ASSESSING FOREST ECOLOGICAL INTEGRITY USING LANDFIRE AND USFS FOREST INVENTORY AND ANALYSIS DATA

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Front cover:

A field crew measures a forested plot at Acadia National Park. From Tierney et al. 2009.

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This project began through some informal discussions between Randy Swaty and Don Faber-Langendoen. We discovered a mutual interest in how to assess forest integrity at multiple scales, including scales relevant to conservation managers at site and sub-regional scales. We thank Jim Smith for his encouragement and support for this project, which was set up on a very short timeline. We thank Regan Smyth for assistance with the maps.

This report explores some issues around a few particular questions, but tries to put them in a general context, within the limitations of the project. We hope these explorations can set the stage for a more thorough assessment and discussion of these issues.

[Note, this draft does not include input from TNC Pennsylvania project writers]

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INTRODUCTION

There has been a strong interest in developing ecological integrity assessment methods (EIAs) to guide conservation and management practices, such as choosing sites for conservation, setting performance expectations for restoration or mitigation, or tracking trends in condition over time. Such approaches are being widely promoted among a number of agencies, conservation organizations, and research scientists who focus on the critical role of indicators for assessing ecological integrity of communities and ecosystems (Harwell et al. 1999, Andreasen et al. 2001, Young and Sanzone 2002, U.S. EPA 2002a, Parrish et al. 2003, Faber-Langendoen et al. 2008a, Tierney et al. 2009).

Assessing the current ecological integrity of an ecosystem requires developing measures of the structure, composition, and function of an ecosystem as compared to reference or benchmark ecosystems operating within the bounds of natural or historic disturbance regimes (Lindenmayer and Franklin 2002, Young and Sanzone 2002). However, selection and development of indicators to measure ecological integrity can be challenging, given the diversity of organisms and systems, the large number of ecological attributes that could be measured, and concerns over cost-effectiveness and statistical rigor, and loss of adequate reference sites to guide the assessment (Brewer and Menzel 2009). Many conservation and resource managers are struggling with the task of implementing condition assessments, without re-inventing the wheel for every site or region, while still being sensitive to differences among ecological regions, natural resources, staff capacity, and relevant partner activities (Fancy et al. 2009). There is a need for a set of methods that provides guidance on the range of options for assessing ecological integrity, scaled both in terms of the level of ecosystem type that is being assessed, and the level of information required to conduct the assessment.

To address these needs, NatureServe, working with ideas from many partners, has develop a thematically structured set of Ecological Integrity Assessments (EIAs) methods based on considerations of data types: remote sensing (Level 1) assessment, rapid field data (Level 2) assessment, and intensive, sampling design-based (Level 3) assessment), as well as classification scales (e.g., Formation, Ecological Systems, Association) (Faber-Langendoen et al. 2008). All methods are guided by a similar conceptual model that specifies the major ecological attributes for which metrics should be identified, namely Landscape Context, Size, Biotic and Abiotic Condition. A generic Level 1 assessment method has been developed for all ecosystems (Faber-Langendoen et al. 2008), Level 2 methods have been developed for wetlands and forests (Faber-Langendoen et al. 2008, 2009), and a Level 3 method has been developed for northeast temperate forests (Tierney et al. 2009).

Developing the methods is one part of the task; collecting or accessing data that can be used to conduct the assessments is another! Recent completion of the national ecological systems maps of the coterminous U.S. (Comer ……) have provided an unprecedented level of information for conducting ecological integrity assessments. NatureServe's Level 1 assessment methods originally relied on land cover map information from the National Land Cover Data sets (NLCD), but availability of the Landfire map is allowing us to rethink how we can more accurately characterize ecological condition (Comer….). NatureServe's Level 2 and 3 assessment methods required on-the-ground field data. Access to such data is improved through collaborations between NatureServe and the U.S. Forest Service Forest Inventory and Analysis (FIA) program, whereby all FIA plot data are being classified to both the SAF Cover Types and the U.S. National Vegetation Classification USNVC) types, allowing for a range of ecosystem scales to be addressed (Faber-Langendoen and Menard 2006).

There are several critical challenges for applying the EIA methods. For Level 1 assessments, identifying metrics for Landscape Context, Size, and Abiotic Condition is fairly tractable, but metrics for Biotic Condition are more challenging (Faber-Langendoen et al. 2008). For Level 2 assessments, a somewhat different issue occurs, because ground data provide an opportunity to refine Biotic Condition scales to finer levels of classification, such as Formation or Ecological System. Here the issue becomes how to efficiently identify both a set of metrics and data that can be scaled to these levels of ecosystem. NatureServe has begun to address these questions for wetlands (Faber-Langendoen et al. 2008), but has had less opportunity to address them for forests and woodlands.

Here we focus on addressing these two challenges – 1) assessing Biotic Condition for Level 1 assessments, and 2) identifying metrics and data to address Biotic Condition that are sensitive to different characteristic of integrity among different forest and woodland types. Our purpose for this project is to:

a) Explain the NatureServe Ecological Integrity Assessment (EIA) methods.

b) Introduce the application of EIA to Temperate Forests.

c) Describe how to assess Vegetation Condition for NatureServe Level 1 EIA assessments, using the linkage between forest information available in LANDFIRE National project products (spatial and vegetation models), and

d) Describe the role of USFS FIA forest plot data for assessing Vegetation Condition by comparing the NatureServe EIA process and the Pennsylvania Forest Tool.

e) Propose next steps.

Readers familiar with NatureServe's methods can proceed directly to the 3rd purpose" FOREST LEVEL 1 ASSESSMENT AND LANDFIRE VEGETATION MODELS."

THE NATURESERVE ECOLOGICAL INTEGRITY ASSESSMENT METHOD

For over twenty-five years, NatureServe has advanced the Natural Heritage Methodology for documenting the viability and integrity of individual occurrences of species and ecosystems[1]. Our **ecological integrity assessment** method builds on that methodology, but has adapted them by building on a variety of existing rapid assessment methods (Mack 2001, Collins et al. 2006, 2007), and the 3-level approach of the U.S. Environmental Protection Agency and others (Brooks et al. 2004, US EPA 2006, Faber-Langendoen et al. 2006, 2008a).

DEFINITION OF ECOLOGICAL INTEGRITY

Building on the related concepts of biological integrity and ecological health, ecological integrity is a broad and useful endpoint for ecological assessment and reporting (Harwell et al. 1999). "Integrity" is the quality of being unimpaired, sound, or complete. Ecological integrity can be defined as "an assessment of the structure, composition, and function of an ecosystem as compared to reference ecosystems operating within the bounds of natural or historic disturbance regimes" (adapted from Lindenmayer and Franklin 2002, Young and Sanzone 2002, Parrish et al. 2003). To have ecological integrity, an ecosystem should be relatively unimpaired across a range of ecological attributes and spatial and temporal scales. The notion of naturalness depends on an understanding of how the presence and impact of human activity relates to natural ecological patterns and processes (Kapos et al. 2002). Identification of reference or benchmark conditions based on natural or historic ranges of variation, although challenging, can provide a basis for interpretation of ecological integrity (Swetnam et al. 1999). These general concepts needs greater specificity to become a useful guide for conducting ecological integrity assessments, as illustrated later in this document.

PURPOSES OF ECOLOGICAL INTEGRITY ASSESSMENTS

The purpose of an ecological integrity assessment and of assigning an index of ecological integrity (what the Network calls an EO rank) is to provide a succinct assessment of the current status of the composition, structure and function of occurrences of a particular ecosystem type and give a general sense of conservation value. These assessment methods can be used to address a number of objectives, including to:

- assess ecological integrity on a fixed, objective scale (global EO rank, subnational[2] rank).

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[1] The Natural Heritage methodology was originally developed by The Nature Conservancy (TNC), but Heritage methods staff transferred to NatureServe when it was formed in 2000. Since then, NatureServe has worked with the Network of Natural Heritage Programs to maintain and improve the methodology, while continuing to collaborate with TNC.

[2] In this document, the term "subnation" will refer to the first order subdivision of a nation (*e.g.,* state, province, district, department).

- compare ecological integrity of various occurrences of the same ecosystem type, to determine the best examples and support selection of sites for conservation priority, recognizing that issues such as cost, practicality, etc. also affect priorities.[3]
- inform decisions on monitoring individual ecological attributes of a particular occurrences (e.g., floristic quality, vegetation structure, hydrology).
- provide an aggregated index of integrity to interpret monitoring data, including tracking the status of ecological integrity over time.

Other related purposes within the Network include:

- Contribute to information on an ecosystem type's overall conservation status ("extinction risk"), whether for global, national, and subnational Element conservation status ranks (G rank, N rank, and S rank). The "number of good ccurrences" or "percent area of an element that is good condition" are factors relevant to assessing the extinction risk.

- Prioritize field survey work. Occurrence ranks may be used effectively in conjunction with conservation status ranks to guide which occurrences should be recorded and mapped, and to help prioritize occurrences for purposes of conservation planning or action, both locally and rangewide.

- Inform species occurrence viability ranks. Rarely, for species dependent on particular habitats, and which may themselves be hard to track, the occurrence rank of the habitat may serve as a guide for the species viability ranks.

These objectives are inter-related, and can be jointly addressed as we revise our current methodology. However, we expect that individual purposes and projects may require additional tailoring of the method.

ECOLOGICAL INTEGRITY AND OTHER ASSESSMENT TYPES

Ecological integrity may only be one aspect of an ecosystem assessment. Other aspects include 1) conservation status / biodiversity value, which includes aspects of ecosystem irreplaceability, 2) Wetland functional assessments or ecosystem services, such as flood control, nutrient retention (Hruby 2001, Fennessy et al. 2004), 3) specific resource

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[3] Although Element and Element occurrence (EO) ranks help to set conservation priorities, they are not the sole determining factors. The determination of priority occurrences for conservation action will include not only the conservation status of the Element and the likelihood of persistence of the occurrence, but will also include consideration of other factors such as the taxonomic distinctness of the Element; the genetic distinctness of the EO; the co-occurrence of the Element with other Elements of conservation concern at a site; the likelihood that conservation action will be successful; and economic, political, and logistical considerations.

productivity, such as saw timber or forage. The first aspect, assessing the conservation status and irreplaceability value of ecosystems types and occurrences, can be part of a risk assessment process, where more irreplaceable occurrences are preferentially targeted for threat abatement or subject to greater degree of protection, thereby avoiding further losses. This assessment can begin by assessing the relative conservation status (or risk of extirpation) of a given type. For example, the Heinz Center (2002) uses the "At-risk wetland plant communities" (based on NatureServe's conservation status assessment approach), as an indicator of overall wetland or aquatic condition.

Functional assessments have been widely developed for wetlands (e.g., the Hydrogeomorphic Approach of Brinson et al. 1993). Similar to ecological integrity assessments, functional assessments estimate the structure, composition, and processes of ecosystems. However, these methods use this information to evaluate the capacity of wetlands to perform certain functions or ecosystem services, independently of how those services relate to ecological integrity. For example, metric ratings that assess flood / storm water control or wildlife habitat utilization may not have a direct correspondence to metrics for hydrologic condition as it relates to ecological integrity (Hruby 2001, Hruby 2004). In an ecological integrity assessment, an ecosystem is considered to have excellent integrity if it performs all of its functions or processes within an expected range of natural variation for that type.

Other perspectives on the condition of an ecosystem may include sustaining levels of forest or rangeland productivity. In the context of an overall assessment of natural resources and biodiversity, consideration will need to be given to balancing the relative goals of any assessment, and determining where on the landscape these various goals may be achieved. Ecological integrity assessments provide an important piece of information on the historic, natural ranges of variation on ecosystem composition, structure, and processes.

OVERVIEW OF THE ASSESSMENT METHOD

Our approach to establishing ecological integrity assessment methods builds on the NatureServe methodology for conducting ecological integrity assessments (Stein and Davis 2000, Brown et al. 2004, Faber-Langendoen et al. 2008). We develop the assessments using the following steps; we:

1) outline a general conceptual model that identifies the major ecological attributes, provide a narrative description of declining integrity levels based on changes to those ecological attributes, and introduce the metrics-based approach to measure those attributes and assess their levels of degradation.
2) use ecological classifications at multiple classification scales to guide the development of the conceptual models, to allowing improved refinement of assessing

attributes, **as needed**. E.g., the characteristics of vegetation, soils or hydrology for tropical forests differs strongly from that of temperate forests, the characteristics of temperate Red Spruce-Fir Forest differ in many respects from temperate Longleaf Pine Woodland, and the characteristics of montane Red Spruce-Balsam Fir Forest may differ in some respects from that of lowland Red Spruce–Hardwood Forest.

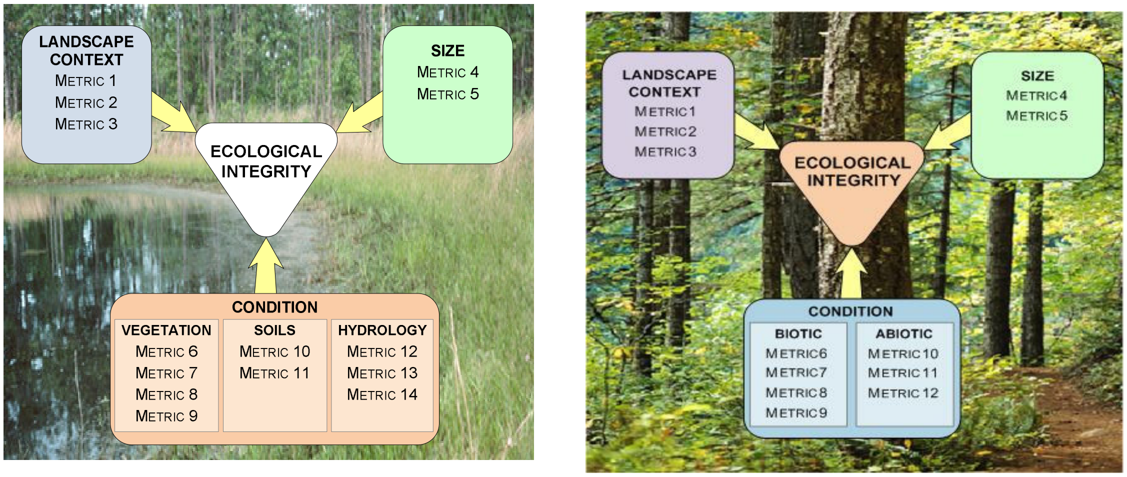
3) use a three level assessment approach – (i) remote sensing, (ii) rapid ground-based, and (iii) intensive ground-based metrics – to guide development of metrics. The 3-level approach is intended to provide increasing accuracy of ecological integrity assessment, recognizing that not all conservation and management decisions need equal levels of accuracy.
4) identify ratings and thresholds for each metric based on "normal' or "natural range of variation" benchmarks.
5) provide a scorecard matrix by which the metrics are rated and integrated into an overall index of ecological integrity.
6) provide tools for adapting the metrics over time as new information and methods are developed.

A full account of the method is presented in Faber-Langendoen et al. (2008). Here we detail several parts relevant to our objectives for this report.

CONCEPTUAL MODEL

A conceptual ecological model that identifies the major ecological attributes and linkages to known stressors or agents of change is a useful tool for guiding ecological integrity methods (Noon 2003). We developed a general conceptual model that identifies a) **major ecological attributes** of ecosystems, including the condition of vegetation, soils (and hydrology for wetlands), landscape context, and size that help characterize overall structure, composition and process, and b) important drivers and stressors acting upon ecosystems (Fig. 1, Table 1). Other major attributes, such as birds, amphibians, and macroinvertebrates can also be assessed where resources, time and field sampling design permit. The model is fairly intuitive, but a key component is that integrity incorporates spatial aspects of ecological integrity using both size and landscape context attributes.

Figure 1. Conceptual Model for Assessing Ecological Integrity
The major ecological attributes of ecosystem integrity are shown for upland and wetland models. Ecosystem drivers, such as climate, geomorphology, and natural disturbances maintain overall integrity, whereas stressors act to degrade it. See also Table 1.



WETLANDS **UPLANDS**

Table 1. Example of an ecological integrity table, based on the conceptual model of major ecological attributes and rank factors (see Fig. 1). Indicators are identified for each major ecological attribute. Stressors can be described using checklists (wetland example).

Rank Factor	Major Ecological Attribute	Indicator
LANDSCAPE CONTEXT	**Landscape Structure**	Landscape Connectivity
		Buffer Index
		Surrounding Land Use Index
	Landscape Stressors	Landscape Stressors Checklist
SIZE	**Size**	Patch Size Condition
		Patch Size
CONDITION	**Vegetation**	Vegetation Structure
		Organic Matter Accumulation
		Vegetation Composition
		Relative Total Cover of Native Plant Species
	Vegetation Stressors	Vegetation Stressors Checklist
	Soils (including physico-chemica	Physical Patch Types
		Water Quality
		Soil Surface Condition
	Soils Stresors	Soils Stressors Checklist
	Hydrology (wetlands)	Water Source
		Hydroperiod
		Hydrologic Connectivity
	Hydrology Stressors (wetlands)	Hydrology Stressors Checklist

The conceptual model helps guide the selection of indicators, organized across a standard set of ecological attributes and factors (e.g., Harwell et al. 1999, Young and Sanzone 2002, Parrish et al. 2003). The indicators are placed within the interpretive framework provided by the conceptual model, organizing the metric by **major ecological attributes** – broad attributes that have an important (driving) function in the viability or integrity of the element – and by **rank factors** (Table 1).

OVERVIEW OF THE 3 LEVELS OF ASSESSMENT

The conceptual model and the selection of metrics to assess ecological integrity can be executed at three levels of intensity depending on the purpose and design of the data collection effort (Brooks et al. 2004, Tiner 2004, US EPA 2006). This ”3-level approach” to assessments, summarized in Table 2, allows the flexibility to develop data for many sites that cannot readily be visited or intensively studied, permits more widespread assessment, while still allowing for detailed monitoring data at selected sites. In the context of a restoration project, the three levels allow for comparison of impacted sites against restored sites in a cost-effective manner.

The 3-level approach is intended to provide increasing accuracy of ecological integrity assessment, recognizing that not all conservation and management decisions need equal levels of accuracy. At the same time, the 3-level approach allows users to choose their assessment based in part on the level of classification (and thereby the specificity of the conceptual model). If one is only classifying to the level of tropical forest versus temperate forest, the use of remote sensing metrics may be sufficient. If one is classifying to montane Red Spruce-Balsam Fir Forest, one has the flexibility to decide to use any of the three levels, depending on the need of the assessment (i.e., there is no presumption that a fine-level of classification requires a fine-level of ecological integrity assessment).

Table 2. Summary of 3-level approach to conducting ecological integrity assessments (adapted from Brooks et al. 2004, USEPA 2006).

Level 1 – Remote Assessment	Level 2 – Rapid Assessment	Level 3 – Intensive Assessment
General description: Remote assessment	**General description:** Rapid field-based assessment	**General description:** Detailed field-based assessment
Evaluates: Condition of individual assessment areas/sites **using:** – metrics within the site that are visible with remote sensing data – Landscape / watershed condition metrics around the site – Limited ground truthing	**Evaluates:** Condition of individual assessment areas/sites **using:** - relatively qualitative or narrative field metrics within the site - remote sensing metrics for landscape context, with limited to expanded ground truthing.	**Evaluates:** Condition of individual assessment areas / sites **using:** - relatively detailed quantitative field metrics - remote sensing / and or field metrics for landscape context, expanded ground truthing / resolution.
Based on: • GIS and remote sensing data • Layers typically include: – Land cover – Land use – Other ecological maps • Stressor metrics (e.g. land use, roads)	**Based on:** • Condition metrics (e.g., hydrologic regime, species composition); and • Stressor metrics (e.g., ditching, road crossings, and pollutant inputs) • Calibration based on reference sites	**Based on:** • Condition metrics that have been calibrated to measure responses of the ecological system to disturbances (e.g., indices of biotic or ecological integrity) • Validation of metrics based on reference sites
Potential uses: • Identifies priority sites • Identifies status and trends of acreages across the landscape • Identifies integrity of ecological types across the landscape • Informs targeted restoration and monitoring	**Potential uses:** • Identifies/confirms priority sites • Informs monitoring of many attributes • Provides baseline data for implementation of restoration or mitigation projects • Supports landscape / watershed planning • Supports assessment of impacted sites based on reference sites	**Potential uses:** • Informs monitoring of a select set of attributes • Identifies status and trends of specific occurrences or indicators • Supports monitoring for restoration, mitigation, and management projects
Example metrics: - Landscape Development Index (integrates stressor impact of various land use types) - Land Use Map - Road Density - Impervious Surface	**Example metrics:** - Landscape Connectivity - Vegetation Structure - Invasive Exotic Plant Species - Forest Floor Condition	**Example metrics:** - Landscape Connectivity - Structural Stage Index - Invasive Exotic Plant Species - Floristic Quality Index (mean C) - Vegetation Index of Biotic Integrity - Soil Calcium:Aluminum Ratio

Level 1 Remote Assessments rely almost entirely on Geographic Information Systems (GIS) and remote sensing data to obtain information about landscape integrity and the distribution and abundance of ecological types in the landscape or watershed (Mack 2006, US EPA 2006, Faber-Langendoen et al. 2008b). Metrics are usually developed from readily available, processed imagery. Limited ground-truthing may be a component of some assessments.[4]

Level 2 Rapid Assessments use relatively rapid field-based metrics that are a combination of qualitative and narrative-based metrics with quantitative or semi-quantitative metrics. Field observations are required for many metrics, and observations will typically require professional expertise and judgment (Fennessey et al. 2007).

Level 3 Intensive Assessments require more rigorous, intensive field-based methods and metrics that provide higher-resolution information on the integrity of occurrences within a site. They often use quantitative, plot-based assessment procedures coupled with a sampling design to provide data for detailed metrics (Barbour et al. 1996, Blocksom et al. 2002). Calculations of indices for assessing Biotic Condition are often used, e.g., Floristic Quality Index, or Vegetation Index of Biotic Integrity ("VIBI") (DeKeyser et al. 2003, Mack 2004, Miller and Wardrop 2006, Miller et al. 2006). The focus of the general Level 3 assessment for biota is on the vegetation, since this is readily observable and measurable, and has been found to be a good indicator of overall condition (Mack 2004), but level 3 assessments typically can include metrics for soils, hydrology, and the surrounding landscape, and can be extended to **birds**, **fish**, **amphibians**, **invertebrates,** and other major ecological attributes of a system (see Fig. 1). These attributes are typically more time-consuming and costly to measure, but their response may differ enough from that of the vegetation that they provide additional valuable information on ecological integrity.

To ensure that the 3-level approach is consistent in how ecological integrity is assessed among levels, a standard framework or conceptual model for choosing metrics is used, as shown in Figure 1. Using this model, a similar set of metrics are chosen across the 3 levels, organized by the standard set of ecological attributes and factors - landscape context, size, condition (vegetation, hydrology, soils).

We move now to explaining the model for forest systems.

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[4] It should be pointed out that although remote sensing metrics are usually thought of as "coarser" or less accurate than field-based rapid or intensive metrics, this is not always the case. Some information available from imagery may be very accurate and more intensive than can be gathered in the field. Such information may also be more time-demanding and expensive. For that reason, we also assign a "tier" value to a metric, reflecting its level of precision. Thus it is possible to have a remote sensing indicator (L1) that has 3 metric variants (T1, T2, and T3), reflecting increasing accuracy of the metric. We may expect that for Level 1 assessments a Tier 1 version of the metric is used.

ECOLOGICAL INTEGRITY ASSESSMENT OF TEMPERATE UPLAND FOREST

LEVEL 1 METRICS AND RATINGS

A comprehensive set of Level 1 metrics and protocols have been developed for all natural ecosystems, including temperate forests (Faber-Langendoen et al 2008b). Table 3 provides the list. A Level 1 assessment is based primarily on metrics derived from remote sensing imagery. We can take the imagery and select and organize metrics by our conceptual model (Fig. 1). The assessment includes landscape context, size and condition metrics. For each metric, a rating is developed and scored, from excellent (A) to poor (D), usually in a 4-category scale, but sometimes 3 or 5. The background, methods, and rationale for each metric are described in a protocols document (Faber-Langendoen et al. 2008b). After each metric is rated, then various metric ratings are aggregated together into ratings for the major attributes and rank factors, and into an overall index of ecological integrity.

Table 3. A draft ecological integrity table for a level 1 assessment.

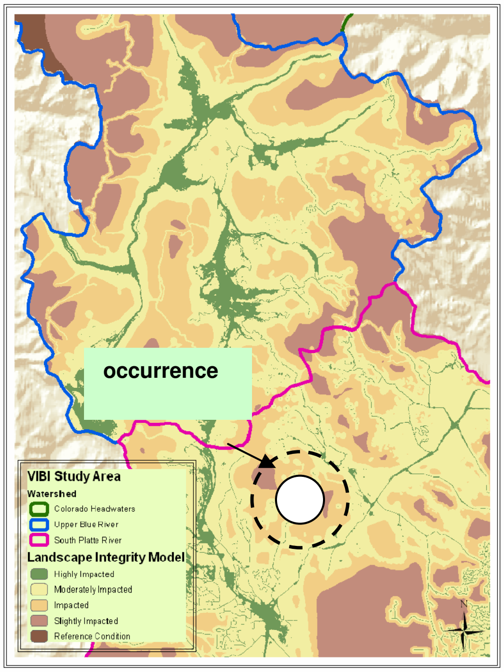
The table is applicable to all natural ecosystems. Stressor checklist information is not used directly to assess condition, but is considered informative.

Rank Factor	Major Ecological Attribute	Indicator/Metric
LANDSCAPE CONTEXT	**Landscape Context**	Landscape Connectivity
		Surrounding Land Use Index
		Buffer Index
SIZE	**Size**	Patch Size
		Patch Size Condition (opt).
CONDITION	**Vegetation**	Vegetation Structure OR Vegetation Structural Class Distribution (opt)
		Vegetation Composition (opt.)
		Relative Percent Cover of Native Plant Species (opt.)
		Invasive Exotic Plants (opt.)
	Soils	Soil/Substrate Condition
		On-Site Land Use Index
	Hydrology (opt)	Hydrologic Alterations (opt.)

Testing of level 1 metrics can be done by checking to see how well Level 1 metrics predict Level 2 or Level 3 ranks for specific association or system occurrences (see "Calibration" section below).

An example of how to implement a Level 1 assessment is as follows: Locations are chosen within the watershed or landscape. These locations are any or all examples of an ecosystem type that is of interest, e.g., all or some forest stands, or wetlands, identified to level of ecosystem classification. Points or polygons are established for each of these locations, and these are overlain on the Landscape Condition Model. A landscape context area is defined around the occurrence (Fig. 2). The landscape condition model provides the data for the "landscape condition model index" metric, based on the average score of the pixels within the landscape context. Connectivity and Size can be readily assessed. The same model can be used to produce the data for the "On-Site Land Use Index" metric. Other remote sensing data will be needed to estimate the other metrics. Together these metrics provide a simple means of characterizing the integrity (or EO rank) of the occurrence.

Figure 2. Demonstration of Level 1 Assessment based on a Landscape Condition Model. Values for landscape context metrics and condition metrics for an occurrence can be derived from the model.



LEVEL 2 METRICS AND RATINGS

We structure our selection of level 2 indicators/metrics using the current model. To compile an initial set of Level 2 metrics, we reviewed a variety of existing methods. We reviewed existing wetland rapid assessment and monitoring materials, including the California Rapid Assessment Manual (Collins et al. 2006, 2007), the Ohio Rapid Assessment Manual (Mack 2001), and the NatureServe wetland Ecological Integrity Assessment methods (Faber-Langendoen et al. 2006, 2008). We reviewed state Natural Heritage Program field forms, which typically include a rapid narrative evaluation of a site, from across the country. We also reviewed metrics developed for more intensive forest surveys, including those available from U.S. Forest Service Forest Inventory and Analysis methods (Mitchell et al. 2006, Tierney et al. 2009).

THE METRICS TABLE

A list of Level 2 metrics for forests is provided in Table 4, organized by the major ecological attributes: Landscape Context, Size, Vegetation and Soils. Metrics were developed through workshops and field trials each year for two years (2007, 2008) in the Northeast and Midwest United States, inviting Heritage program ecologists to review and critique the methods. Details are provided in Appendix A.

Each major ecological attribute contains 1 or more metrics (in bold), except for vegetation, which contains 5 metrics, for a total of 11 core metrics. These are primarily condition metrics, but occasionally a stressor metric is used as a substitute if obtaining the condition metric is too costly or hard to calibrate (e.g. Surrounding Land Use is a stressor metric that substitutes for a Surrounding Landscape Condition metric).

For upland forests, Hydrology is not considered a separate major attribute, but a specific hydrology metric is included within Soils/Substrate for moist or riverine associated upland forests where alterations to hydrology may be relevant.

In addition to the condition metrics, a variety of stressor metrics and checklists are available in order to assess the level of stress (threat impacts) on a given site (occurrence or stand). The information can be helpful in interpreting reasons for the current level of integrity, or changes to integrity over time, and in suggesting management options for improving integrity, if that is a goal.

Table 4. Level 2 (rapid field based) metrics for assessing temperate upland forest condition and stressors: Overview of metrics. Tier: 1 = Remote sensing based metric, 2 = Rapid field based metric. Metric Type: C = condition. S = stressor or checklist (grey shaded cells).

Major Ecological Attribute	**Key Ecological Attribute**	**Metric Name**	**Tier**	**Metric Type**	**Metrics Definition**
LANDSCAPE CONTEXT	Landscape Structure	**Landscape Connectivity**	1,2	C	A measure of the percent of unaltered (natural) habitat within a specified core and supporting landscape areas. E.g., core landscape = 4,000 ha / 10,000 ac , supporting landscape = 40,000 ha / 100,000 ac.
	Landscape Composition	**Surrounding Land Use**	1,2	S	An index of the intensity of human dominated land uses within a specified landscape area (E.g., core landscape = 4,000 ha / 10,000 ac, supporting landscape = 40,000 ha / 100,000 ac.
		Buffer Index	1,2	C	An index of the buffer characteristics surrounding the wetland, using 3 measures: 1) Percent of Wetland with minimum Buffer, 2) Contiguous Area of Buffer within buffer zone, and 3) Buffer Condition.
	Landscape Context Stressors	*Landscape Stressors Checklist*	*2*	*S*	*A checklist and impact assessment of stressors that could affect landscape context condition.*
SIZE	Size	**Patch Size**	1,2	C	A measure of the current size (ha) of the occurrence or stand.
		Patch Size Condition	1,2,	C	An assessment of the naturalness of the current size of occurrence or stand.
VEGETATION (BIOTA)	Community Structure	**Vegetation Structure**	2	C	An assessment of the proportion of structural stage or age-class distribution, based on canopy and stem-size characteristics of the vegetation layers.
		Coarse Woody Debris	2	C	An assessment of the overall accumulation of coarse woody debris, both standing and fallen logs.
	Community Composition	**Vegetation Composition**	2	C	An assessment of the overall species composition and diversity, including by layer, and evidence of negative impacts of diseases or mortality.
		Relative Percent Cover of Native Plant Species	2	C	A measure of the relative percent cover of the plant species that are native to the region. Typically estimated by subtracting exotic species cover from total absolute species cover.
		Vegetation Woody Regeneration	2	C	An assessment of the saplings and/or seedling regeneration found in forest ground layers.
	Biotic Stressors	*Indicator Species – Invasive Exotic Plants (opt.)*	*2*	*S*	*The percent cover of a selected set of exotic species that are considered invasive. Could be refined to include aggressive native species.*

		Biotic Condition Stressors Checklist	*2*	*S*	*A checklist and impact assessment of stressors that could affect biotic condition.*
SOIL	Physical Structure	**Forest Floor Condition**	2	C	An assessment of the extent of soil trampling and compaction, erosion, and the presence of pit and mound topography.
	Hydrology*	Hydrologic Alterations (opt.) (moist & riparian upland forests)	2	C	An assessment of the degree of alteration of hydrological regimes to moist and riparian forest types.
	Physical/Chemical Stressors	*Air Pollution*	*1*	*S*	*An assessment of the impacts of air pollution stresses.*
		Physical Stressors Checklist	*2*	*S*	*A checklist and impact assessment of stressors that could affect physico-chemical condition.*

Condition, Stressor, and Functional Metrics

Metrics are categorized as either Condition or Stressor metrics (Table 4). **Condition metrics** are used to assess the ecological attributes of an ecosystem (e.g., vegetation structure, hydrologic connectivity). **Stressor metrics** are used to measure activities or processes which are known or hypothesized to degrade the condition of an ecosystem, such as air pollution or roads. They summarize the threat impacts to a site. Condition metrics are the primary tool for generating an ecological integrity rank. Stressor metrics can, however, be a rapid and cost-effective way of assessing the likelihood that a system is in good condition, but they typically should be scored separately from condition metrics and used as supporting information. Separating the metrics into these two categories also allows the ecologist to assess the relative correlation of stressors to condition.

Functional or Ecosystem Services metrics are a third kind of metric that assesses the ecological service of an ecosystem (e.g., forest productivity, floodwater retention). Ratings for these metrics do not directly assess the ecological integrity or stresses to that integrity, and so they are not considered further here. However, when assessing stewardship or sustainability issues, one can bring all three metrics (and even others, such as socio-economic ones) into an evaluation. Here we focus on ecological integrity.

Tier and Level of Metric

Metrics may belong to one of three possible "tiers," referring to levels of intensity of sampling required to document a metric (Table 4). Tier 1 metrics are able to be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 typically require some kind of ground sampling, but may require only qualitative or semi-quantitative data. Tier 3 metrics typically require a more intensive plot sampling or other intensive sampling approach. For a given level of assessment (e.g., level 2), the majority of the metrics will also be at that tier (tier 2), but there is flexibility to bring in metrics from other tiers. For example, in a suite of some 10-15 metrics for a Level 2 assessment, one could choose to include several tier 1 metrics to assess landscape context, and include a tier 3 metric to assess vegetation composition.

METRIC RATINGS

For each metric, a rating is developed and scored, usually in a 4-category scale, from excellent (A) to poor (D), but sometimes 3 or 5, depending on the sensitivity of the metric (See Appendix A). The background, methods, and rationale for each metric and rating are provided in a separate Protocols document (Faber-Langendoen et al. unpubl).

FOREST LEVEL 1 ASSESSMENT AND LANDFIRE VEGETATION MODELS

THE PROBLEM – ASSESSING VEGETATION CONDITION AT LEVEL 1

A generic Level 1 assessment method has been developed for all ecosystems (Faber-Langendoen et al. 2008). Our conceptual model emphasizes several major ecological attributes for a level 1 assessment (Table 5).

Table 5. A draft ecological integrity table for a level 1 assessment.

The table is applicable to all natural ecosystems. Vegetation Structure (Or Vegetation Structural Class Distribution) is a very difficult metric to obtain information for.

Rank Factor	Major Ecological Attribute	Indicator/Metric
LANDSCAPE CONTEXT	**Landscape Context**	Landscape Connectivity
		Surrounding Land Use Index [or Landscape Condition Model Index]
		Buffer
SIZE	**Size**	Patch Size
		Patch Size Condition
CONDITION	**Vegetation**	**Vegetation Structure** **Or Vegetation Structural Class Distribution**
		Vegetation Composition
		Relative Percent Cover of Native Plant Species (opt.)
		Invasive Exotic Plants
	Soils	Soil/Substrate Condition
		On-Site Land Use Index
	Hydrology (opt)	Hydrologic Alterations

NatureServe’s Level 1 assessment methods originally relied on land cover map information from the National Land Cover Data sets (NLCD), but recent completion of the national ecological systems maps of the coterminous U.S. available through Landfire (Comer ……) have provided an unprecedented level of information for improving Level 1 ecological integrity assessments. For example, for Landscape Context, we can address the landscape connectivity metrics using the Ecological Systems maps (also available through a Landfire initiative!), whereby all natural ecosystems surrounding a given occurrence are treated as contributing to natural connectivity. (Fig. 2)

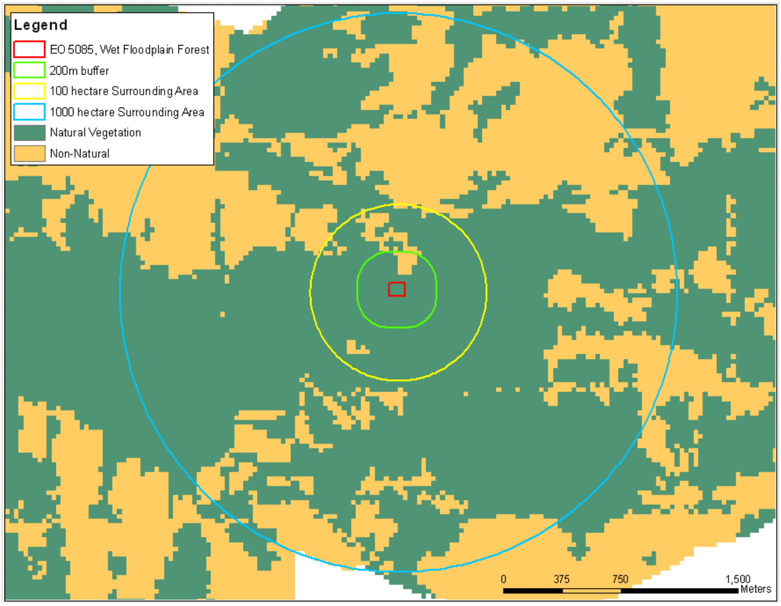


Fig. 2. Example of Landscape context metrics are applied at two scales, and the data to assess these metrics is available from the National Landfire Systems map.

The National Ecological systems maps, coupled with widely available Land use data, provide the data for other metrics of Landscape Context, Size and even Abiotic Condition (Table 5). More challenging, however is addressing metrics for Biotic Condition, such as Vegetation Structure, Vegetation Structural Class Distribution, or Vegetation Composition. In fact, these metrics are very challenging to use for Level 1 assessments.

But the National Ecosystems Map does condition data relevant to addressing the Vegetation Structural Stage Class, which is a strong indicator of natural processes. Here we develop an example of how the map can help develop the indicator and fill a critical need in the Level 1 EIA Assessment.

ASSESSING VEGETATION STRUCTURE USING LANDFIRE DATA

We take the following approach. For any given ecological system, we can use the Landfire VDDT models to determine the proportion of structural stages that are expected under natural disturbance regimes (REFS). VDDT models exist for each Ecological System in the U.S. (REFS). We can then use the Landfire layer of structural stages to rate the Vegetation Structural Class Distribution metric for that system.

As an example, we use the Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland. Its disturbance regime is summarized as follows:

Disturbance Description

> Frequent, low-intensity fire provides the dominant natural ecological force. Component communities are naturally burned every few years, many averaging as often as every 3 years. Fires are naturally low to moderate in intensity. They burn above-ground parts of herbs and shrubs, but have little effect on the fire tolerant trees. Vegetation recovers very quickly from fires, with live herbaceous biomass often restored in just a few weeks. Many plants have their flowering triggered by burning. Fire is important in creating the structure of the vegetation. In the absence of fire, less fire-tolerant species increase and others invade the system. The scrub oaks and shrubs, kept to low density and mostly reduced to shrub size, become tall and dense and can suppress tree regeneration. Herb layer density and diversity decline. However, even in the absence of fire, given the poor soil conditions of most sites, it would take a number of years for a hardwood mid-story to develop and even then some longleaf regeneration continues to occur.
>
> Canopies are believed to naturally be many-aged, consisting of a fine mosaic of small even-aged groves driven by gap-phase regeneration. Longleaf pine is shade-intolerant and slow to reach reproductive age, but is very long-lived. Most plants in these systems appear to be conservative, living a long time and only rarely sexually reproducing or colonizing new sites (NatureServe 2006).

It belongs in Fire Regime Group I, with a 0-35 year frequency of surface severity fires (3-5 yrs may be typical). Stand replacing fires have a probability of occurring ever 132 years, and mixed severity fires every 370 years.

We accessed information on the distribution of the longleaf pine system from the Landfire map, including structural stage information, across its entire range, and then focused on one management unit area, Ft. Bragg, North Carolina (Fig. 3).

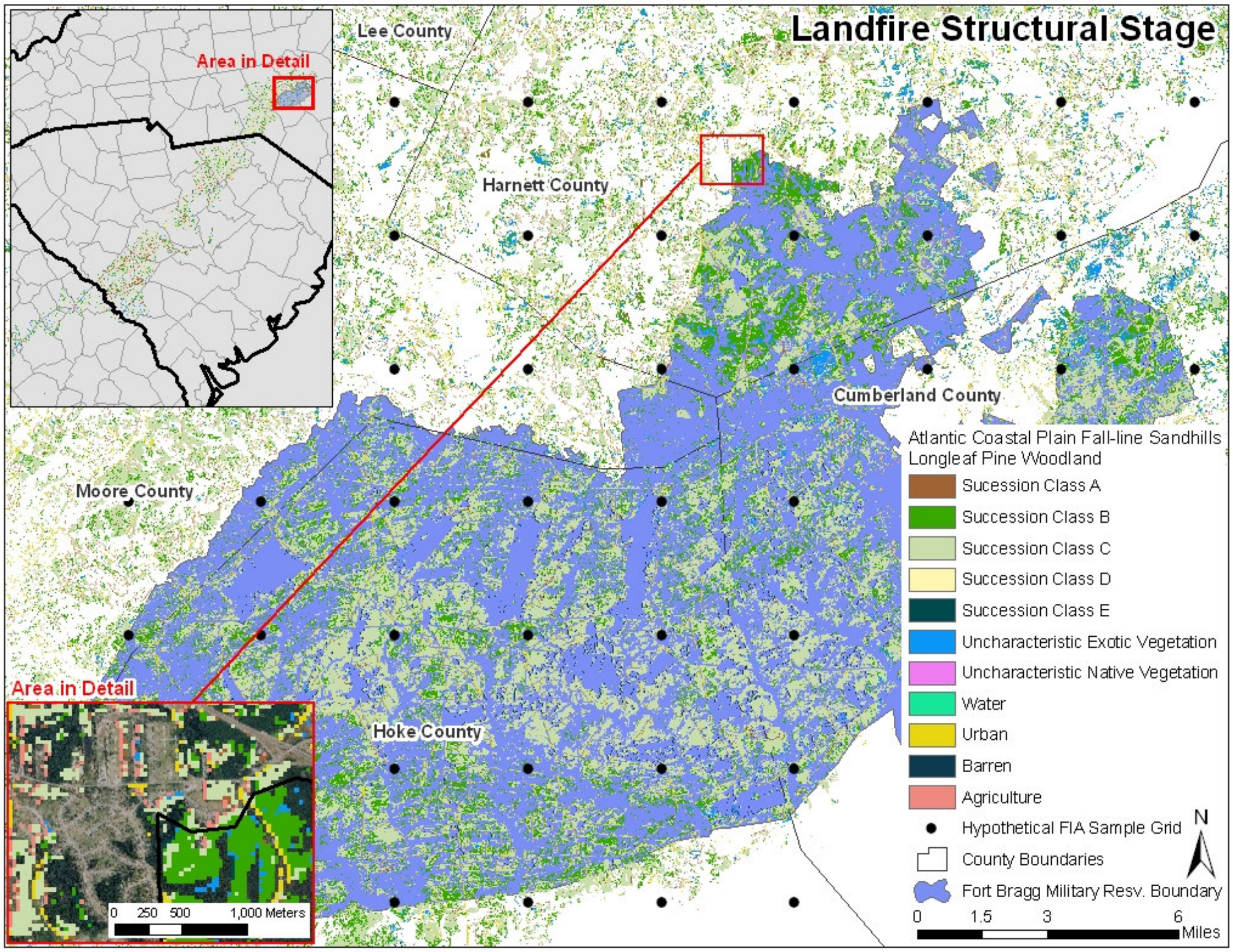


Figure 3. Map of Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland in and around Fort Bragg, NC. Map is based on the Landfire map (REF), and shows the structural stage assignment for each pixel of the type. Overlain on the map is a hypothetical grid of U.S. Forest Service FIA sample points (based on 1 point per 6,000 ac), of which 26 fall within Fort Bragg. Inset in lower left shows the details on structural stage mapping, and the inset in upper right shows the range wide distribution of the system from Georgia to North Carolina.

Using the map data, we suggest developing a metric rating for Vegetation Structural Class Distribution for this system by scoring the level of departure of the observed structural stage proportions from that of the expected based on VDDT models. We can assess level of departure at two scales, a site and a county. We used Fort Bragg as one unit of comparison. It is a military base, with a total area of 148,609 acres (232.2 sq mi) (6,013 km^2). We also scored the ecological system across entire counties (Harnett, Moore, Cumberland, and Hoke), but, as the percentage varied little at the county level, we only report the summary for all counties (Table 6, Fig. 4).

Table 6. Comparison of structural stages of Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland across its range and at Fort Bragg, NC.

5-stage model	A	B	C	D	E
Landfire VDDT model	**13%**	**5%**	**40%**	**40%**	**2%**
All Surrounding Counties - excluding Fort Bragg	2%	21%	56%	1%	0%
Fort Bragg	2%	23%	59%	1%	0%

4-stage model	A	B	C+D	E
Landfire VDDT model	**13%**	**5%**	**80%**	**2%**
All Surrounding Counties - excluding Fort Bragg	2%	21%	57%	0%
Fort Bragg	2%	23%	60%	0%

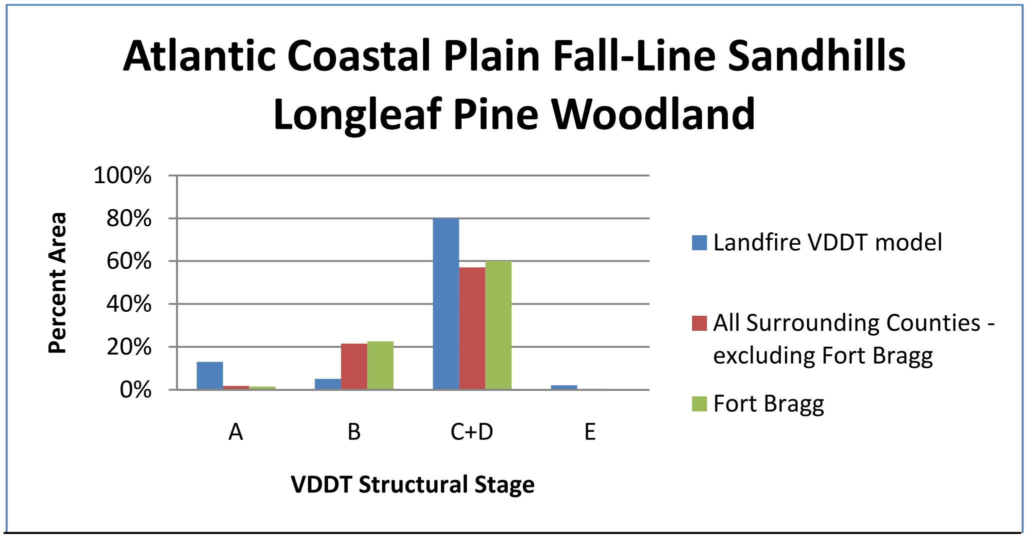


Figure 4. The same data able x. Comparison of structural stages of Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland across its range and at Fort Bragg, NC.

At this time we have not specified how the ecological integrity rating would be applied, but it would follow something like the form shown in Table 7.

Table 7. Vegetation Structural Class Distribution metric, based on Landfire VDDT model.

	Ecological Integrity Assessment Ratings		
Metric	A B	C	D
Expected Structural Class Distribution: Landfire VDDT model.	**Structural Class Distribution is very near (A) to acceptably near (B) the percentage distribution of structural classes.**	**Structural Class Distribution is outside, but near acceptable limits for the percentage distribution of structural classes.**	**Structural Class Distribution is well outside the percentage distribution of structural classes. Strong restorative management is needed.**

Conclusion

Landfire data hold great promise as one source of information on vegetation structure for our Ecological Integrity Assessments at level 1. There are many caveats to be added in terms of accuracy of this data for level 1. For that we need ground data, which brings us to the USFS FIA data set discussed in the next section (see also Fig x for how FIA data would contribute to an assessment of the structural stages of the longleaf pine type.

Next Steps

1. To explore the full range of VDDT models for all Ecological System types, and determine how to use these to guide applications of a Vegetation Structural Class Distribution metrics.
2. Develop statistical criteria to evaluate levels of departure from the model that determine the ecological integrity rating for the Structural Class Distribution model.
3. For forested ecosystems, use FIA data as ground-truth data for the VDDT models (see section below).
4. Demonstrate how this one metric fits into a larger EIA assessment (see Table 5 above).
5. Conduct a pilot ecological integrity assessment throughout the range of an ecological system, using a landscape-unit based approach (e.g., watershed, subsection).

FOREST LEVEL 2 ASSESSMENT AND THE USFS FIA PLOT DATA

The Problem –Assessing Vegetation Condition at Level 2

NatureServe has developed methods for ground-based surveys of ecological integrity, especially for wetlands (Faber-Langendoen et al. 2008) and forests and woodlands (see Faber-Langendoen et al. 2009, Tierney et al. 2009). For Level 2 assessments, ground data provide an opportunity to refine Biotic Condition scales to finer levels of classification, such as Formation or Ecological System. But now, the problem becomes how to identify metrics and data to address Biotic Condition that are sensitive to different characteristic of integrity among different forest and woodland types.

FIA DATA

One widespread source of data for forests is that of the U.S. Forest Service (USFS) Forest Inventory and Analysis (FIA) dataset. In fact, both tree structure and composition data are available through the FIA dataset. Thus it is not surprising that various researchers have turned to this data set directly, or modeled their protocols around this data set (REF).

FIA data provide an important source of data on the condition of U.S. forests. There are several reasons for this:

- Consistent plot design
- Statistically-based sample design
- Repeat sampling of permanently registered plots every 7-15 years
- Continuous program, since 1960s.
- Detailed information on each stem in a plot
- Information is collected on all tree species (for at least the last 20+ years.

There are limitations

- The sampling design allocates 1 plot per 6,000 acres. Thus for even relatively large management units, only a few plots may be available for each ecosystem type. For example, at Fort Bragg (148,609 acres, 232.2 sq mi, 6,013 km^2), only a maximum of 26 FIA plots would be available for ALL forested ecosystem types.
- FIA data are best used for assessments at scales larger than the county level.
- Only tree (including regeneration) data are collected, not shrubs and herbs.
- Despite overall consistency in plot and sampling design, there is some variation over time and by region, complicating larger-scale analyses.
- A full plot takes 1 full day, which is expensive.

With respect to NatureServe's EIA method, FIA data best fits into a Level 3 design, because it is a quantitative, plot-based method with a statistically based sampling design. However, as we explore below, the restriction of data collection to only tree data limits how it can be used for EIAs. Still, the question is how to best use this data for ecological integrity assessment. Here we compare the Pennsylvania model addressing Biotic condition (TNC 2008), with that of NatureServe's approach.

PENNSYLVANIA PROJECT

The Pennsylvania project was developed by Dylan Jenkins, Mike Eckley, Emily Just, and Scott Bearer, Ph.D. (TNC 2008). It has the following goals:

> *"This set of attributes is designed to provide forest managers, planners, and stakeholders with a robust but quick and concise diagnostic to characterize ecological and economic forest health. The*

> *carefully selected key ecological attribute set also attempts to create consistent and scalable ecosystem health indicators that can be used across all spatial scales at which The Nature Conservancy and conservation partners work: (forest stand > property > forest block > landscape > eco-region). The data collected for the selected attributes will satisfy FSC CRM program goals and TNC organizational measuring and monitoring requirements, and are replicable among other eastern forested landscapes.*
>
> *Selected indicators contain data able to be generated using industry standard or slightly modified forest inventory protocols and datasets, which also are consistent and available from the USFS Forest Inventory and Analysis Program (FIA). The broad forestry community is completely reliant on the USFS FIA dataset to characterize landscape scale forest conditions, hence we chose a set of standard or slightly modified from standard property-level forest inventory attributes that could be directly compared against FIA data at the landscape level. Similarly we chose attributes that we believe would provide a clear picture of stand and property level ecological conditions that are not only ecologically diagnostic, but managerially feasible to collect using inventory protocols familiar to the forest management industry and that would be useful for assessing both economic and ecological values."*
>
> *This set of attributes is meant to be relatively small, but very reliable, set of ecosystem health indicators that are not exhaustive. The set of attributes should be used together to assess the health and quality of that forest unit. Generally, using one attribute alone to evaluate forest health or quality should be avoided and assessed with caution. These attributes are meant to provide early warning of failing ecosystems or evidence of strengthening ecosystems, but is not a complex, extensive list of ecosystem factors. "*

Thus, many of the issues NatureServe has encountered in the development of its methods were of primary concern to the Pennsylvania project. Metrics should be a small set that are robust, quick and concise, consistent and scalable, and use readily available data. The authors turn to FIA data to address their needs.

COMPARISON OF PA PROJECT TO NATURESERVE EIA

We compare the metrics suggested by the PA project to the metrics used by NatureServe (see Table 8). We do so at a fairly general level. A main difference between NatureServe's approach and that of the PA project is that they address both ecological and economic values.

Table 8. List of Ecological Attributes From Pennsylvania Project (TNC 2008).

Pennsylvania Attributes	Type of Metric EI – Ecological Integrity ES – Ecosystem Services	NatureServe Attributes
VEGETATION		VEGETATION
COMPOSITION ATTRIBUTES		
KEA 1: Total Stocking	ES	-
KEA 2: Acceptable Growing Stock (AGS)	ES	-
KEA 3: Tree Species Diversity (Richness)	EI	Relative Percent Cover of Native Plant Species
KEA 4: Tree Species Evenness (Richness Distribution)	EI	
		Vegetation Composition
STRUCTURE ATTRIBUTES		
KEA 5: Large Live Trees	EI	Vegetation Structural Stage Distribution
KEA 6: Large Snags	EI	Coarse Woody Debris
KEA 7: Large Coarse Woody Debris	EI	
REGENERATION ATTRIBUTES		
KEA 8: Established Seedlings	EI	Woody Regeneration
KEA 9: Desirable Established Seedlings	ES	
KEA 10: Absence of Deer Impact	EI	Indicator Species – Deer Browse
?		SOILS
?		SIZE
?		LANDSCAPE CONTEXT

There are several issues.

1. NatureServe model attempts to address a fuller range of ecological attributes. PA project addresses vegetation only.
2. NatureServe metrics typically rely on full vegetation surveys, not just trees. PA project is based solely on Tree data.
3. NatureServe metrics address ecological integrity; ecosystems services metrics are treated separately. PA project combines ecological integrity and ecosystems services metrics within the same ecological attribute categories.

CONCLUSION

FIA data hold a great deal of promise for Level 2 and 3 Ecological Integrity assessments. The PA project uses FIA data directly to guide metrics development, and assesses both ecological integrity and ecosystem services. NatureServe EIAs use full vegetation (tree, shrub, herb) to develop metrics, but should consider how to use tree data when that is only available. Further work is needed to determine how well the metrics developed by PA project assess biotic condition.

One metrics – Structural Stage Distribution - can be estimated directly from FIA data (see Goodell and Faber-Langendoen 2007). In addition, this metric is a ground-based version of the Vegetation Structural Class Distribution metric developed for Level 1 assessments, so it could provide an important means of verifying that Level 1 metric.

NEXT STEPS

1. NatureServe should consider tailoring some of its Level 2 and 3 metrics so they can be applied based on FIA data, as exemplified by the– Vegetation Structural Stage Distribution metric.
2. Further review of the PA metrics is needed to see if they adequately characterize biological integrity. For example, tree species richness may vary substantially in natural forest types, complicating our ability to use trends in richness as a measure of integrity.
3. We should discuss whether the PA project would benefit from a fuller ecological conceptual model beyond biological condition to include landscape context, size and abiotic condition.
4. FIA data have 1 plot per 6,000 acres. Many conservation applications for site or landscape analyses need a finer grain of analysis. Further discussion is needed to determine the appropriate scales at which conservationists may find the FIA data relevant (including both ecosystem type and spatial scale) and how best to supplement the design.

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[to be whittled down]

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APPENDIX A. Temperate Forest Metric Ratings: Level 2

Level 2 (rapid field based) metrics for assessing temperate upland forest condition and stressors: Metric Ratings. Tier: 1 = Remote sensing based metric, 2 = Rapid field based metric. Metric Type: C = condition based metric. S = stressor based metric or checklist (grey cells; if rest of rows are also shaded grey, then metric is not used directly to assess condition, but is considered informative).

Major Attribute	**Metric Name**				*Metric*	*Rating*	*Criteria*
		Tier	**Metric Type**	**Excellent (A)**	**Good (B)**	**Fair (C)**	**Poor (D)**
LANDSCAPE CONTEXT	**Landscape Connectivity (core, supporting landscapes)**	1	C	Intact: Embedded in 90-100% natural habitat; connectivity is expected to be high.	Variegated: Embedded in 60-90% natural habitat; habitat connectivity is generally high, but lower for species sensitive to habitat modification.	Fragmented: Embedded in 20-60% natural habitat; connectivity is generally low, but varies with mobility of species and arrangement on landscape.	Relictual: Embedded in < 20% natural habitat; connectivity is essentially absent.
		2	C	Intact: Embedded in 90-100% natural habitat; connectivity is expected to be high; remaining natural habitat is in good condition (low modification); and a mosaic with gradients.	Variegated: Embedded in 60-90% natural habitat; habitat connectivity is generally high, but lower for species sensitive to habitat modification; remaining natural habitat with low to high modification and a mosaic that may have both gradients and abrupt boundaries.	Fragmented: Embedded in 20-60% natural habitat; connectivity is generally low, but varies with mobility of species and arrangement on landscape; remaining natural habitat with low to high modifications and gradients shortened.	Relictual: Embedded in < 20% natural habitat; connectivity is essentially absent; remaining natural habitat generally highly modified and generally uniform.
	Surrounding Land Use (core, supporting landscapes)	1,2	S	Average Land Use Score = 1.0-0.95 (see Protocols document for scoring).	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4
	BUFFER INDEX Length	1,2	C	Buffer is > 75 – 100% of occurrence perimeter.	Buffer is > 50 – 74% of occurrence perimeter.	Buffer is 25 – 49% of occurrence perimeter.	Buffer is < 25% of occurrence perimeter.
	Contiguous Buffer			Contiguous Buffer is > 75 – 100% of buffer zone (200 m).	Buffer is > 50 – 74% of buffer zone (200 m).	Buffer is 25 – 49% of buffer zone (200 m).	Buffer is < 25% of buffer zone (200 m).
	Condition			Buffer for occurrence is characterized by abundant (>95%) cover of native vegetation and little to no (<5%) cover of non-native plants, with intact soils, and little or no trash or refuse.	Buffer for occurrence is characterized by substantial (75-95%) cover of native vegetation, low (5-25%) cover of non-native plants, intact or moderately disrupted soils, moderate or lesser amounts of trash or refuse, and minor intensity of human visitation or recreation.	Buffer for occurrence is characterized by a moderate (25-50%) cover of non-native plants, and either moderate or extensive soil disruption, moderate or greater amounts of trash or refuse, and moderate intensity of human visitation or recreation.	Buffer for occurrence is dominated by non-native plant cover (>50%) characterized by barren ground and highly compacted or otherwise disrupted soils, with moderate or greater amounts of trash or refuse, and moderate or greater intensity of human visitation or recreation; OR there is no buffer present.

	Landscape Stressors Checklist	*2*	*S*	*Checklist Rating Under development*			
SIZE	**Patch Size** Matrix	2	C	>5,000	500-5,000	50-500	<50
	Large Patch			>500	50-500	5 – 50	<5
	Small Patch			>10	2-10	0.5-2	0.5
	Linear			> 5 km in length	1-5 km in length	0.1-1 km in length	< 0.1 km in length
	Patch Size Condition	1, 2	C	Stand or polygon is at, or only minimally changed from, its current natural extent (<5%). Changes can include destroyed or severely disturbed (e.g., large changes due to roads, grazing, development, or changes caused by recent clearcutting).	Stand or polygon is only modestly changed from its current extent (5-20%). Changes can include...(see ”Excellent”).	Stand or polygon is substantially changed from its natural extent (20-50%). Changes can include...(see ”Excellent”).	Stand or polygon is heavily changed from its original extent (>50%). Changes can include... (see ”Excellent”).
VEGETATION (BIOTA)	**Vegetation Structure** *Mesic to Dry Forest*	2	C	Old growth dominant, OG > 70%, Mature (M), Pole (P) variable.	Old growth common, or mature dominant. OG = 30-69% of area, or OG > 10% & OG+M > 70%.	Old growth uncommon, or mature common, OG = 10-29% of area, or OG+M = 30-70%.	D [if no E] Old growth absent, mature uncommonn OG <10% & OG+M<30%] D: OG <10% of area, or OG+M=1-30%, or M+P=30-70%. E: OG+M <1% & M+P <30%
	Xeric or Substrate-Driven Forest/Woodland (e.g, Rocky, Flats)			Old growth age dominant, old growth structure common, mature dominant, other stages variable OG > 30% of area, or OG > 10% & OG + M > 70% (based on structure or age).*Note structure less linked to age.	Old growth age common, old growth structure uncommon, mature common, other stages variable OG = 10-30%, or OG+M=30-70%.	Old growth age uncommon, old growth structure absent, mature uncommon, other stages variable. OG < 10%, or OG+M <30% & M+P=30-70%.	Old growth age and structure absent, mature absent, other stages variable OG <10%, or OG+M= 1-30% & M+P<30%.
	Fire Dependent – ground/catastrophic, long rotation - Forest/Woodland				Old growth common, or mature dominant. OG = 30-69% of area, or OG > 10% & OG+M > 70%.	Old growth uncommon, or mature common, OG = 10-29% of area, or OG+M = 30-70%.	D [if no E] Old growth absent, mature uncommonn OG <10% & OG+M<30%] D: OG <10% of area, or OG+M=1-30%, or M+P=30-70%. E: OG+M <1% & M+P <30%
	Fire Dependent – catastrophic, short term - Forest/Woodland			Mature dominant, old growth and other stages variable. M >70%, OG, P, S, variable.	Mature common to uncommon, pole common to uncommon, old growth uncommon or dominant. OG < 10%, or >70%, or M=30-70% or P & S variable.	Mature uncommon, pole common to dominant, or old growth very dominant, sapling variable. OG >90%,or M =10-30%, or M+P >30-70%.	Mature, old growth absent, pole uncommon, sapling or seedling dominant. OG+M absent & P<30%
	Coarse Woody Debris (organic matter	2	C	A wide size-class diversity of downed coarse woody	A moderately wide size-class diversity of downed	A relatively narrow size-class diversity of downed	A low size-class diversity of downed coarse woody debris

accumulation) *Mesic to Dry Forest [maybe same for Fire Dependent – long rotation?}*			debris (logs) and standing snags, with several or more logs and snags exceeding 50 cm dbh / ha, and logs in various stages of decay.	coarse woody debris (logs) and standing snags, with a few logs and snags exceeding 50 cm dbh / ha, and logs in various stages of decay.	coarse woody debris (logs) and standing snags, with no logs and snags exceeding 50 cm dbh / ha, and logs mostly in early stages of decay.	(logs) and standing snags, with logs and snags absent to rarely exceeding 25 cm dbh / ha, and logs in mostly early stages of decay (if present).
Xeric, or Substrate-Driven Forest/Woodland (e.g., rocky, flats)			A wide size-class diversity of downed coarse woody debris (logs) and standing snags, with several or more logs and snags exceeding 30 cm dbh / ha, and logs in various stages of decay.	A moderately wide size-class diversity of downed coarse woody debris (logs) and standing snags, with a few logs and snags exceeding 30 cm dbh / ha, and logs in various stages of decay.	A relatively narrow size-class diversity of downed coarse woody debris (logs) and standing snags, with no logs and snags exceeding 30 cm dbh / ha, and logs mostly in early stages of decay.	A low size-class diversity of downed coarse woody debris (logs) and standing snags, with logs and snags absent to rarely exceeding 30 cm dbh / ha, and logs in mostly early stages of decay (if present).
Fire Dependent Forest/Woodland			Not relevant? Reword to discuss charring of stumps etc?	Not relevant?	Not relevant?	Not relevant?
Vegetation Composition	2,3	C	Vegetation composition is at or near reference standard in species present and their proportions. Lower strata composed of appropriate species, with exotic plants absent or sparse, and tree regeneration good. Native species sensitive to degradation are all present, functional groups indicative of disturbance (e.g., pioneer or early successional trees) are absent to minor, and full range of diagnostic/indicator species are present.	Vegetation composition is close to reference standard in species present and their proportions. Upper or lower strata may be composed of some native species reflective of past degradation (e.g., pioneer or early successional species, lack of regeneration) and exotic plants are low in abundance. Some indicator/diagnostic species may be absent.	Vegetation composition is moderately altered from reference standard in species diversity or proportions, but still largely composed of native species characteristic of the type. This may include weedy (pioneer, early successional) native species that develop after clearcutting or clearing. Regeneration of expected native trees may be sparse. Exotics may be common, but not dominant. Many indicator/diagnostic species may be absent.	Vegetation composition is severely altered from reference standard. Various strata dominated by exotic species or composed of planted stands of non-characteristic species or inappropriately composed of a single species. Regeneration of expected native trees minimal or absent. Most or all indicator/diagnostic species are absent.
Relative Percent Cover of Native Plant Species	2,3	C	>99% relative cover of native plant species.	95- 99% relative cover of native plant species.	80-94% relative cover of native plant species.	D: 50-79% relative cover of native plant species. E: < 50% relative cover of native plant species. N.B. between 5 and 50% native cover, a type may convert to a ruderal or planted (semi-natural) type.
Woody Regeneration	2,3	C	Saplings and/or seedlings present in expected amounts; obvious regeneration.	Saplings and/or seedlings present but less than expected.	Saplings and/or seedling present but low amounts; little regeneration.	No reproduction of woody species.
Indicator Species – Invasive Exotic Plants	*2*	*S*	*No key invasive species present.*	*Key invasive species 1-2% cover.*	*Key invasive species 3-5%.*	*Key invasive species > 5%.*

	Biotic Condition Stressors Checklist	*2*	*S*	*Checklist Rating Under development*			
SOIL	**Forest Floor Condition**	2	C	Presence of humus layer AND pit and mound topography well-developed AND trampled area less than 1%.	Humus layer not well developed, OR pit and mound topography somewhat developed, OR trampled area 1-5%.	Humus layer not well developed, OR pit and mound topography sparse to absent OR trampled area 5-15%.	Trampled area >15%.
	On-Site Land Use	2	S	Average Land Use Score = 1.0-0.95 (see Protocols document for scoring).	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4
	Hydrology (opt.) [draft, needs review]		C	No alterations. No dikes, diversions, ditches, flow additions, pugging, fill present in assessment area that restricts, redirects, or lowers flow. ***pugging = livestock trampled soils**	Low intensity alteration such as roads at/near grade, pugging, small diversion or small amount of flow additions.	Moderate intensity alteration such as 2-lane road, low dikes, pugging, roads w/culverts adequate for stream flow, medium diversion or ditches (1-3 ft. deep) or moderate flow additions.	High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable of lowering water table, large amount of fill, or high amounts of flow additions.
	Air Pollution	*1*	*S*	*Air pollution levels minimal to absent. Rating Under development. This metric could substitute for soil chemistry metrics.*	*Air pollution levels low.*	*Air pollution levels moderate.*	*Air pollution levels high.*
	Physical Stressors Checklist	*2*	*S*	*Checklist Rating Under development*			

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