorescence differed significantly among the sites. Minimum and maximum fluorescence both tended to decline with disturbance. However, the percent deviation from the maximum fluorescence exhibited a more complex pattern, possessing both the lowest and highest values at Medium and High disturbance sites. The use of developmental instability and of physiological metrics of selected plant species represent an important component to developing Ecological Indicator guilds.

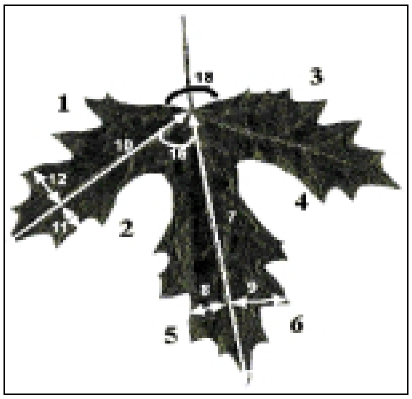


Figure 2. Multiple leaf measurements as taken for Tred-Softly specimens.

The Low disturbance upland sites have not changed significantly in either bacterial or fungal functional diversity over the past year. These data suggest that low impacted sites are characterized by low seasonal and yearly variation in microbial functional diversity. The major impact of disturbance within this landscape results in an increase in the seasonal heterogeneity in the ability of the soil microbes to process carbon. It is hypothesized that the high seasonal variation in microbial functional diversity that is a result of disturbance will result in ecosystem instability and increased susceptibility to climatic stress, such as drought. Bacterial and fungal functional diversity and microbial carbon biomass have not been impacted by disturbance at most of the bottomland sites. The only exception was the High disturbance site where the removal of trees for improving visual target engagement has reduced microbial functional diversity and microbial carbon biomass when compared to the other bottomland sites. Microbial carbon biomass was significantly less at the High disturbance upland sites, but not significantly different between the Low and Medium disturbance upland sites. These data support the hypothesis that disturbance in this system will increase the yearly and seasonal variations in microbial activities.

Presentations

Wrinn, Kerri. "Effects of Disturbance on Spider Communities at Fort Benning, Georgia." Student Research Symposium, Berry College (poster) April 2001.

Roth, Susan. "Ants as Indicators of Environmental Disturbance." Student Research Symposium, Berry College (poster), April 2001.

Krzysik, A.J., J.C. Zak, E. Sobek, D.A. Kovacic, D.C. Freeman, J.H. Graham, M.L. Brown, J.J. Duda, C.C. Graham, M. Wallace, J.M. Emlen, and H.E. Balbach. "Ecological Indicators for Quantifying Landscape Disturbance." SERDP Symposium (poster) 27-29 November 2001.

D. C. White, V. H. Dale, W. F. DeBusk, A. Krzysik, A. Ogram, J. Prenger , J. Zak, and A. D. Peacock. "Comprehensive Soil Microbial Analysis of Military Disturbance at Fort Benning, GA." SERDP Symposium (poster) Washington DC, November 2001.

J. C. Zak, E. Sobek, C. Hernandez, J. Dobranic, M. Kerr, J. Duda, and A. Krzysik. "The Effects of Disturbance Severity on Microbial Functional Diversity and Activity." Soil Ecology Society, Biannual Meeting (poster) Calloway Gardens, GA, 2001.

Address for Full Report

https://www.denix.osd.mil/denix/Public/Library/SEMP/Research/ResearchProjects/RPFY99/development.html

Indicators of Ecological Change (CS-1114C-99)

The principal investigator for this project is Dr. Virginia H. Dale from Oak Ridge National Laboratory, Oak Ridge, TN.

Background

The intent of this identification of indicators is to improve managers' ability to manage activities that are likely to be damaging and to prevent long-term, negative effects. Therefore, a suite of variables is needed to measure changes in ecological conditions. The suite that we examine includes measures of landscape patterns, soil microbial biomass and community composition, terrestrial understory, and stream conditions (both stream chemistry and aquatic biological integrity). This project was selected to help identify indicators of ecosystem change focusing on the test site of Fort Benning, GA, but with the intent that the ideas would be applicable across the diversity of DoD lands.

Objective

This effort will identify indicators that signal ecological change in intensely and lightly used ecological systems. The goal is that these indicators improve managers' ability to manage activities that are likely to be damaging and to prevent long-term, negative effects. Therefore, a suite of variables is needed to measure changes in ecological conditions. The suite to be examined includes measures of terrestrial biological integrity, stream chemistry and aquatic biological integrity, and soil microorganisms as a measure of belowground integrity of the ecosystem.

Approach

Identifying indicators will encompass five steps: (1) analyzing historical trends in environmental changes to identify potential indicators; (2) collecting supplemental data relating to indicators (this will of course build upon existing data already available at Fort Benning); (3) performing experiments to examine how disturbances at Fort Benning might affect these indicators; (4) analyzing the resulting set of indicators for the appropriateness, usefulness, and ease of taking the measure; and (5) developing and implementing a technology transfer plan.

Landscape Patterns

Historical land survey maps and field notes from the early 1800s were used to create a digital GIS model of the forests covering the Fort Benning area. The map provides baseline conditions for the area currently occupied by the base. Non-forest/cleared areas were added to represent large Native American settlements. The map shows that pine species dominated the landscape at Fort Benning (Figure 3).

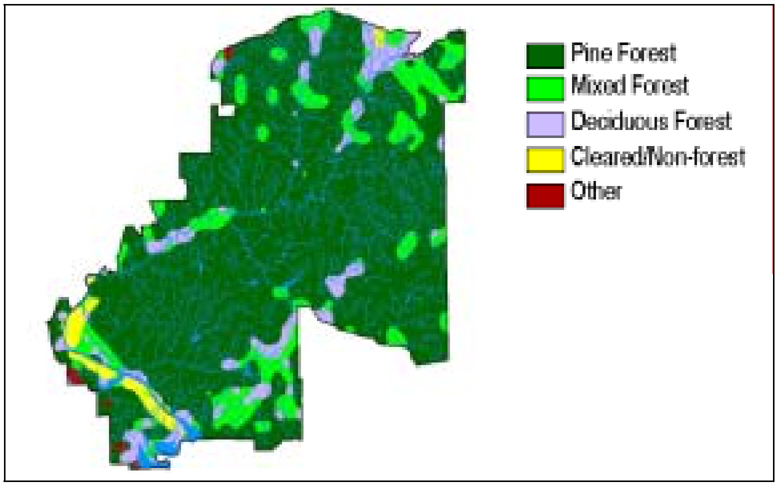


Figure 3. Forest cover map of Fort Benning, GA (1827).

LandSAT 7 Thematic Mapper images and a series of North American Landscape Characterization (NALC) data were used to analyzed changes in landscape patterns. Fort Benning has experienced a gradual decrease in forest populations coupled with an increase in non-forest vegetation. Areas of pine forest appear to be increasing, although the magnitude of this increase may be underestimated due to the misclassification of pine pixels into the mixed forest class.

Soil Microbiology

Using the soil microbial biomass and community composition as ecological indicators, reproducible changes showed increasing traffic disturbance decreases soil viable biomass, biomarkers for microeukaryotes, and Gram-negative bacteria, while increasing the proportions of aerobic Gram-positive bacterial and actinomycete biomarkers. Soil samples were obtained from four levels of disturbance (reference, light, moderate, and heavy) with an additional set of samples taken from previously damaged areas that were remediated via planting of trees and ground cover. Utilizing 17 phospholipid fatty acid (PLFA) variables that differed significantly with land usage, a linear discriminant analysis with cross-validation classified the four groups. Wilks' Lambda for the model was 0.032 ($P<0.001$). Overall, the correct classifications of profiles was 66 percent (compared to the chance that 25 percent would be correctly classified). The analysis suggests that as a soil is remediated it does not escalate through states of succession in the same way as it descends following disturbance.

Understory Indicators

A total of 137 plant species occurred in sampled transects, with the highest diversity (95 species) in light training areas and the lowest (16 species) in heavily disturbed plots. The variability in understory vegetation cover among disturbance types was trimodal ranging from less than 5 percent cover for heavily disturbed areas to 67 percent cover for reference, light, and remediated areas. High variability in species diversity and lack of distinctiveness of understory cover led us to consider life form and plant families as indicators of military disturbance. Life form successfully distinguished between plots based on military disturbances. In addition, the diversity of plant families and, in particular, the presence of grasses and composites, was indicative of training and remediation history. These results are supported by prior analysis of life form distribution subsequent to other disturbances and demonstrate the ability of life form and plant families to distinguish between military disturbances in longleaf pine forests.

Stream Chemistry Studies

Preliminary analyses suggest that baseflow suspended sediment concentrations are generally higher in streams draining disturbed catchments, particularly those that are highly disturbed. However, our data on baseflow nutrient chemistry shows no obvious effect of disturbance. There was evidence that storm hydrographs in streams draining disturbed catchments were somewhat more "flashy" than streams draining reference catchments, particularly for larger rainfall events. Disturbed catchment streams also had higher peak concentrations of suspended sediments, with the differences between reference and disturbed streams being greater for inorganic sediments than total sediments. A comparison of diurnal dissolved oxygen profiles in a reference stream and a highly disturbed stream suggests that this may be a useful disturbance indicator.

Stream Macroinvertebrate Studies

Two methods were used to quantify benthic invertebrates: (1) Hester-Dendy multiplate samplers; and (2) semi-quantitative sweep net samples. Taken together, both sampling methods provide a robust means to assess (1) the relationship between sediment disturbance and stream biological communities and, in turn, (2) the efficacy of using benthic macroinvertebrates as ecological indicators of landscape disturbance from military training. Streambed organic matter (OM) decreased with increasing catchment disturbance, although there was some high within-site variation in OM. Organic matter is being used as a measure of food availability for macroinvertebrates. Stream sediment movement (accretion, erosion) was higher in catchments receiving moderate to high disturbance from military training than from low-disturbance or reference sites.

Total numbers of macroinvertebrate taxa and EPT taxa (i.e., number of taxa within the aquatic insect orders Ephemeroptera, Plecoptera, and Trichoptera) were not useful in differentiating disturbance regimes among catchments. Preliminary data suggest that the abundance of populations of sediment-tolerant chironomid midges may be a useful indicator of high sediment disturbance in streams at Fort Benning.

Publications

Beyeler, S.C. 2000. "Ecological indicators." Master's thesis. University of Miami in Ohio.

Dale, V.H. and S.C. Beyeler. 2001. "Challenges in the development and use of ecological indicators." *Ecological Indicators* 1: 3-10.

Dale, V.H., L. Olsen, and L.K. Mann. In review. "Contributions of federal lands to protection of endangered and threatened species." *Natural Areas Journal*.

Dale, V.H., S.C. Beyeler, and B. Jackson. In review. "Understory indicators of anthropogenic disturbance in longleaf pine forests." *Ecological Indicators*.

Foster, H.T., II and M.D. Abrams. In review. "Physiographic analysis of the pre-European settlement forests in east-central Alabama." *Canadian Journal of Forest Research*.

Peacock, A. D., S. J. MacNaughton, J. M. Cantu, V. H. Dale, and D. C. White. In review. "Soil microbial biomass and community composition along an anthropogenic disturbance gradient within a longleaf pine habitat. Ecological Indicators."

Presentations

Dale, V.H. "Using indicators for restoration and management." Ohio State University. November 2, 2000.

Foster, T. "Evolutionary Ecology of Creek Residential Mobility," Southeastern Archaeological Conference, Macon, Georgia, November 2000.

Dale, Virginia attended a workshop on "Climate Change and Species Survival: Implications for Conservation Strategies" on February 19-21, 2001 at the headquarters of The World Conservation Union (IUCN) in Gland, Switzerland. She gave a presentation on the "Use of indicators."

Dale, Virginia attended the Fall Line Workshop on March 6-7, 2001 in Aiken, S.C. and gave on talk on "Lessons for Ecosystem Management."

Dale, V.H. Virginia Polytechnic Institute, Blacksburg, Virginia, April 2001.

Dale, V.H. University of Illinois in Chicago, April 2001.

Dale, V.H., J. Feminella, T. Foster, P. Mulholland, L. Olsen, A. Peacock, D. White. "Ecological indicators for land management." Ecological Society of America Annual Meeting, August 6, 2001, Madison, WI.

Olsen, Lisa M., Virginia Dale, and Thomas Foster. "Landscape Patterns as Indicators of Ecological Change at Fort Benning, GA." ESRI User Conference, July 9-13, 2001, San Diego, CA.

Address for Full Report

https://www.denix.osd.mil/denix/Public/Library/SEMP/Research/ResearchProjects/RPFY99/indicators.html

Disturbance of Soil Organic Matter and Nitrogen Dynamics: Implications for Soil and Water Quality (CS-1114D-00)

The principal investigator for this project is Mr. Charles Garten, Jr., from Oak Ridge National Laboratory, Oak Ridge, TN.

Background

The goal of this research was to investigate the effects of soil disturbance and land use/land cover (LU/LC) on various indicators of soil quality at Fort Benning, GA. Military activities at Fort Benning that result in soil disturbance include infantry, artillery, wheeled, and tracked vehicle training. We are conducting studies of soil organic matter (soil carbon) and soil nitrogen dynamics across a range of spatial scales at Fort Benning. These studies are concentrated on the effects of anthropogenic and natural disturbances on key measures of soil quality and the potential recovery of soil quality following disturbance. We currently do not know where thresholds to sustainability exist for properties and processes in different ecosystems. However, thresholds may exist such that once a threshold is crossed, the path to recovery of a degraded landscape may be qualitatively or quantitatively different than expected. Therefore, one objective of this research is to examine LU/LC differences in soil carbon and nitrogen as they represent a baseline for assessing changes in soil quality over time.

Research Plan

First, measurements have been made along a disturbance gradient that included: (1) reference sites, (2) light use, (3) moderate use, (4) heavy military use, and (5) remediated sites. With the exception of surface soil bulk density, measured soil properties at reference and light military use sites were similar. Relative to reference sites, greater surface soil bulk density, lower soil Carbon (C) concentrations, and less C and nitrogen (N) in particulate organic matter (POM) were found at moderate use, remediated, and heavy military use sites. Studies along a chronosequence indicated that POM-C stocks gradually increased with forest stand age. An analysis of soil C/N ratios, as well as soil C concentrations and stocks, indicated a recovery of soil quality at remediated sites.

Second, 41 sampling sites were classified into 1 of 5 major LU/LC categories: (1) deciduous forest, (2) mixed forest, (3) evergreen forest/plantation, (4) transitional land, and (5) barren land. There were significant LU/LC differences in soil bulk density. The greatest surface soil compaction was under the forested classes rather than under barren land. Extractable soil NO3-N was significantly greater under barren land than under forests. LU/LC differences in soil N availability were statistically significant and net N mineralization in soils from deciduous forests, mixed forests, and transitional lands was generally greater than that in soils from evergreen forests and barren land. Stocks of labile soil C (i.e., C in O-horizons plus POM-C corrected for refractory soil C) increased in the following order: barren < transitional land < forests. A small and highly variable part of total soil C was comprised of refractory soil C that had properties similar to charcoal. Stocks of organomineral soil C and total soil C were similar under forests and transitional land cover and were greater than those under barren land.

FY01 Progress

Because of a strong connection between soil organic matter and soil quality, models of soil C dynamics can be used to predict the recovery of soil quality when barren land is remediated by forest establishment. This research team (Oak Ridge National Laboratory [ORNL] Team 2) has begun to develop an approach to determining thresholds for soil quality based on simple mathematical models of soil carbon and nitrogen dynamics. The modeling incorporates the concept of desired future conditions based on targets for aboveground biomass and litterfall. Initial conditions are specified for different soil carbon pools as they indicate existing levels of soil quality. The model user specifies the rate of recovery and the extent of recovery to the desired future state. The model calculates belowground and aboveground biomass as well as the carbon inputs to soil. Soil carbon dynamics and stocks are calculated on the basis of carbon inputs and turnover times of various soil pools. Soil nitrogen stocks are calculated on the basis of soil carbon:nitrogen ratios. The model calculates potential excess nitrogen (i.e., available soil nitrogen) on the basis of predicted soil nitrogen stocks and measured potential net soil nitrogen mineralization rates (Figure 4).

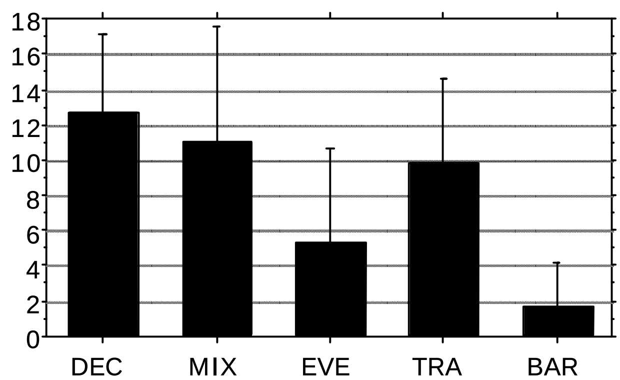


Figure 4. Land cover differences in soil N availability at Fort Benning.
DEC = deciduous forest, MIX = mixed forest, EVE = evergreen forest,
TRA = transitional land, BAR = barren land

Thresholds for soil quality are determined in this model on the basis of a comparison of system nitrogen requirements with potential excess nitrogen. If ecosystem nitrogen requirements exceed supplies, then the system is not sustainable. Simulations with the model indicate that there are various sets of conditions where soil carbon stocks become too low to achieve any recovery to a desired future state because:

1. the inputs to soil carbon can not sustain soil organic matter and thus soil quality progressively deteriorates, or
2. soil nitrogen availability falls below the nitrogen requirements of biomass and the desired future state can not be achieved.

The model is still under development as a result of research during FY01. Additional work with the model will incorporate data from prior soil sampling by this research team (ORNL Team 2) as well as data from the disturbance experiment planned at training compartment K11 (by the ORNL Team 1, investigating Indicators of Ecological Change). To the extent possible, ORNL Team 2 will collaborate with the Savannah River Ecology Laboratory (SREL, team investigating Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics) to develop a means for extrapolating laboratory measurements of net soil nitrogen mineralization potential to field estimates. The latter information would be particularly helpful in parameterizing and calibrating ORNL Team 2's model of soil carbon and nitrogen dynamics.

Publications

Garten, C.T., Jr. and T.L. Ashwood. "Effect of Military Training on Indicators of Soil Quality at Fort Benning, Georgia." In review.

Garten, C. T., Jr, and T. L. Ashwood. "Land Use/Land Cover Differences in Soil Carbon and Nitrogen Dynamics at Fort Benning, Georgia." In review.

Address for Full Report

https://www.denix.osd.mil/denix/Public/Library/SEMP/Research/ResearchProjects/RPFY00/disturbance.html

Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics (CS-1114E-00)

The principal investigator for this project is Dr. Beverly S. Collins from Savannah River Ecology Laboratory, Aiken, SC.

Background

Upland forests at Fort Benning must sustain the military mission and are managed to promote longleaf pine savanna habitat for the endangered red-cockaded woodpecker. Current land use for military training at Fort Benning ranges from light disturbance by foot and light vehicle traffic through heavy disturbance by repeated heavy vehicle traffic; site-specific management of uplands for the endangered red-cockaded woodpecker (*Picoides borealis*) entails thinning and burning to promote longleaf pine (*Pinus palustris*) savanna. At some intensity and frequency, disturbances due to land use may no longer be sustainable. That is, the ecosystem may lose nutrients, become dominated by early successional or invasive species, or fail to regenerate key species. Identification of thresholds beyond which ecosystems cannot sustain a disturbance can guide land management practices. The broad objective of this research is to evaluate the ecological effects of military training and forest management, to determine if there are thresholds beyond which upland ecosystems cannot sustain the combined effects of thinning, burning, and lighter or heavier military use. This project takes an experimental approach that compares vegetation dynamics and cycling of a key element, nitrogen, in 32 sites on clayey and sandy soil subjected to different forest management scenarios (2-yr or 4-yr burn cycle, thinned or unthinned) and heavier (open to tracked vehicles) or lighter (primarily foot traffic) military use.

Objective

The broad objective of the 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 traffic disturbances.

Approach

We hypothesize that the 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 take an experimental approach, in which we will compare 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 a 2-year cycle, burned on a 4-year cycle, thinned, unthinned) and to either heavier (open to vehicles) or lighter (primarily infantry) military use.

Research Plan

Field research sites were established during Summer, 2000. Surveys were conducted to determine baseline vegetation, environment (soil texture), and "disturbance" features due to past land use at each site. Results of these surveys show an interaction between land use and soil texture among sites, with a gradient of texture (percent clay) from clayey sites within light training areas, to sandy sites in heavier training areas. Road-like features, including active and remnant trails, roads, and vehicle tracks or trails, are the most frequent and abundant disturbance feature among sites (Figure 5).

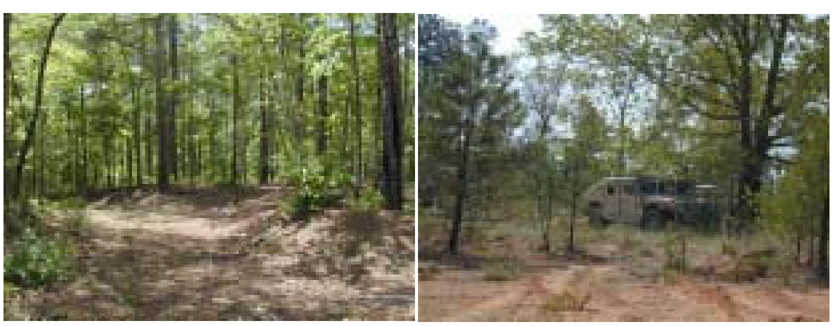


Figure 5. Examples of road-like disturbance features.

FY01 Progress

Clayey sites in heavier military use areas have a greater abundance of disturbance features. Species richness of ground layer vegetation is greater on clayey soil. Differences in ground layer and canopy composition among sites scale by disturbance intensity. Sweetgum sprouts/seedlings, broomsedge, and other grasses, and the forb *Heterotheca graminifolia* are the most common plants in the ground layer vegetation of all sites. Pines dominate the canopy of most sites; but four sites, each with less than 30 percent pine in the canopy, are considered hardwood sites. Overall, the 32 sites 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.

The field sites were burned prior to the 2000 growing season; half the sites (2-yr burn sites) will be winter-burned by Spring 2002; the other half (4-yr burn sites) will have burning delayed until Spring 2004. Research efforts during 2001 concentrated on installing equipment or establishing procedures to compare the environment, vegetation, and nitrogen dynamics among sites. Sensors have been installed to monitor soil and air temperature and soil moisture. Ground layer vegetation was re-surveyed to monitor year-to-year changes in the understory of each site. Naturally-established oak and pine seedlings were marked in each site. Additional seedlings of both types were planted in 4-yr burn sites, to monitor seedling survival and growth of individuals. Litter traps were installed to sample litterfall rates and carbon/nitrogen inputs among the sites. Samples were collected to determine the amounts of carbon and nitrogen in the forest floor, and to measure mineralization. Litter decomposition bags were arrayed in half the sites to monitor mass loss over time. Together, these procedures and equipment will allow us to monitor biogeochemical and vegetation changes in response to the burning treatments and land use among the sites.

In summary, results of the baseline surveys suggest plant species diversity and composition in the 32 research sites are influenced by soil texture and the intensity of land use. Early results suggest that soil texture influences soil moisture, and, potentially, nitrogen cycling. Initial samples show soil moisture increases with clay content and the potential for nitrogen loss in sandy sites with heavy military use. 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 practices differ with soil texture.

Publications

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.

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.

Presentations

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.

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.

Address for Full Report

https://www.denix.osd.mil/denix/Public/Library/SEMP/Research/ResearchProjects/RPFY00/thresholds.html

3 Ecosystem Characterization and Monitoring Initiative (ECMI)

The principal investigator for this initiative is Dr. David Price, Engineer Research and Development Center (ERDC) Environmental Laboratory, Vicksburg, MS.

Background

The SEMP ECMI supports SERDP's ecosystem management research investment, which focuses on ecological indicators, disturbance regimes and ecological thresholds, and adaptive management. The ECMI compliments this research through design, development, and demonstration of an ecological baseline monitoring program.

Objective

The objective of the ECMI is to characterize the long-term spatial and temporal dynamics of key ecosystem properties and processes — hydrologic flux, biological productivity, biogeochemical cycling, decomposition, and maintenance of biological diversity — in support of ecological research on sustainable management of DoD lands and installation objectives. The resulting monitoring concepts and protocols will have applications on subsequent SEMP research sites beyond Fort Benning.

Design Requirements and Specifications

There are four major principles upon which the ECMI is designed, beyond the parameters set by SEMP's major research themes. These are:

1. Consider elements of ecosystem management.
2. Incorporate monitoring within an ecosystem management protocol.

3. Link science, land management, and data/information requirements.
4. Incorporate adaptation into the monitoring system.

Within the SEMP, the ECMI was established to design, develop, and demonstrate an ecosystem characterization and monitoring concept appropriate for military installations. The ECMI products must support multiple SEMP objectives and be beneficial to installation land managers. The ECMI baseline monitoring concepts are intended to have broad applicability and may serve as a model for other installations.

Approach

A science-based approach to ecosystem management can be defined as "management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function" (Christensen, N.L. et al. 1996 "The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management." *Ecological Applications* 6(3):665-691.). Key to this and other definitions is the concept of sustainability, i.e., sustaining ecosystem composition, structure, and function to meet the needs (social, economic, and environmental) of present and future generations. Balancing these competing needs to achieve the goal of sustainability is one of the essential challenges of ecosystem management (e.g., Kaufmann, M.R., R.T. Graham, D.A. Boyce, Jr., W.H. Moir, L. Perry, R.T. Reynolds, R.L. Bassett, P. Mehlhop, C.B. Edminster, W.M. Block, and P.S. Corn. 1994. *An Ecological Basis for Ecosystem Management*. General Technical Report RM-246. Fort Collins, CO, U.S. Department of Agriculture, Forestry Service, Rocky Mountain Forest and Range Experiment Station.). This goal is applicable across Federal land management agencies, including the DoD.

The approach has been to complete the design and implementation phase (Phase I, 1999-2001) as described in "Long-Term Monitoring Program, Fort Benning, GA (see M. R. Kress, 2001, *Long-Term Monitoring Program, Fort Benning, GA: Ecosystem Characterization and Monitoring Initiative, Version 2.1*. ERDC/EL TR-01-15). Some adjustments have been made to the original design; in particular to the surface water component because of the extended drought that was experienced in 2000 in the Fort Benning region. The ECMI product is now ready to enter the modification phase (Phase II, 2002-2005).

Summary of Monitoring Activities and Results for FY01

Meteorology

Meteorology parameters have been monitored at 10 sites since FY99. The data and summary statistics from 1999 through July 2001 are on the SEMP data repository. The ECMI team worked with personnel in the land management branch at Fort Benning to provide them with the software and training necessary to enable them to download the meteorology data directly, twice a day for their in-house needs.

Surface Water

The surface water component was redesigned and reimplemented during Summer 2001 to accommodate the current drought trend and subsequent low stream flows. We are now monitoring water flow, level, and temperature only with automated stations. Water quality parameters are being monitored at six sites via manual sampling on a bi-weekly basis. When the precipitation pattern trends toward a wetter period and stream flows are more robust, we will consider deployment of fully automated systems.

Groundwater

The groundwater monitoring system was fully implemented at four sites during Spring and Summer 2001. Groundwater data are being collected hourly and entered onto the repository monthly.

Aquatic

The aquatic monitoring procedure was fully implemented during 2000 and the first resampling was completed in June 2001. Initial characterization and monitoring results will be placed on the repository in the first quarter (1QTR)of FY02. A summary of the preliminary results is described below under findings and conclusions.

Land Cover

A land cover map (using 1999 LandSAT enhanced Thematic Mapper [ETM] data) with accuracy assessment was developed during FY01 and placed on the repository. Pattern analysis of land cover, using fragmentation statistical procedures, was completed during 4QTR FY01. These data will be placed on the repository during 1QTR FY02. The team is also in the process of working with

Virginia Dale and Lisa Olsen of ORNL to compare procedures and lessons learned in developing land cover maps of Fort Benning. They are developing a tool and procedure to develop land cover maps using a series of imagery, photos, and other land cover information from 1999 and previous dates (e.g., a historical time series) and the ECMI team will be developing a series of land cover maps with imagery from 1999 into the future.

Erosion and Deposition

The erosion/deposition component was fully implemented during FY01 and the first resampling occurred in early October 2001. The characterization data has been placed on the repository and the resampling results will be placed on the repository during 1QTR FY02. The ECMI team is working with Lawson Smith of the team working on Development of Ecological Indicators for Land Management to ensure that the ECMI method (watershed- and installation-scale monitoring) supports their research effort to characterize specific small-scale erosion processes. The idea is to link the two efforts so that the results of their research can provide a more complete picture of the small to large-scale erosion processes occurring on Fort Benning.

Woody Productivity

The woody productivity component was implemented during FY01 in cooperation with the Fort Benning Land Management Branch (LMB) personnel. Woody productivity is being derived using data from the Forest Inventory procedure used by Fort Benning personnel. This procedure will provide watershed-level and installation-wide estimates of woody productivity and will support both the installation and research group needs.

Important Findings and Conclusions for FY01

Meteorology

The meteorology stations have performed very well since Summer 1999. Aside from recommended routine maintenance, they require very little attention. A technical report is currently being prepared that describes the meteorology stations, the hydrology stations, and the groundwater wells. The specifications for each and summarized data will be included. The report should be published during FY02.

Surface Water

The automated hydrological stations have been maintenance intensive. Aside from problems caused by the drought and low stream flows, sedimentation in and around the sensor packages has caused problems and the dissolved oxygen (DO) sensor did not perform to specifications. We are working with vendors to obtain more reliable DO sensors for the future. Currently, only temperature, flow, and level can be reliably monitored with automated stations; all water quality data are collected manually every 2 weeks.

Ground Water

Five wells were drilled during FY01 to monitor the shallow alluvial aquifers. The Bonham Creek site was dry with no indication of water down to 55 feet. The well site was within 100 feet of the main streambed. It is not known if this is a result of the current drought.

Aquatic

The streams selected for monitoring are; Little Pine Knot, Wolf Creek, Randall Creek, Sally Branch, Bonham Creek, Uchee Creek, Cox Creek, Upatoi Creek, and Oswichee Creek. The range in habitat units at the 9 sites surveyed was from 101 to 162 units. Overall, the average score given to pool variability and pool substratum conditions (1.9 and 2.3, respectively) for all sites combined was extremely low (Figure 6). The values for channel sinuosity and presence of cover for epiphytic invertebrates were both slightly less than 10. The average value for all other habitat variables was higher than 15; the average value of variables that rated terrestrial vegetation and bank stability was 19 to 20.

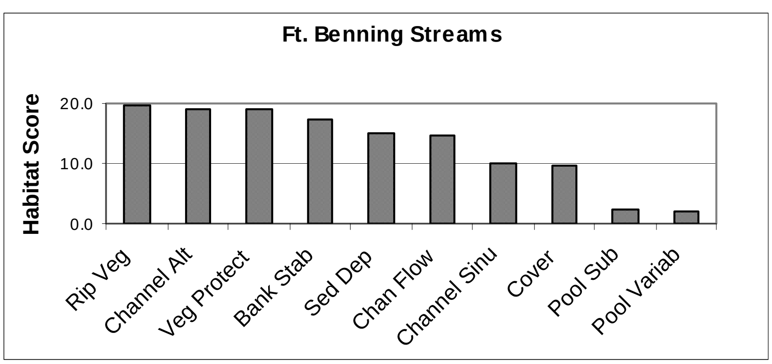


Figure 6. Habitat scores by variable; across all sites.

With respect to water quality, all sites were negatively affected by low pH and low specific conductance. Aquatic insects, crustaceans, and mollusks all have exoskeletons that rely on calcium and magnesium, associated mainly with carbonate ions, for hardness. Although dissolved oxygen, water temperature, and water clarity were all optimal for aquatic life, the low pH, which is always associated with reduced levels of calcium and carbonates is sub-optimal for aquatic life.

Land Cover

All land cover maps produced using an imagery classification process result in a generalization of the real land cover types. The level of agreement or disagreement between the LandSAT classification and the reference data indicated that the overall accuracy of the classification was 69.5 percent. The major forest-stand classes, hardwood and evergreen, displayed the highest level of agreement with the reference data, with user accuracies of 85 and 83 percent, respectively. Accuracies for evergreen planted, herbaceous, bare ground, and scrub/shrub were 70, 61, 61, and 5 percent, respectively. Data based on a more current monitoring of the LCTA plots or additional ground truth data collection has been planned to improve the accuracy assessment for future classification.

Land Cover Pattern Analysis

Figure 7 represents the initial findings of an analysis of landscape pattern metrics using the FRAGSTATS software. Metrics based on core area represent both landscape composition and landscape configuration and are usually thought of as being a better predictor of habitat quality than metrics based on patch size alone. Further work is required to complete specific landscape pattern analyses.

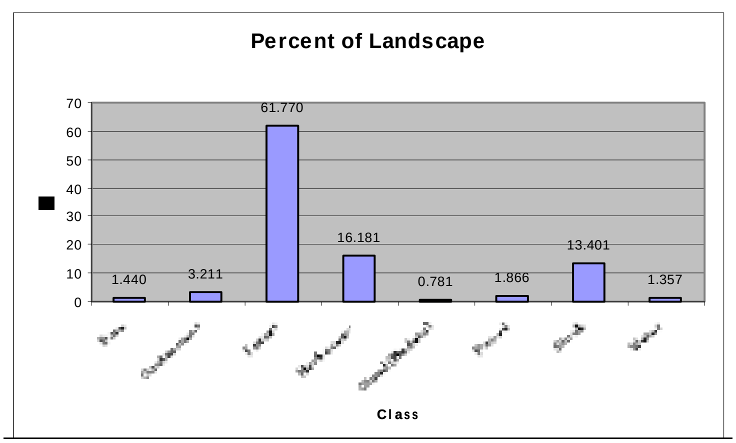


Figure 7. Land cover as percent of landscape.

Erosion and Deposition

Currently, there are 26 erosion/deposition monitoring sites (20 X 20 meters) located on Fort Benning via a restricted random process. Ten sites are located in Sally Branch and 10 are located in Bonham Creek watersheds. An additional six sites are co-located with existing Land Condition Trend Analysis (LCTA) sites to represent the installation scale. These sites were characterized by micro-topographic surveys during Spring 2001 and were resurveyed (monitored) in late September and early October of 2001. They will be monitored every year thereafter.

Woody Productivity

Fort Benning Forestry staff are scheduled to begin implementing the revised Forest Inventory protocol in the Summer of 2002. In cooperation with the ECMI team, the staff have agreed to implement the revised inventory protocol at the species level for at least the major woody species. This is a direct effort to design the ECMI to meet both research and installation needs, be easily incorporated into the installations business process, and provide monitoring information at multiple spatial scales.

Publications

Bourne, S., and M.R. Graves. 2001. *Classification of Land-Cover Types for the Fort Benning Ecoregion Using Enhanced Thematic Mapper Data*. ERDC/EL TN-ECMI-01-01, U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS.

Graves, M. R. 2001. *Watershed Boundaries and Relationship Between Stream Order and Watershed Morphology at Fort Benning, GA*. ERDC/EL TR-01-23,ERDC, Vicksburg, MS.

Hahn, D. C. 2001. *Ground Control Survey at Fort Benning, GA*. ERDC/EL TN-ECMI-01-02, ERDC, Vicksburg, MS.

Hahn, D. C., M. R. Graves, and D. L. Price. 2001. *S-Tracker Survey of Sites for Long-Term Erosion/Deposition Monitoring.* ERDC/EL TR-01-18, ERDC, Vicksburg, MS.

Kress, M. R. 2001. *Long-Term Monitoring Program, Fort Benning, GA; Ecosystem Characterization and Monitoring Initiative, Version 2.1*. ERDC/EL TR-01-15, ERDC, Vicksburg, MS.

Address for Full Report

https://www.denix.osd.mil/denix/Public/Library/SEMP/Monitoring/monitoring.html

4 SEMP Data Repository

The principal investigator on this project is Dr. Rose Kress, ERDC Environmental Laboratory, Vicksburg, MS.

Repository Conceptual Design

The conceptual design for the SEMP repository is simple and functional. It is designed specifically to provide data access and exchange among the SEMP study partners and serve as a stable, long-term data archive mechanism to protect the SERDP investment. The approach was to build a simple, functional, well-documented repository that has low long-term maintenance requirements. The SEMP repository is designed to operate as a stand-alone archive and to be directly or remotely accessed by other more complicated systems and data archives as a “node” or “object.” It is a file-based repository, organized using a directory structure based on the Spatial Data Standards for Facilities, Infrastructure and Environment (SDS/FIE) entity set.

Several important design decisions guided the development of the SEMP/ECMI repository. These decisions were made early in the program to ensure early availability of the repository and to remain within the projected budget. The most important of these design considerations were: (1) the SEMP repository does not function as a graphic map product server; (2) the SEMP repository does not function as an enterprise-level geospatial data warehouse for operational use at Fort Benning; and (3) the SEMP repository is file-based rather than Relational Database Management System (RDBMS)-based.

The four main design components of the ECMI data repository are Data Storage, The Repository Index/Data Catalog, The User-Web Interface, and the User Profile Information.

Index/Data Catalog Component

The Index component is the key to maintaining and accessing the data repository. Each file submitted to the repository is described and indexed using a standard procedure. The Index component provides the mechanism for tracking the name, location, and description of each file, which allows for efficient searching of the repository's contents. All repository searches are executed using Index records. Physically, the Index is a MS Access database containing 23 fields. Each file in the repository has one unique Index record. Most Index items can be used as search fields. The repository is not searchable by geographic co-ordinates.

User Interface Component

SEMP Data Repository users interact with the repository by using a Web browser. Either Microsoft Internet Explorer or Netscape Navigator 4.75 may be used.

User Profile Component

Data submissions and retrievals are password protected. Each user issued a password must provide standard profile information for system administration purposes.

Repository Contents

The repository contains important baseline geospatial data for Fort Benning and the surrounding region as well as the initial data collected under the ECMI. Additional data collected under the ECMI have been added, as has the biogeochemical soil data set collected by The University of Florida at Gainesville. Figure 8 shows the SEMP Repository Data Catalog. Sets containing data are shadowed in 3-D.

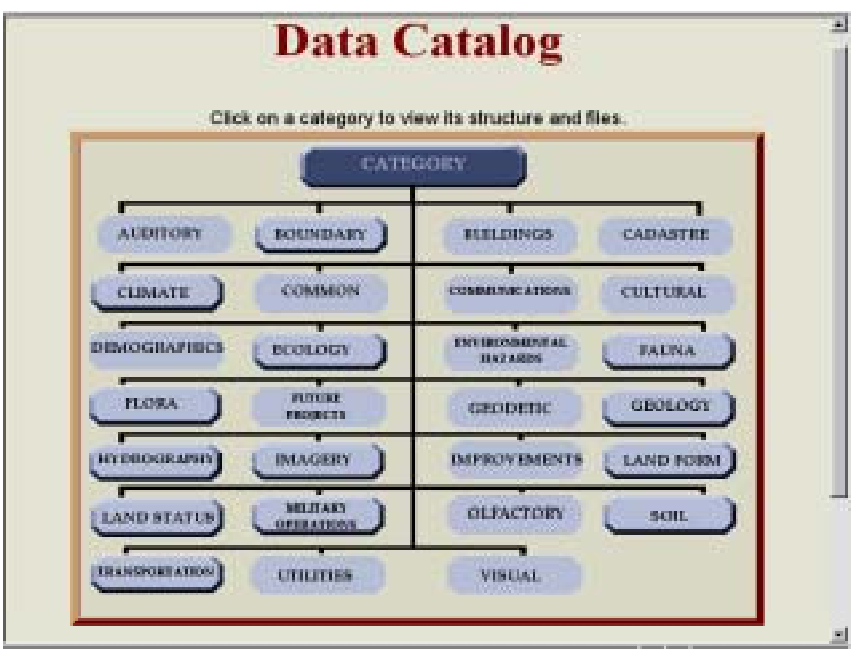


Figure 8. SEMP Data Catalog

FY01 Progress

Repository Modifications

Recent modifications to the repository include:

1. Search pages were simplified resulting in more logically organized data results.
2. Graphical aids were added to help users more easily locate desired data.
3. Overall design made clearer, background was simplified, menu choices were added, and user "how to" explanations have been put into place.

Repository Data

To date, ECMI and the University of Florida, Gainesville, have contributed data from the SEMP Research Community. The following data are included as of the last quarter of FY01:

1. ECMI Data
   a. Meteorological Data: There are 10 meteorological stations located throughout the Fort Benning Military Installation
      i. Graphical images of each station are is linked to the data allowing the user to select a particular station from the graphic to view or download the data.
      ii. Monthly weather data are uploaded to the site.
      iii. Monthly summary sheets were added.

   b. Hydrological Data: There are currently 6 locations where hydrological data are collected.
      i. 4 Groundwater well locations.
      ii. 6 Surface Water monitoring locations.
      iii. 6 Water Quality Sites.
      6 Stream Cross-Section Profiles were measured in Aug 01.

   c. Erosion/Deposition Data:
      i. Geospatial data layers developed for each Erosion/Deposition site:
         1. Survey Points
         2. Contour Lines
         3. TIN Surface Model
      ii Graphics in PDF format were generated showing the various data layers.
         Survey Points
         1. Contour Lines (Interval 0.05 Meters)
         2. Contour Lines shaded by elevation (Interval 0.05 Meters)

3. TIN Surface Model shaded by elevation
4. 5-Meter Profile Lines (See Figure 6.)

d. LandSat 7 Enhanced Thematic Mapper Satellite Data:
   i. Two LandSat 7 images were uploaded
   ii. Landcover Classifications were generated and uploaded to Repository.

2. The University of Florida-Gainesville team successfully completed the first data submission from a research project team to the SEMP Data Repository.

5 SEMP Management Activities

The Principal Investigator responsible for SEMP actions grouped within this section is Dr. Harold Balbach, ERDC/CERL, Champaign, IL, who is the overall SEMP project manager.

FY01 Progress

Meetings/Workshops

Research Coordination Meeting in Columbus, GA, 14-16 November 2000

SEMP researchers and the Fort Benning Directorate of Public Works, Environmental Management Division, held a Research Coordination Meeting 14 through 16 November 2000, in Columbus, GA. The objectives of this meeting were to better coordinate the research among the different research teams, provide information on SEMP to non-SEMP and non-Army persons to promote possible cooperation and to develop recommendations for improving SEMP.

During the morning of the first day, the five research teams gave detailed presentations about their research projects. In the afternoon John Brent gave a Fort Benning perspective and then invited non-SEMP participants to talk about what their organizations are doing in and around Fort Benning. These organizations included: Columbus State University, Army Environmental Policy Institute, The Nature Conservancy, Columbus Water Works, and the Georgia Institute of Technology. Conclusions from the day include the following: the availability of good data supports the military mission, need to solidify how Fort Benning will use these data, how will the climatic extreme experienced in 2000 affect long-term planning, there are relevant data acquisition activities outside of SEMP, different persons and groups on and off post define success in very different terms, it is important to make multiple measure of some elements, and training intensity must be described more quantitatively than low, medium, and high.

The second day began with Dr. Rose Kress detailing the work that has been done on the data repository. John Brent talked about Fort Benning's needs regarding data availability and application, and discussion was raised on what some of the SERDP and Army concerns might be regarding data sharing. In the afternoon

Pete Swiderek gave an overview on the interactions between natural resource management and the Army training mission, and Hugh Westbury identified his roles and responsibilities as Host Site Coordinator. Hugh also discussed what he expects of the different research teams, when scheduling field studies. Conclusions from this day were as follows: the data repository has several access and submission issues to be resolved (within SEMP), a study site map should be posted on the website, many instrumented sites are vulnerable to training and land management activities, quantification of level of disturbance is necessary, some data gaps are identified (training intensity distribution maps, more historic land use maps desired), plans need to reflect the "desired future conditions" stated in the Integrated Natural Resources Management Plan (INRMP), need to work even more closely with site coordinator, many field study sites need (minor) NEPA documentation per Fort Benning regulations, Fort Benning requests real-time access to certain ECMI data for fire hazard and other purposes, HSC will require additional site metadata to describe nature of the instruments or other sensitive features, proactive measures are needed to protect equipment, and realizing that several plots will be "treated" or "restored" during the studies; all teams should be made aware of added opportunities for "calibration."

The meeting was concluded on the third day with discussion of those things that are going well within SEMP. Some of these are as follows: very rich field data collections, existing GIS data well-received, data repository was initiated and is working, field support/coordination is indispensable, collaboration has been good; a team of teams is developing, safety record has been perfect, minimal conflicts with military mission, communications among SEMP teams and with Fort Benning have been good, and full funding for FY01 is anticipated.

SEMP TAC Meeting in Arlington, VA, 30 November thru 1 December 2000

The SEMP Technical Advisory Committee met in two half-day sessions held on 30 November and 1 December 2000, in Arlington, VA in conjunction with the SERDP/ESTCP Symposium. During the first day of this meeting, Dr. Harold Balbach, Acting SEMP Project Manager, brought the TAC members up to date on the current SEMP activities. Previous TAC, SAB, and TTAWG action items were reviewed, and their status updated. A list of new or continuing action items was opened, to be added to as the meeting progressed. Dr. Beverly Collins, Savannah River Ecology Laboratory, and Mr. Chuck Garten, Oak Ridge National Laboratory, the lead PIs for the two FY00 research teams, gave detailed briefings on the objectives of their work, as well as their progress in the first year. Dr. David Price, ERDC/EL, gave a status report on the monitoring program and progress of the data repository.

During the second day, Dr. Balbach summarized the purpose, content, and outcomes of the Research Coordination Meeting, that was held in Columbus, GA on 14 through 16 November 2000. This meeting involved more than 40 persons representing 21 interested organizations. The closing sessions, restricted to SEMP research teams and Fort Benning personnel, developed a set of proposed actions to improve the quality of research coordination among the SEMP groups. This will help to guide the SEMP management planning for FY01 and beyond. Dr. John Hall, of The Nature Conservancy, reviewed the approach taken within the SEMP "framework" document to establish a linkage between Fort Benning's natural resources management philosophy and desired management trajectory, as expressed in its draft Integrated Natural Resources Management Plan, and SEMP-directed research meant to inform the management process and its technical basis. This will be distributed separately to the TAC, and will also form a chapter of the SEMP Technical Report now in final preparation. Dr. Beverly Collins described the "Along the Fall Line" ecosystem management workshop, which is to be held at SREL in March 2001. Pete Swiderek gave a brief perspective from the host site about progress and issues regarding SEMP, as well as what they were looking for in the future. In closing, Teresa Aden summarized the action items developed from the meeting.

Fall Line Workshop in Aiken, SC, 6-7 March 2001

The Savannah River Ecology Laboratory hosted a technical transfer workshop 6 and 7 March 2001. There were 47 invited participants, who included representatives of the Army, Air Force, Marine Corps, U.S. Forest Service, three different DOE laboratories, and the U.S. Environmental Protection Agency. Following presentations on several local and regional monitoring and ecosystem management partnerships, 22 different possible topics were raised for discussion. Of these, four were selected for half-hour, rotating, facilitated sessions. They were: (1) Regional Strategies, Goals, and Clustering, (2) Issues with the Long Leaf Pine emphasis, (3) SEMP, Possible Outcomes, Incomes, and Extensions, and (4) The Value of Monitoring Programs. The general consensus was that regional cooperative efforts related to ecosystem management research and experimentation was a potentially valuable initiative. Follow-up activities are in the planning stages. This workshop was documented in *Proceedings of the* "Partners Along the Fall Line*: Sandhills Ecology and Ecosystem Management Workshop* , ERDC/CERL Special Report SR-02-2, March 2002. It is available through: http://www.cecer.army.mil

SEMP TAC Meeting in Arlington, VA, 18-19 July 2001

The SEMP Technical Advisory Committee (TAC) met at the SERDP Program Office site in Arlington, Virginia on 18 and 19 July 2001. This meeting included two new TAC members: George Carellas, Director of the Southeastern Regional Coordination Office, U.S. Army Environmental Center, Atlanta, Georgia; and Neal Burns, an ecologist/spatial analyst with U.S. EPA Region IV, Atlanta, Georgia. The TAC also desires a new member from the Fish and Wildlife Service, with a strong technical background related to ecosystem management.

David Price and Wade West provided a briefing on the current monitoring activities at Fort Benning. This briefing showed that great strides have been made in fulfilling the Phase I of the ECMI monitoring plan.

Bill Goran was tasked as TAC Coordinator, to (1) manage the Action Item list, and provide it to all meeting participants shortly after each meeting, with a suspense for comments, (2) provide approved Action Items to all TAC members and the SERDP Program Office, as quickly as possible after the meeting, and (3) review the status of these action items at subsequent TAC meetings, to ensure that all actions have been addressed and inform TAC members of action item resolutions.

Progress in Meeting SEMP Goals

Many specific milestones were established and met within the research teams during FY01. Enumeration of the milestones accomplished by each team may be found in the annual reports for each project at the SEMP website (www.denix.osd.mil/SEMP). The goals referred to here are much more general, and were personally formulated by the present SEMP project director at the time he assumed responsibility in September 2000. In summary, and with some perspective developed over the intervening year, they may be stated as follows: (1) Encourage the SEMP research teams to work together, rather than separately, (2) Develop a higher level of liaison between SEMP and the Fort Benning elements with which SEMP was expected to work, (3) Develop recognition that the SEMP Data Repository is a separate effort from the ECMI, and that the individual research teams have a relationship to it, (4) Initiate examination of the need for a common scale upon which to place the (now) hundreds of SEMP study sites (beyond “low, medium, and high”). Others could have been formulated, but these were developed and kept for internal focus.

Working Together

The seven research teams (five based on SONs plus ECMI and Repository) met in a Research Coordination Meeting (RCM) for the specific purpose of presenting their project information to each other, and providing almost the first opportunity for researchers to see and hear what the other teams were doing and proposing to do. Another RCM was scheduled for November 2001, and one or more such RCMs will be a part of the SEMP cycle for the foreseeable future. As one specific example of cooperative work, researchers from four different teams initiated joint preparation of a presentation to be given at the November 2001 SERDP/ESTCP conference. At the end of FY01, the SEMP research teams had developed a much better relationship and understanding of mutual goals.

Fort Benning Liaison

Led largely by the actions of the new Host Site Coordinator (HSC), a systematic structure was prepared whereby all research teams provided both annual and quarterly field access requests on the same schedule the military users of Fort Benning are required to meet. The HSC, using the improved structure, was able to schedule 1,700 requests for field access by SEMP researchers. Five hundred of these required that cooperative shared-use agreements be reached with the Army unit training officers. SEMP researchers performed these 1000+ field study events, and completed 20,000 miles of on-post vehicle operation without an accident or incident, and with no reports of interference with the military mission. Liaison was also provided for non-SEMP research ,including SERDP-sponsored projects. This unique capacity to coordinate field research provides Fort Benning with the capability to host advanced land management program initiatives. Regular briefings were established with the Environmental Management Division (EMD), and special presentations were made to EMD staff and managers on the nature of SEMP and its potential for help to the EMD mission. The SEMP project director met regularly with the Chief of the EMD to discuss concerns and initiatives. At the end of FY01, SEMP coordination with all elements at Fort Benning had been significantly improved.

Data Repository Identity

A perceived issue exists relating to the uniqueness of the Data Repository. Early on in SEMP, what is now clearly an error was made in regularly referring to the two efforts in one phrase, as in “ECMI and Data Repository.” It is understandable that the research teams may have perceived that the two were closely aligned, and separate from the five SON-based projects. The ECMI effort was the first to generate data streams suitable for inclusion in the data repository, so all the data included in the repository were from the ECMI program. This was not the intent of the efforts. Data were and are supposed to be entered in the repository from **all** the research teams; a special effort was made in the Summer of 2001 to test the data entry process as used by a research team. The test was successful, and a follow-on FY02 goal will be to get data from all teams as a regular procedure. In addition, SEMP reports and execution plan documents now refer to the two efforts as separate entities: the "ECMI" and the "Data Repository." We believe it is now clear that they are two efforts, with interrelated, but distinct goals.

Develop a Common Scale for High/Medium/Low Levels of Disturbance

A major concern that arose from both the November Research Coordination Meeting and the December TAC meeting was the clear need to develop a uniform scale for ranking the degree of disturbance at each study site. This is necessary so that different sites maintained by different teams may more uniformly report the degree of disturbance present. In many cases, this was the first time that a team viewed the sites being used by the other teams, and became aware of the disturbance level assigned. Not only are the existing categories (High, Moderate, and Low) very broad, it became clear that they are not uniformly applied by the different teams. One team's "Moderate" might be very much like another's "High". A proposed standardized technique was prepared by a team of SEMP and ERDC researchers between January and April 2001. It was sent to the research teams on 18 May 2001 for testing and other responses. It proved time-consuming to apply, and probably inapplicable to the many ephemeral sites where only a small soil sample had been taken. It *was* more applicable to the larger, fixed sites where continuous studies were planned. The subsequent discussions among the principal investigators and the TAC suggest that a more sophisticated multivariable approach will need to be developed. Among the characteristics that appear to be relevant are surface vegetation cover, soil compaction, and/or soil bulk density; characteristics of the soil microflora; and some application of a Raunkier-based life form system. This will be further advanced in FY02.

Other Accomplishments

Publications

Balbach, Harold E., William D. Goran, Teresa Aden, David L. Price, M. Rose Kress, William F. DeBusk, Anthony J. Krzysik, Virginia H. Dale, Chuck Garten, and Beverly Collins, *Strategic Environmental Research and Development Pro-*

gram (SERDP) Ecosystem Management Project (SEMP) FY00 Annual Report, ERDC SR-01-3, September 2001.

SEMP Information Systems

A more detailed version of the FY01 annual reports for each of these areas has been posted at the SEMP website, http://www.denix.osd.mil/SEMP. You can also find quarterly reports, project fact sheets, and the content of periodic briefings and presentations as well as reduced-sized versions of posters, which were displayed at scientific meetings and conferences.

CERL Distribution

Chief of Engineers
ATTN: CEHEC-IM-LH (2)

Engineer Research and Development Center (Libraries)
ATTN: ERDC, Vicksburg, MS
ATTN: Cold Regions Research, Hanover, NH
ATTN: Topographic Engineering Center, Alexandria, VA

SERDP (3)

SEMP Technical Advisory Committee (19)

Defense Tech Info Center 22304
ATTN: DTIC-O

9
6/00

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY) 03-2002	**2. REPORT TYPE** Final	**3. DATES COVERED (From - To)**

4. TITLE AND SUBTITLE
Strategic Environmental Reserch and Development Program (SERDP) Ecosystem Management Project (SEMP) FY01 Annual Report

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Harold E. Balbach, William D. Goran, Teresa Aden, David L. Price, M. Rose Kress, William F. Debusk, Anthony J. Krzysik, Virgina H. Dale, Charles Garten, Jr., and Beverly Collins

5d. PROJECT NUMBER
SERDP

5e. TASK NUMBER
CS-1114

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC SR-02-2

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Strategic Environmental Research and
Development Program
901 N. Stuart St., Suite 303
Arlington, VA 22203-1853

10. SPONSOR/MONITOR'S ACRONYM(S)
Program Manager

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

14. ABSTRACT

Abstract

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Harold E. Balbach
Unclassified	Unclassified	Unclassified	SAR	48	19b. TELEPHONE NUMBER (include area code) (217) 373-6785

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18