SERDP Ecosystem Management Project's

Integration Plan

Virginia Dale, Amy Wolfe, Latha Baskaran, & Taryn Arthur
Environmental Sciences Division, Oak Ridge National Laboratory

Aaron Peacock
Center for Biomarker Analysis, The University of Tennessee

March 2005

Focus of integration is on:

- Identifying indicators of ecological impacts of prior resource use or management
- Data obtained by SEMP researchers
- Determining how these indicators can be an integral part of the monitoring and management program of Fort Benning
- Developing a procedure for integration (so the approach could be adopted by other DoD installations)

Many “disturbances” affect Fort Benning

- At Fort Benning
  - Military training and testing
  - Timber harvest and thinning
  - Natural and anthropogenic fires
  - Insect outbreaks
  - Spread of introduced, invasive species
- External to Fort Benning
  - Land-use change
  - Climate change
    - Warming and less precipitation
    - Changes to disturbance regimes (ice storms, hurricanes, fire, etc.)

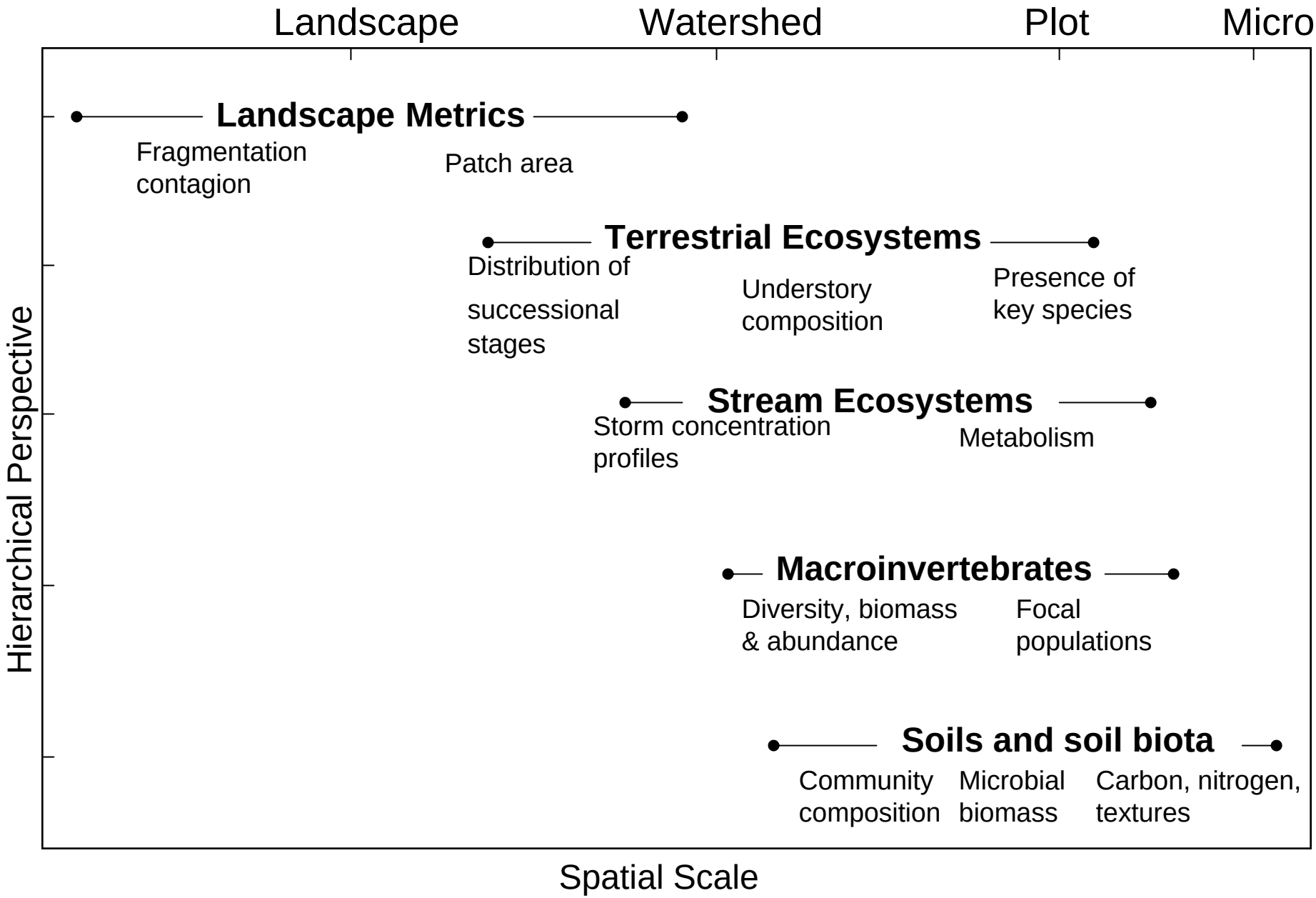
The Army identified priority conservation requirements

1. Reducing impacts of threatened & endangered species (TES) on military training, testing, and other operations
2. Baseline TES inventories and monitoring
3. Land capability/characterization
4. Land rehabilitation
5. Non-native invasive species control for Army installations & operations

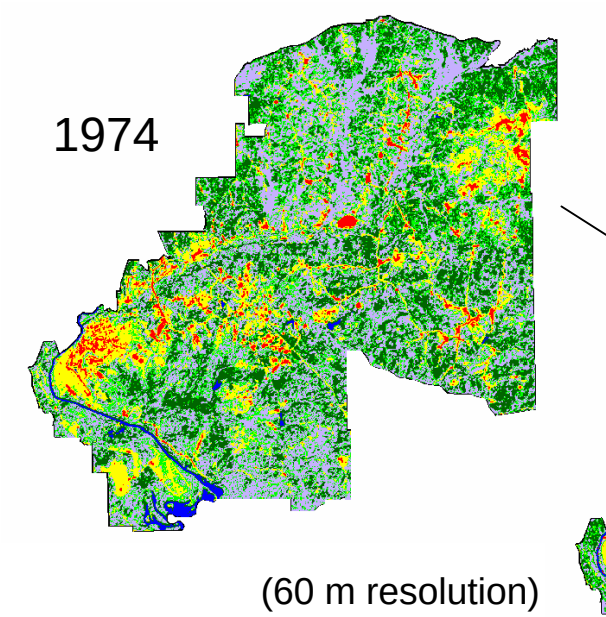
Monitoring disturbances and their effects is problematic

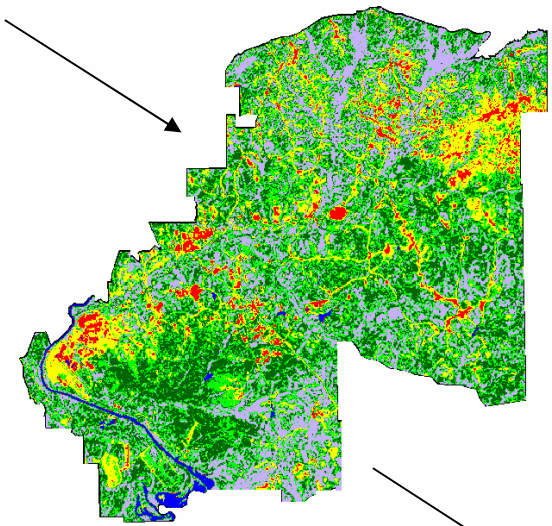
- Projected training is recorded only at the compartment level
- Army's LCTA (land condition trend analysis)
  - The few random points miss many impacts
  - Key indicators are missing
- Categorizing by "high, medium, low" has caused confusion

Hypothesis: Suite of ecological indicators



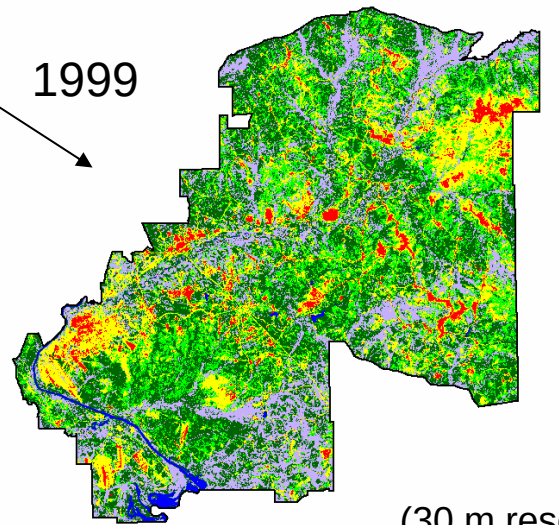
Landscape Indicators





Ft. Benning
Land Cover Classification Key

- Bare ground or developed areas such as buildings. (highly reflective surfaces)
- Non-forest or cleared areas. (ground cover present, includes lawns)
- Deciduous forest (dense)
- Mixed forest (areas of deciduous and pine, widely spaced or sparse forest cover and transitional areas between forest and non-forest)
- Pine forest (dense)
- Water



Landscape Metrics

- Fragmentation
- Habitat extent
- Patch size

Suggested approach for catchment indicators

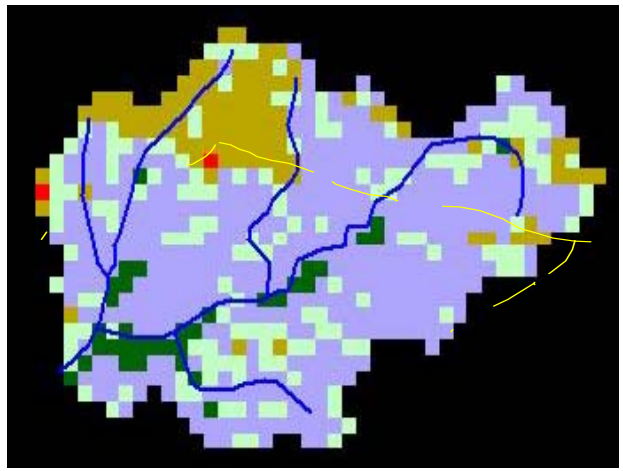
Quantify landscape disturbance – GIS/Landsat imagery

Disturbance Intensity (DI):

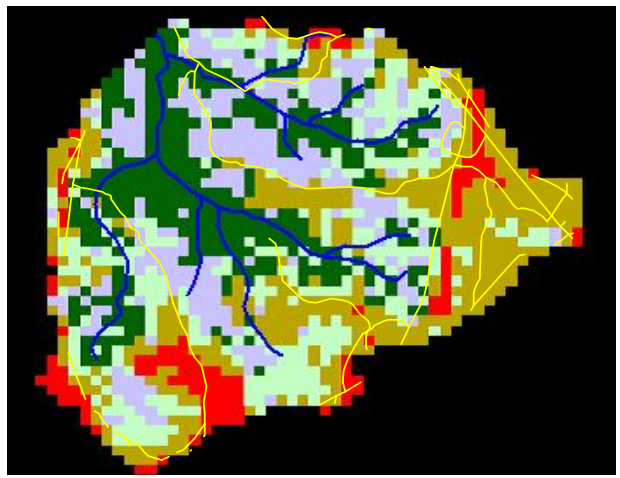
% watershed that is

- bare ground on slopes > 3%
- under roads

LOW



HIGH

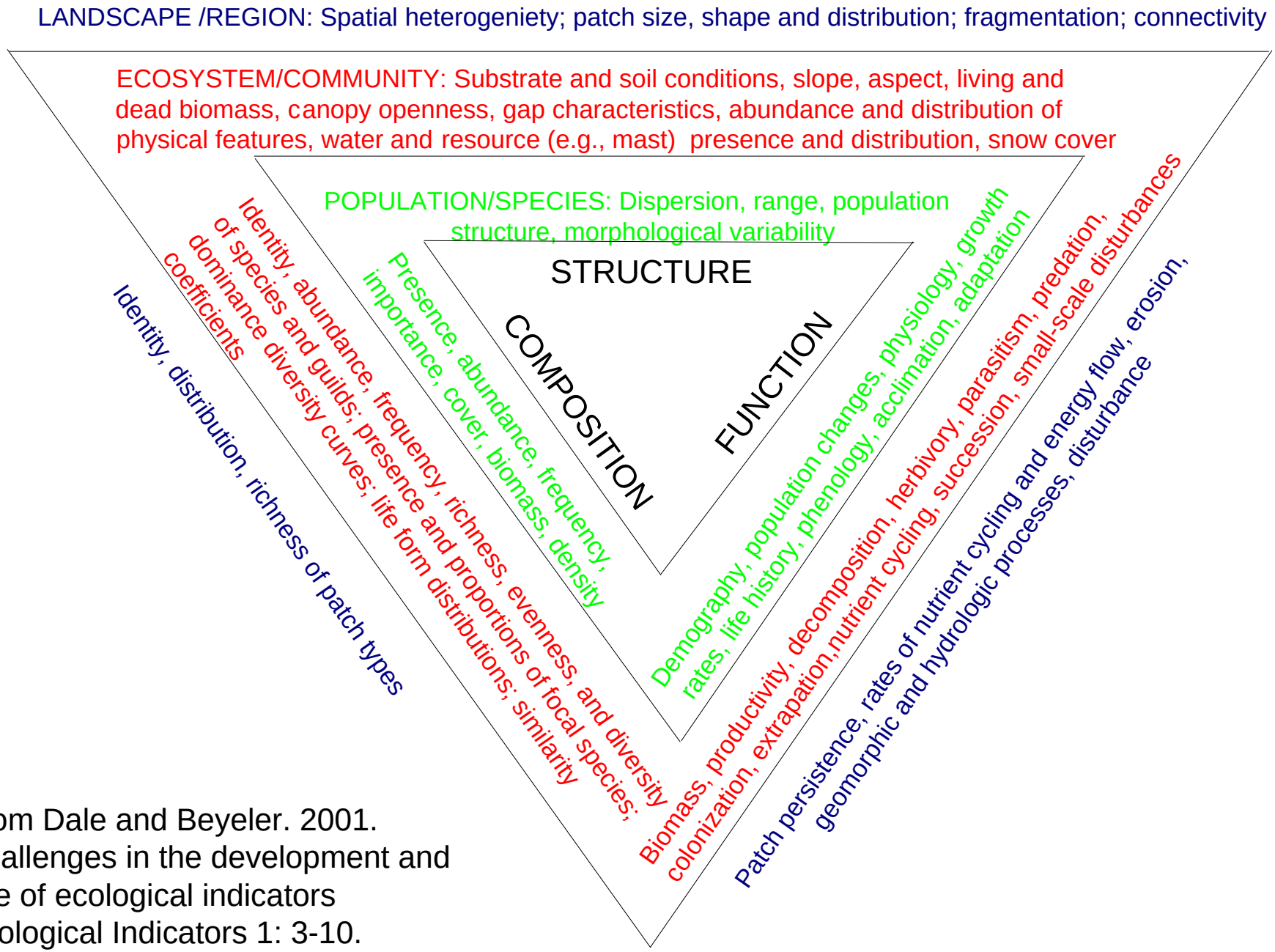


July 1999

- Bare Ground/Urban
- Transitional/Sparse Veg
- Deciduous
- Mixed Forest
- Pine Forest
- Water

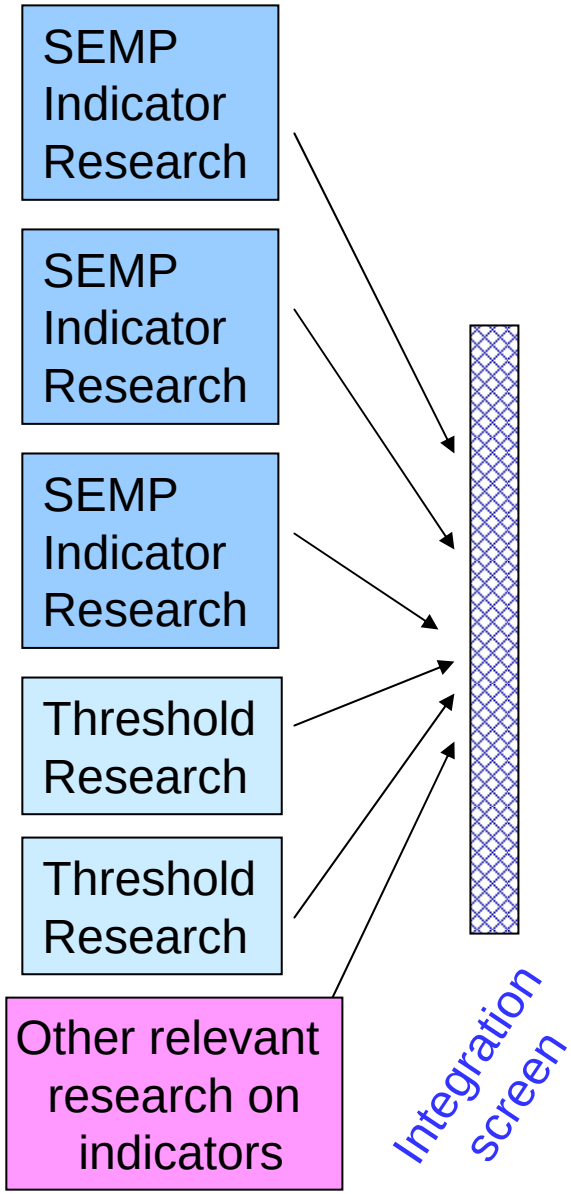
Focus on plot/point level studies

- Reference
- Ground infantry
- Recent tracked vehicle use
- Restored to plantation



From Dale and Beyeler. 2001. Challenges in the development and use of ecological indicators Ecological Indicators 1: 3-10.

Steps to integration



1. Determine final criteria to be used for indicator selection
2. Determine discrete land-management categories
3. Assess ability of indicators to determine differences among land-management categories

Step 1: Determine final criteria to be used for indicator selection

- Started with existing criteria (Dale and Beyeler, 2001)
- Modified criteria based on comments from:
  - Technical Advisory Committee
  - Researchers
  - Fort Benning resource managers

Indicators should be technically effective and practically useful

Most indicator criteria address technical effectiveness

- Are easily measured
- Are sensitive to stresses on system
- Respond to stress in a predictable manner
- Are anticipatory: signify an impending change in the ecological system
- Predict changes that can be averted by management actions
- Have a known response to natural disturbances, anthropogenic stresses, and changes over time
- Have low variability in response
- Are integrative: the full suite of indicators provides a measure of coverage of the key gradients across the ecological systems
  - Are broadly applicable across the system of interest and to other systems
- Consider spatial and temporal context of measure

Steps in developing and applying criteria

- Screen for technical effectiveness based on:
  - SEMP data/model
  - Existing literature/researcher input
- Screening indicators for practical utility based on:
  - Consultation with Fort Benning resource managers
  - Information on indicator data collection from researchers

Criteria are for ideal situation -- no single indicator will meet all criteria

Asked how Fort Benning resource managers might use indicators

Their responses:

- Planning budgets
- Provide a “heads up” regarding compliance
  - Heading toward non-compliance?
- Signal whether on right path toward achieving longer term goals
- Signal whether on right path to achieve shorter term objectives
- Suggest need for targeted research
  - The “holy cow” scenario

Photo: Fort Bragg

Measures of practical utility initially suggested by Fort Benning resource managers

- Provide feedback on whether current ecological conditions are consistent with achieving goals and objectives
- Indicator values are meaningful—quantifiable and able to signal “red flags”
- Help resource managers anticipate potential noncompliance
- Maximize the ratio of sampling effort exerted to information yielded (“biggest bang for buck”)
  - Sampling design, effort, & analyses should be proportionate to need
  - Sampling measurement should be cost-effective*
  - Indicator should be comprehensive*
    - Provide information about a large area, more than one resource, etc.

Resource managers noted that some criteria are conditional

- "Cheaper and broadly applicable is better, but more expensive and narrowly applicable might be ok"

  If associated with

  – critical training needs

  – Endangered Species Act

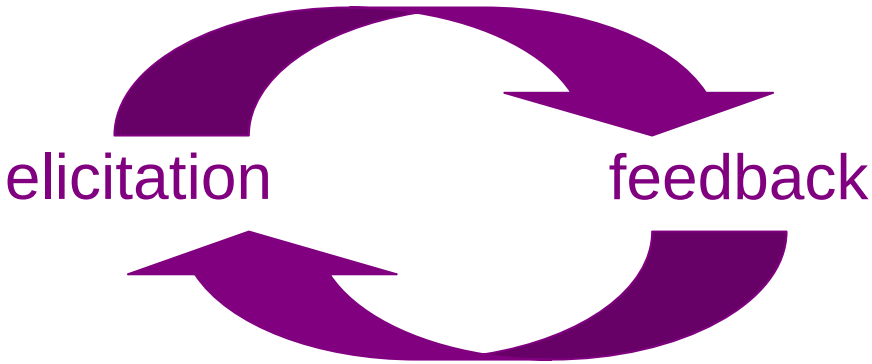
  – isolated populations ("lucrative targets")

Base cost of obtaining indicators differs by scale

- Plot
  - Getting to plots
  - Creation of map of land management categories
- Watershed
  - Getting to watershed
  - Satellite maps to define context of watershed
- Landscape
  - Aerial/satellite imagery

Step 2: Determining discrete land-management categories (LMCs) via the Delphi method

- The Delphi method is an iterative process for achieving consensual validity among raters (in this case, Fort Benning staff and research teams) by providing them feedback regarding other raters' responses



- This application of the Delphi method was unique
  - Two distinct groups of experts
  - Intensive interactions

Delphi method led to 3-D LMC matrix

	Cause of predominant ecological effect from ***military use*** of land
Land management ***goals***	Relative ***frequency*** of military use

- Discrete categories
  - Avoids multiple uses
- More informative than “land cover” or “land use” alone
  - Considers past and adjacent use

Land management categories as determined by military training and land management practices—final version

Key ‘0’ = *military uses* do NOT occur in areas managed in specified ways

‘I’ and ‘F’ = the relative frequency with which *military uses* occur in areas managed in specified ways (I = infrequent and F = frequent).

‘+’ = *land management* options in areas not used by the military

Land management goals and endpoints	Cause of predominant ecological effect from military use(s) of land								
	Tracked vehicles	Wheeled vehicles	Foot traffic	Designated bivouac areas	Firing ranges	Impact areas	Drop or landing zones	No military effect	Administrative use
1. Minimally managed areas									
1.1 Wetlands	I,F	I, F	I	0	0	0	0	+	0
1.2 Vegetation on steep slopes	I, F	I, F	I	0	0	0	0	+	0
1.3 Forests in impact zones	0	0	0	0	0	I,F	0	+	0
2. Managed to restore and preserve upland forest									
2.1 Upland forests 2.1.a Long leaf dominance 2.1.b Mixed pine 2.1.c Scrub oak pine mix	I	I,F	I, F	0	0	0	0	+	0
2.2 RCW mgmt clusters	I	I	I,F	0	0	0	0	+	0
2.3 Sensitive area designated by signs	0	0	I,F	0	0	0	0	+	0
3. Managed to maintain an altered ecological state									
3.1 Intensive military use areas	F	F	0	I,F	F	0	0	0	0
3.2 Wildlife openings	0	I	I	0	0	0	I	+	0
3.3 Mowed fields	0	I	I,F	0	I,F	0	I,F	+	0
3.4 Roads (paved and unpaved)	I, F	I, F	I, F	0	0	0	0	+	0
3.5 Built environment	0	0	0	0	0	0	0	0	+

Researchers assigned LMC to each plot

- Used plot to match LMCs to data
- Field-checked categorization with Fort Benning staff when questions arose

Data unevenly spread across LMC matrix

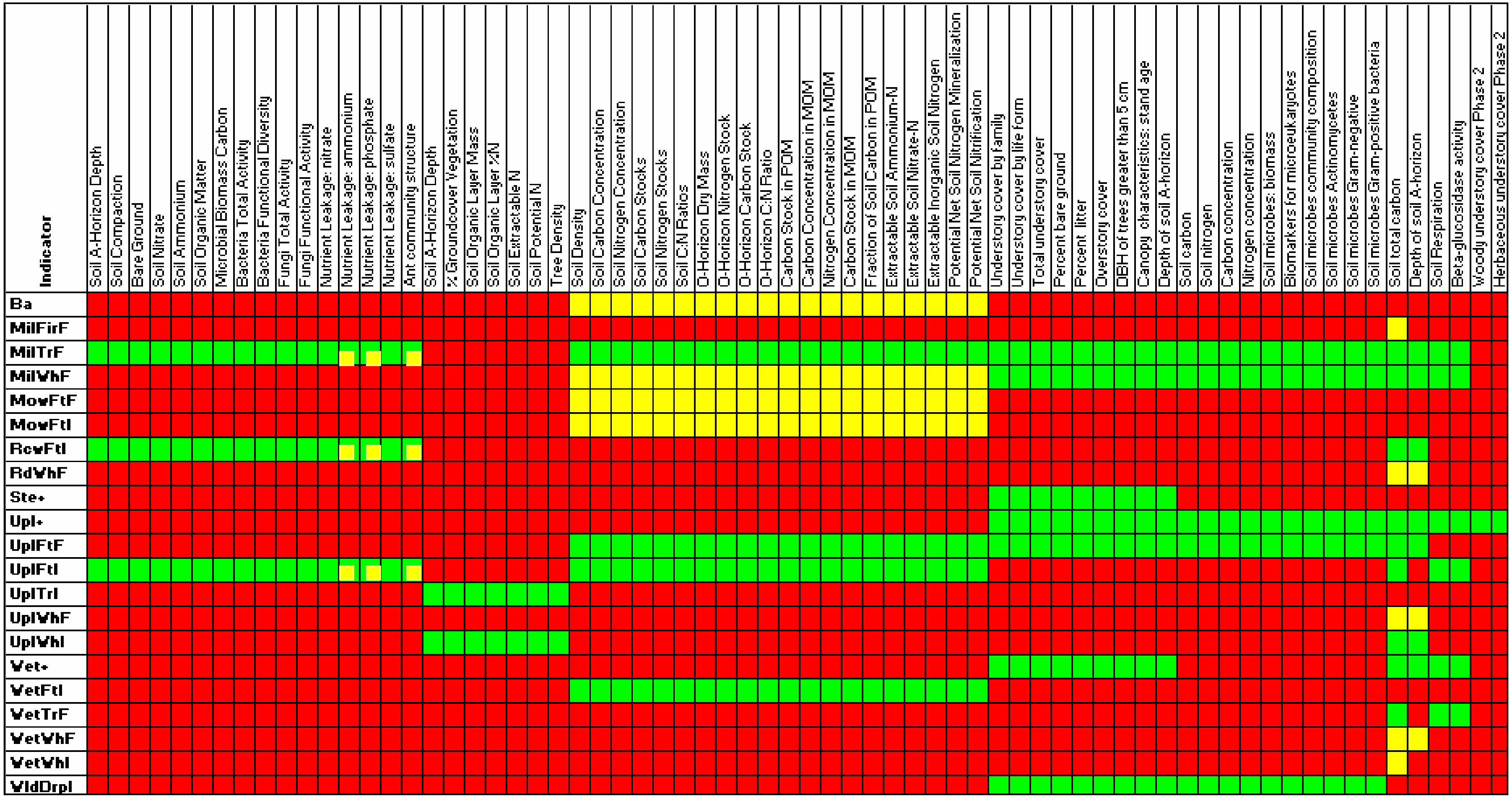
- Research projects were initiated before LMCs existed
- LMCs are unevenly distributed across installation
- LMCs are not of equal management interest

Presence of data by LMC

Land management goals	Cause of predominant ecological effect from military use(s) of land								
	Tracked vehicles	Wheeled vehicles	Foot traffic	Designated bivouac areas	Firing ranges	Impact areas	Drop zones	No effect	Admini-strative use
1. Minimally managed areas									
1.1 Wetlands	WetTrI(-) WetTrF(+)	WetWhI(*) WetWhF(*)	WetFtI(+)	0	0	0	0	Wet+(+)	0
1.2 Vegetation on steep slopes	SteTrI(-) SteTrF(-)	SteWhI(-) SteWhF(-)	SteFtI(-)	0	0	0	0	Ste+(+)	0
1.3 Forests in impact zones	0	0	0	0	0	ForImpI(-) ForImpF(-)	0	For+(-)	0
2. Actively managed to restore and preserve upland forest									
2.1 Upland forest	UplTrI(+)	UplWhI(+) UplWhF(*)	UplFtI(+) UplFtF(+)	0	0	0	0	Upl+(+)	0
2.2 RCW mgmt clusters	RcwTrI(-)	RcwWhI(-)	RcwFtI(+) RcwFtF(-)	0	0	0	0	Rcw+(-)	0
2.3 Sensitive area designated by signs	0	0	SenFtI(-) SenFtF(-)	0	0	0	0	Sen+(-)	0
3. Managed to maintain an altered ecological state									
3.1 Intensive military use areas	MilTrF(+)	MilWhF(+)	0	MilBivI(-) MilBivF(-)	MilFirF(*)	0	0	0	0
3.2 Wildlife openings	0	WldWhI(-)	WldFtI(-)	0	0	0	WldDrpI(+)	Wld+(-)	0
3.3 Mowed fields	0	MowWhI(-)	MowFtI(*) MowFtF(*)	0	MowFirI(-) MowFirF(-)	0	MowDrpI(-) MowDrpF(-)	Mow+(-)	0
3.4 Roads (paved and unpaved)	RdTrI(-) RdTrF(-)	RdWhI(-) RdWhF(*)	RdFtI(-) RdFtF(-)	0	0	0	0	Rd+(-)	0
3.5 Built areas	0	0	0	0	0	0	0	0	Ba(*)

= no data = insufficient data for analysis = sufficient data for analysis

Indicator data across LMCs (Updated Sept 2004)



Indicators

LMC

Indicator	Soil A-Horizon Depth	Soil Compaction	Bare Ground	Soil Nitrate	Soil Ammonium	Soil Organic Matter	Microbial Biomass Carbon	Bacteria Total Activity	Bacteria Functional Diversity	Fungi Total Activity	Fungi Functional Activity	Nutrient Leakage: nitrate	Nutrient Leakage: ammonium	Nutrient Leakage: phosphate	Nutrient Leakage: sulfate	Ant community structure	Soil A-Horizon Depth	% Groundcover Vegetation	Soil Organic Layer Mass	Soil Organic Layer %N	Soil Extractable N	Soil Potential N	Tree Density
Ba	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
MilFirF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
MilTrF	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟩	🟨	🟥	🟥	🟥	🟥	🟥	🟥	🟥
MilVhF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
MovFtF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
MovFtI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
RcvFtI	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟩	🟨	🟥	🟥	🟥	🟥	🟥	🟥	🟥
RdVhF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Ste+	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Upl+	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
UplFtF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
UplFtI	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟩	🟨	🟥	🟥	🟥	🟥	🟥	🟥	🟥
UplTrI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩
UplVhF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
UplVhI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Vet+	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
VetFtI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
VetTrF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
VetVhF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
VetVhI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
VldDrpI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥

Indicator	Soil Density	Soil Carbon Concentration	Soil Nitrogen Concentration	Soil Carbon Stocks	Soil Nitrogen Stocks	Soil C:N Ratios	O-Horizon Dry Mass	O-Horizon Nitrogen Stock	O-Horizon Carbon Stock	O-Horizon C:N Ratio	Carbon Stock in POM	Carbon Concentration in MOM	Nitrogen Concentration in MOM	Carbon Stock in MOM	Fraction of Soil Carbon in POM	Extractable Soil Ammonium-N	Extractable Soil Nitrate-N	Extractable Inorganic Soil Nitrogen	Potential Net Soil Nitrogen Mineralization	Potential Net Soil Nitrification
Ba	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
MilFirF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
MilTrF	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
MilVhF	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
MovFtF	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
MovFtI	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
RcvFtI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
RdVhF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Ste+	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Upl+	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
UplFtF	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
UplFtI	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
UplTrI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
UplVhF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
UplVhI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Vet+	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
VetFtI	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
VetTrF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
VetVhF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
VetVhI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
VldDrpI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥

Indicator	Understory cover by family	Understory cover by life form	Total understory cover	Percent bare ground	Percent litter	Overstory cover	DBH of trees greater than 5 cm	Canopy characteristics: stand age	Depth of soil A-horizon	Soil carbon	Soil nitrogen	Carbon concentration	Nitrogen concentration	Soil microbes: biomass	Biomarkers for microeukaryotes	Soil microbes community composition	Soil microbes Actinomycetes	Soil microbes Gram-negative	Soil microbes Gram-positive bacteria	Soil total carbon	Depth of soil A-horizon	Soil Respiration	Beta-glucosidase activity	Woody understory cover Phase 2	Herbaceous understory cover Phase 2
Ba	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
MilFirF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟥	🟥	🟥	🟥	🟥
MilTrF	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟥
MilVhF	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟥
MovFtF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
MovFtI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
RcvFtI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟥	🟥
RdVhF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟨	🟥	🟥	🟥	🟥
Ste+	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Upl+	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
UplFtF	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥
UplFtI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟩	🟩	🟥	🟥
UplTrI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
UplVhF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟨	🟥	🟥	🟥	🟥
UplVhI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟥	🟥
Vet+	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟥	🟥
VetFtI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
VetTrF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟩	🟩	🟥	🟥
VetVhF	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟨	🟥	🟥	🟥	🟥
VetVhI	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟥	🟥	🟥	🟥	🟥
VldDrpI	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥

🟥 = no data

🟨 = insufficient data for analysis

🟩 = sufficient data for analysis

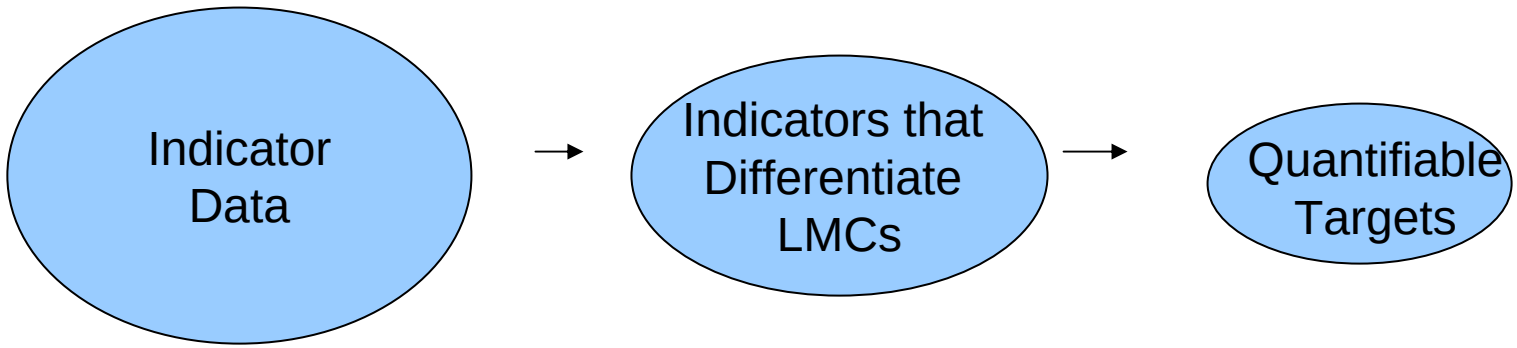
Indicator data across LMCs, grouped by type

	MilTrF	MilWhF	RcwFtl	Ste+	Upl+	UplFtF	UplFtl	UplTrl	UplWhl	Wet+	WetFtl	WetTrF	WldDrpl
Vegetation Characteristics													
Soil Microbial													
Soil Carbon													
Soil Nitrogen													
Soil Organic Layer													
Soil Density, Compaction, Respiration													
Soil A-Horizon Depth													
Nutrient Leakage													
Ant Community Structure													

= no data = insufficient data for analysis = sufficient data for analysis

Step 3: Assess ability of indicators to differentiate among LMCs

- Multivariate analysis of the proposed indicators
  - Define a set of indicators that provide robust information about the LMCs
- Develop quantifiable target ranges for land managers based on distributions of selected indicators



Modeling Approach

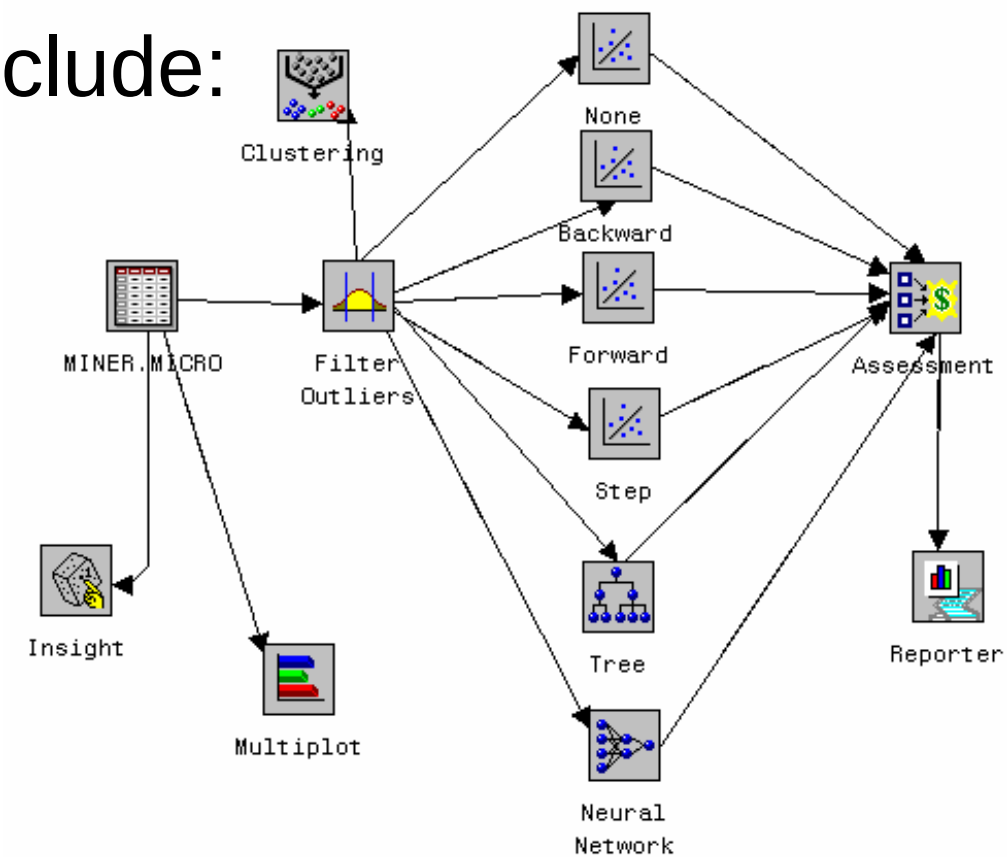
- Data conditioning
- Cluster analysis
- Multiple model generation
- Indicator selection
- Explore distributions of chosen indicators and identify quantifiable targets for indicators within LMCs

Data Conditioning

Problem		Action
Outliers	→	Systematic removal of outliers
Redundancy (collinearity)	→	Interactions
Missing values	→	Imputation
Range of values	→	Transform (standardize) variables

Model Generation

- Models are being used to discriminate between LMCs
- Models to be used include:
  - Dendrograms
  - Multiple Regression
  - Neural Networks
  - Discriminant Analysis



Indicator Selection

- We are not interested in the models per se but in the predictors (indicators) the models find
- Indicators that are robust (appear in multiple predictive models) will be further analyzed by investigating their distribution within and among LMCs

Example: ORNL (2) Soil Indicators

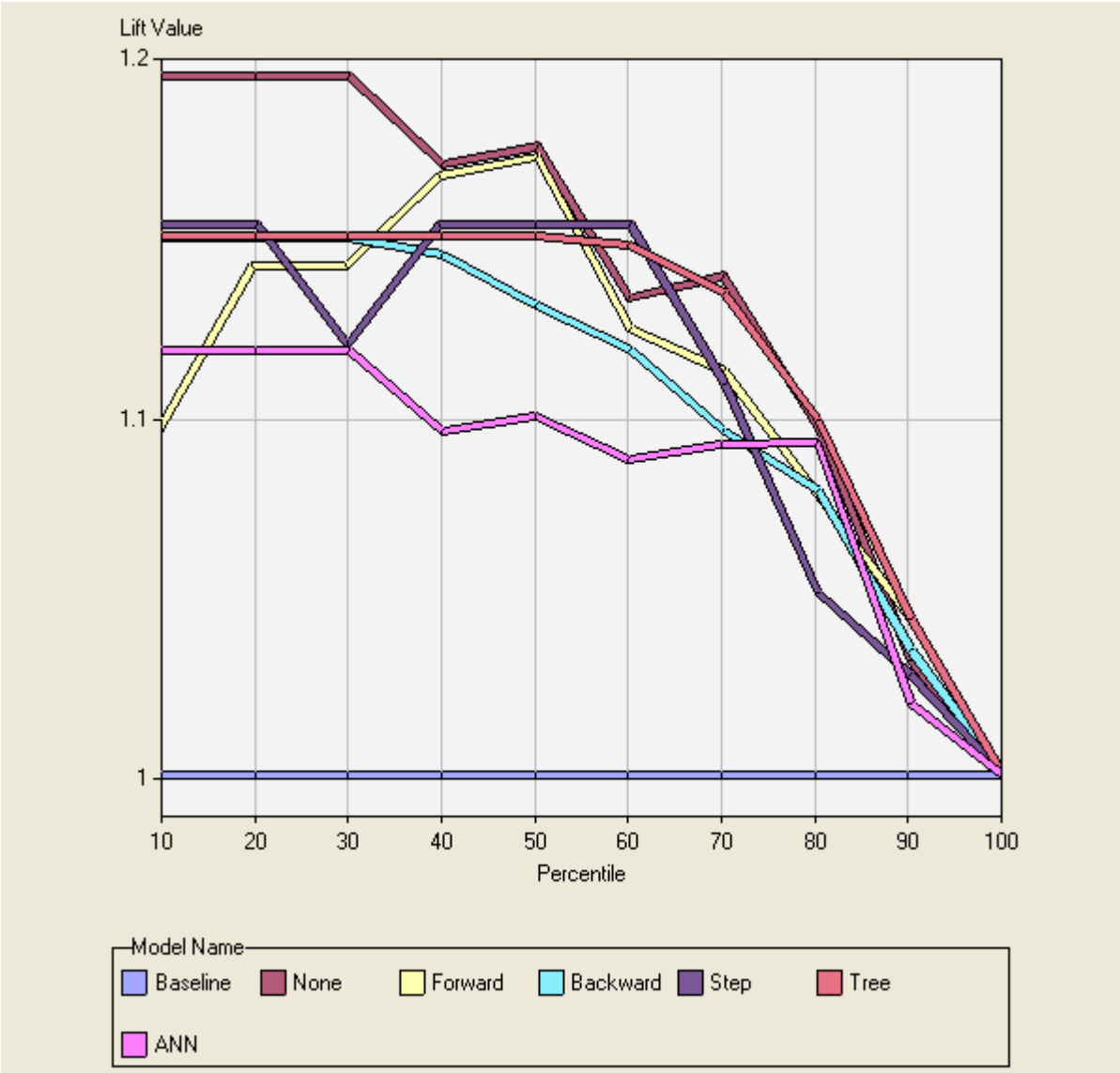
Potential Indicators

- Soil Density
- Soil Carbon Conc.
- Soil Nitrogen Conc.
- Soil C Stocks
- Soil N Stocks
- Soil C:N Ratio
- O horizon dry mass
- O horizon N stock
- O horizon C Stock
- O-horizon C:N ratio
- C stock in POM (particulate organic matter)
- C Conc. in MOM (mineral associated organic matter)
- N Conc. in MOM
- C stock in MOM
- Fraction of soil C in POM
- Potential Net soil N mineralization Potential
- Net soil Nitrification
- Extractable soil ammonium-N
- Extractable soil Nitrate-N
- Extractable Inorganic Soil Nitrogen

LMCs

Military Track Frequent
Upland Foot Traffic Frequent
Upland Foot Traffic Infrequent
Wetland Foot Traffic Infrequent

Cumulative Lift of Models for ORNL (2)



Lift is a measure of the effectiveness of a predictive model calculated as the ratio between the results obtained with and without the predictive model.

No models failed

Misclassification rates ranged from 11 to 20%.

Significant selection results

- Regression
  - All indicators significant
- Backward regression
  - All indicators significant
- Forward analysis
  - N Conc. In MOM
  - Soil Density
  - Soil N Stocks
  - Soil Carbon Concentration
- Stepwise regression
  - Soil density
  - Soil N Stocks
- Tree
  - Soil Nitrogen Concentration
  - Soil Density
  - Soil Carbon Concentration
- ANN
  - Soil Nitrogen Concentration
  - Soil Density
  - Soil Carbon Concentration

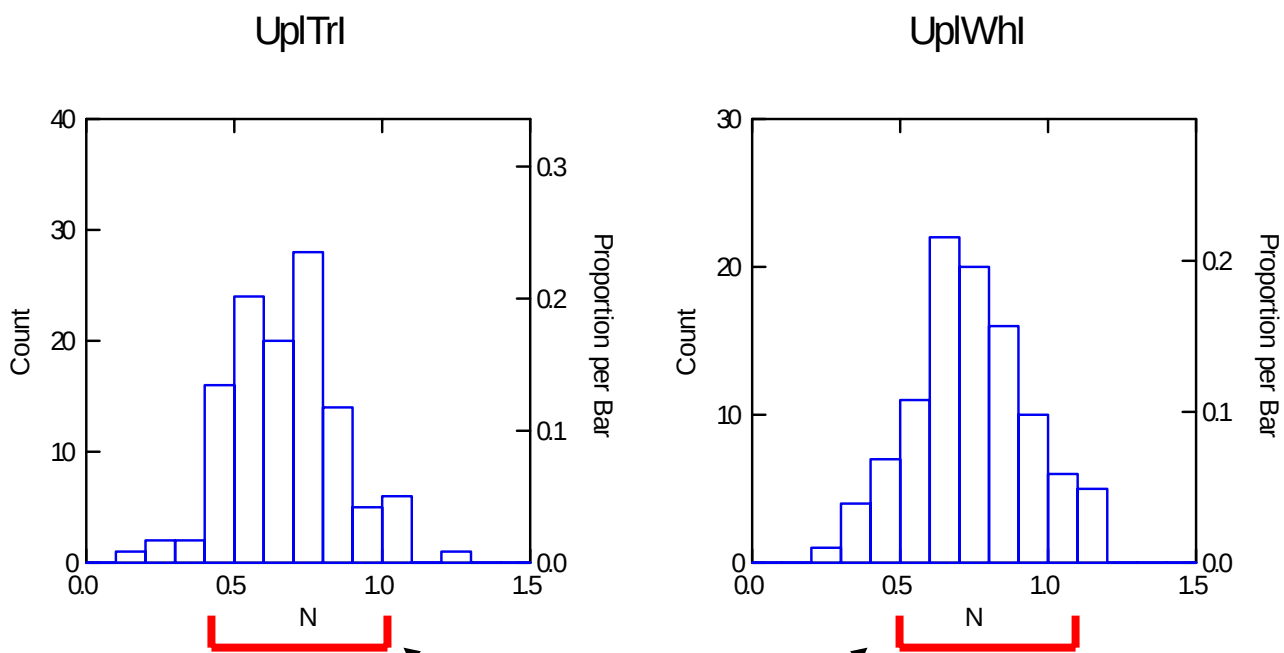
Recommendation

- Move through preliminary screening
  - Soil Density
  - Nitrogen Concentration in MOM
  - Soil Nitrogen Concentration
  - Soil Nitrogen Stocks
  - Soil Carbon Concentration

E. Identifying Quantifiable Targets

We will use the distributions of selected indicators to develop quantifiable targets for each indicator within an LMC

Soil Organic Layer N (SREL)



Target range for
Indicator X for LMC Y

Validation of approach was requested at April 2004 workshop

- Testing of indicators arising from analysis
  - Analyze data collected for site condition index
  - Test at Fort Bragg
    - Adopt LMCs at Fort Bragg
    - Collect data that are systematically distributed across LMCs
    - Analyze data a priori
  - Test Fort Benning, in and around the Digital Multi-Purpose Range Complex (DMPRC)
    - Use map of LMCs being developed for Fort Benning
    - Sample indicators in and around DMPRC
    - Analyze to determine if indicators signify changes to LMCs

Next steps for analysis

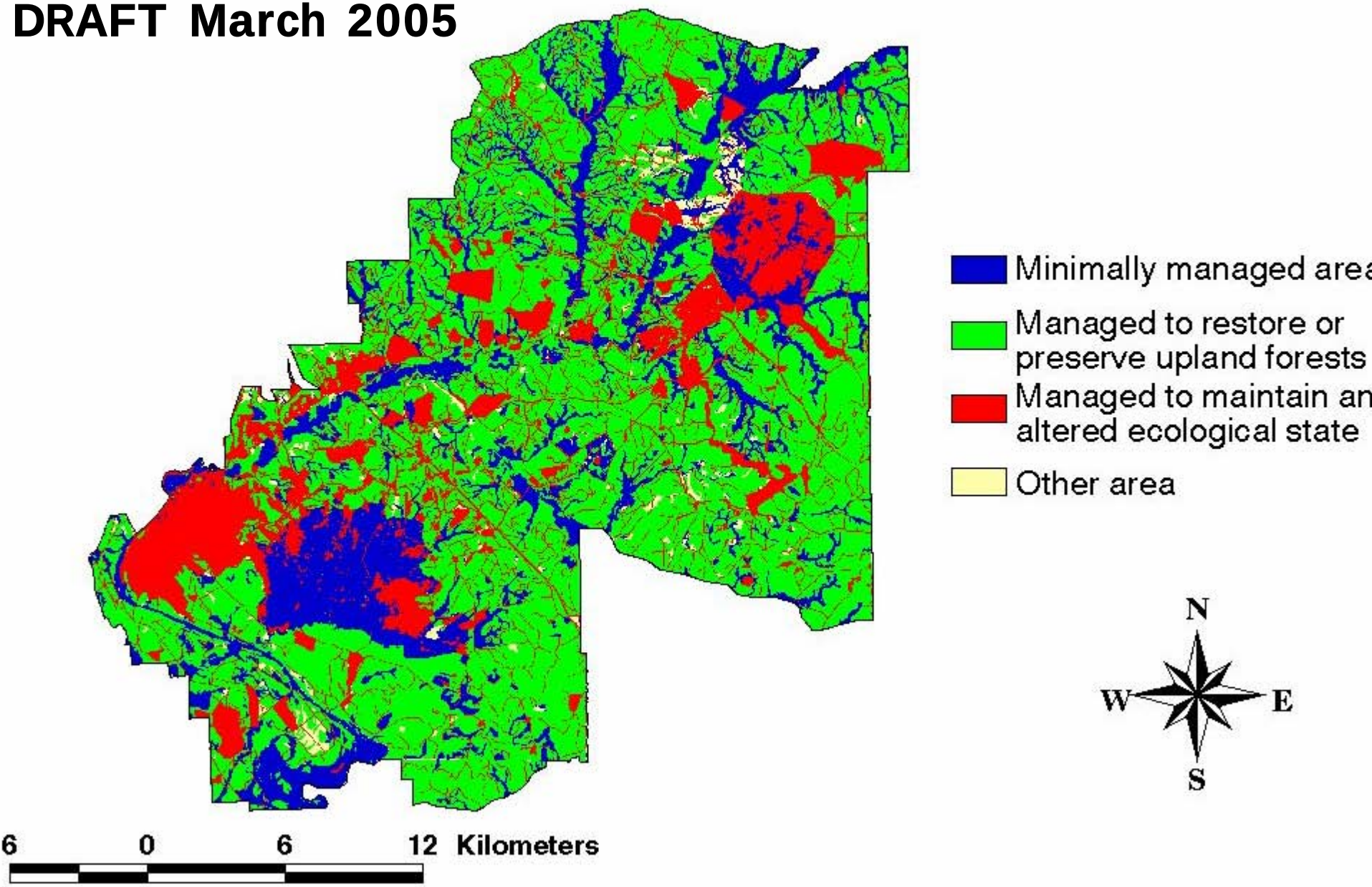
- Complete numerical targets for indicators
- Knowledge maps
  - How do selected indicators interact?
  - What do indicators reveal about ecological interactions?
- Verification
  - Data used in site condition index
  - Fort Bragg
  - DMPRC

Map of LMCs being developed for Fort Benning

- Map developed
  - Based on existing data layers
  - With input from
    - Fort Benning resource managers
    - Nature Conservancy staff at Fort Benning
- Maps will consist of two layers
  - The *land management goals and endpoints* (headers in the far left column of LMC matrix)
  - The *cause of the predominant ecological effects from military use(s) of the land* (the header row at the top of LMC matrix)

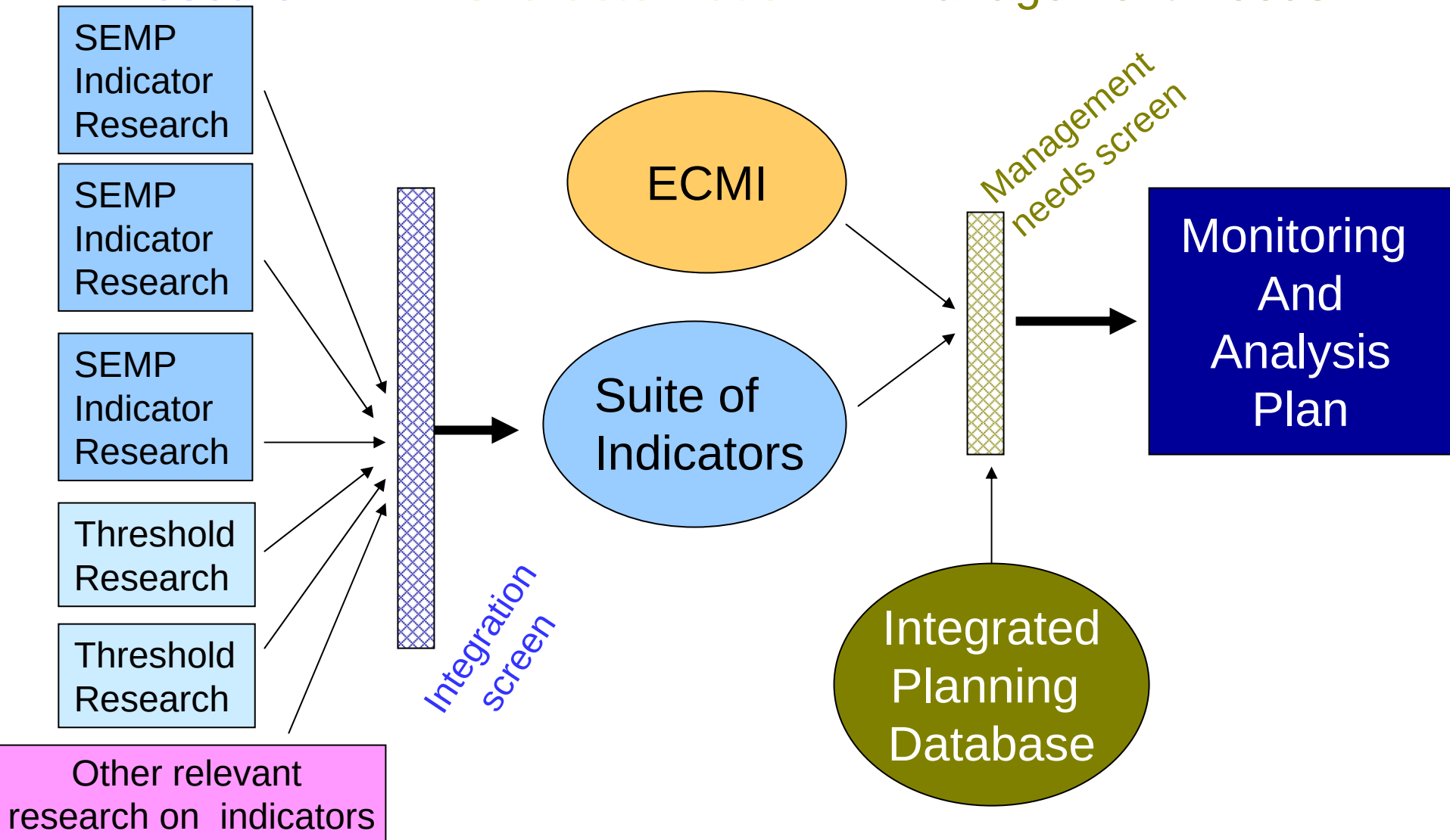
Land management goals and endpoints

DRAFT March 2005

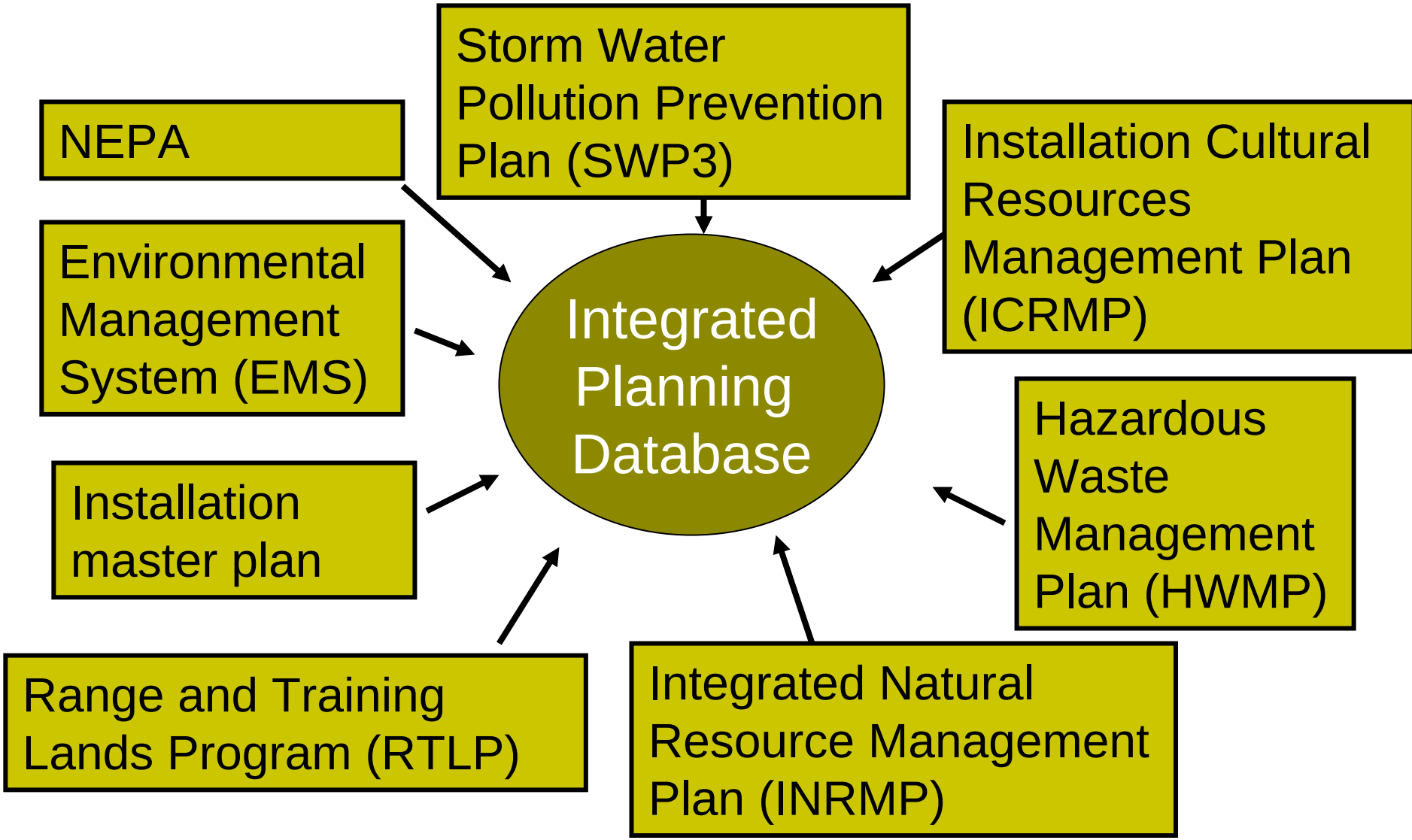


Result of SEMP Integration is plan for monitoring and analysis

= Research + Characterization + Management Needs



Indicators must be put in context of management needs (see report by Jeff Fehmi <CERL will complete?>)



Tasks Completed

- April 2003: Query to SEMP researchers about indicators
- May 2003: Workshop with Fort Benning resource managers to develop approach for land-management categories
- August 2003: Results of compiled query on proposed indicators
- September 2003: Workshop with SEMP team members
  - Land-management categories derived
  - Indicators approach finalized
- November 2003: SEMP teams members assign plots to land-management categories
- March 2004: Indicators compiled by land-management categories
- March 2004: Discussion with Fort Benning managers about use of indicators
- April 2004: Workshop with SEMP team members
- September 2004:
  - Preliminary map and report developed and discussed with Fort Benning resource managers and The Nature Conservancy
  - Indicator selection procedure determined
- March 2005:
  - Results of screening for management needs
  - Draft map of the *cause of the predominant ecological effects from military use(s) of the land*

Tasks to complete

- May 2005:
  - Components of monitoring and analysis plan
  - Scientific papers in integration
  - Guidebook for implementation: A resource manager's guide to using ecological indicators
  - Final report on integration of indicators
- June 2005
  - Final maps
  - Report on method used to develop map
- September 2005
  - Submission of journal article on mapping approach

DoD EPA DOE SERDP

Strategic Environmental Research and Development Program

Improving Mission Readiness Through Environmental Research

ERDP's SEMP

SIP

ornl

Oak Ridge National Laboratory

ERDP's SEMP