SPATIAL IMPACT ASSESSMENT OF CONIFER STANDS IN THE HOOSIER NATIONAL FOREST

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Abstract.—Forest management decisions on Federal lands must be administered at many spatial and temporal scales. Forest condition, size class, and cover type at the stand level determine how silvicultural practices today will impact management area and overall forest goals in the future. The Hoosier National Forest (HNF) Land Resource Management Plan lists eight goals for guiding management decisions on the HNF to meet the needs of the people of Indiana and the rest of the United States. Nonnative conifer species were introduced in the HNF in the 1930s-1950s to reclaim abandoned agricultural lands, but perpetual non-native forest stands are in direct conflict with some current goals. The objective of this study is to assess the impact of existing conifer stands on management goals outlined in the HNF Plan. This assessment ranks HNF stands by forest goal values and the relationships with conifer stand cover. The impact of conifer stands on HNF goals was measured at the stand level by examining the relationship between forest goal values and conifer fraction. Forest goal indices are inversely correlated with conifer fraction within Tell City Management Unit stands. This analysis demonstrates how forest goals, and therefore management strategies, vary over both time and space.

INTRODUCTION

Decisions about managing Federal forest land must consider implications at many spatial and temporal scales. Management objectives incorporate national interests (such as directives mandated in the National Forest Management Act[2]), as well as site-specific conditions impacting local ecology and productivity. Management practices must account for both present conditions and those desired in the future. The way that silvicultural practices implemented today will affect the management area and overall goals in the future depends on forest condition, size class, and cover type at the stand level. However, just as forests evolve over time in response to management practices and local ecological and environmental processes, the demands for forest goods and services also evolve in response to societal needs and attitudes.

To guide management decisions on the Hoosier National Forest (HNF) in Indiana, the HNF Land Resource Management Plan (HNF Plan) contains eight goals intended to meet the needs of residents of the State and the rest of the country (U.S. Department of Agriculture, Forest Service [USDA FS] 2006). The eight goals listed in Table 1 outline a management framework for providing forest resources "now and in the future[,]" including "air quality, cave systems, heritage resources, minerals, natural areas, recreation opportunities, scenery, soil, terrestrial and aquatic ecosystems, timber, water, and wilderness" (HNF Plan p. 2-1).

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[2]October 22, 1976 P.O. 94-588, 90 Stat. 2949, as amended; 16 U.S.C.

Table 1.—Hoosier National Forest goals described in the 2006 land resource management plan (HNF Plan).

1. Conservation of Threatened and Endangered Species Habitat
2. Maintain and Restore Sustainable Ecosystems
3. Maintain and Restore Watershed Health
4. Protect our Cultural Heritage
5. Provide for Visually Pleasing Landscape
6. Provide for Recreation Use in Harmony with Natural Communities
7. Provide a Useable Land Base
8. Provide for Human and Community Development

Nonnative conifer species were introduced in the HNF from the 1930s to the 1950s to reclaim abandoned agricultural lands, providing erosion control and a fast-growing forest stock. Of the many conifer species present in the forest today, only eastern redcedar (*Juniperis virginiana*), and eastern hemlock (*Tsuga canadensis*) are thought to have native populations within the HNF. Although fast-growing southern pine species met the objectives at the time, perpetual non-native forest stands are in direct conflict with some current goals described in the HNF Plan.

OBJECTIVE

The objective of this study is to assess the impact of existing conifer stands on management goals outlined in the HNF Plan. This assessment ranks HNF stands by forest goal values and the relationships with conifer stand cover. Key questions answered in this analysis are:

1. What is the relationship between forest goal values and conifer cover?
2. What impact would removal of conifer stands in the HNF have on forest goal values?

Spatial layers representing forest goal values were created by linking goal descriptions in the HNF Plan to available spatial data layer attributes. Forest goal values and percent conifer cover (conifer fraction) were evaluated across individual forest stands in the Tell City Management Unit (TCU).

STUDY AREA

This analysis was confined to the managed forest stands of the Tell City Management Unit on the Hoosier National Forest (see Figures 1a, b). Forests of this region occur within the maple-beech to oak-hickory transition zone of the Eastern Deciduous Forest (Braun 1950, Barrett 1995) and generally contain a high diversity of tree species. The topography can be described as hilly, with slopes typically ranging from 10 to 40 percent. Elevations of the sites vary from 190 to 240 m. The 30-year mean annual temperature is about 11 °C, with mean monthly temperatures ranging from –1 °C in January to 25 °C in July. Mean annual precipitation is 1,100 mm, occurring as rain from March to July and snow from December to February (National Climatic Data Center).

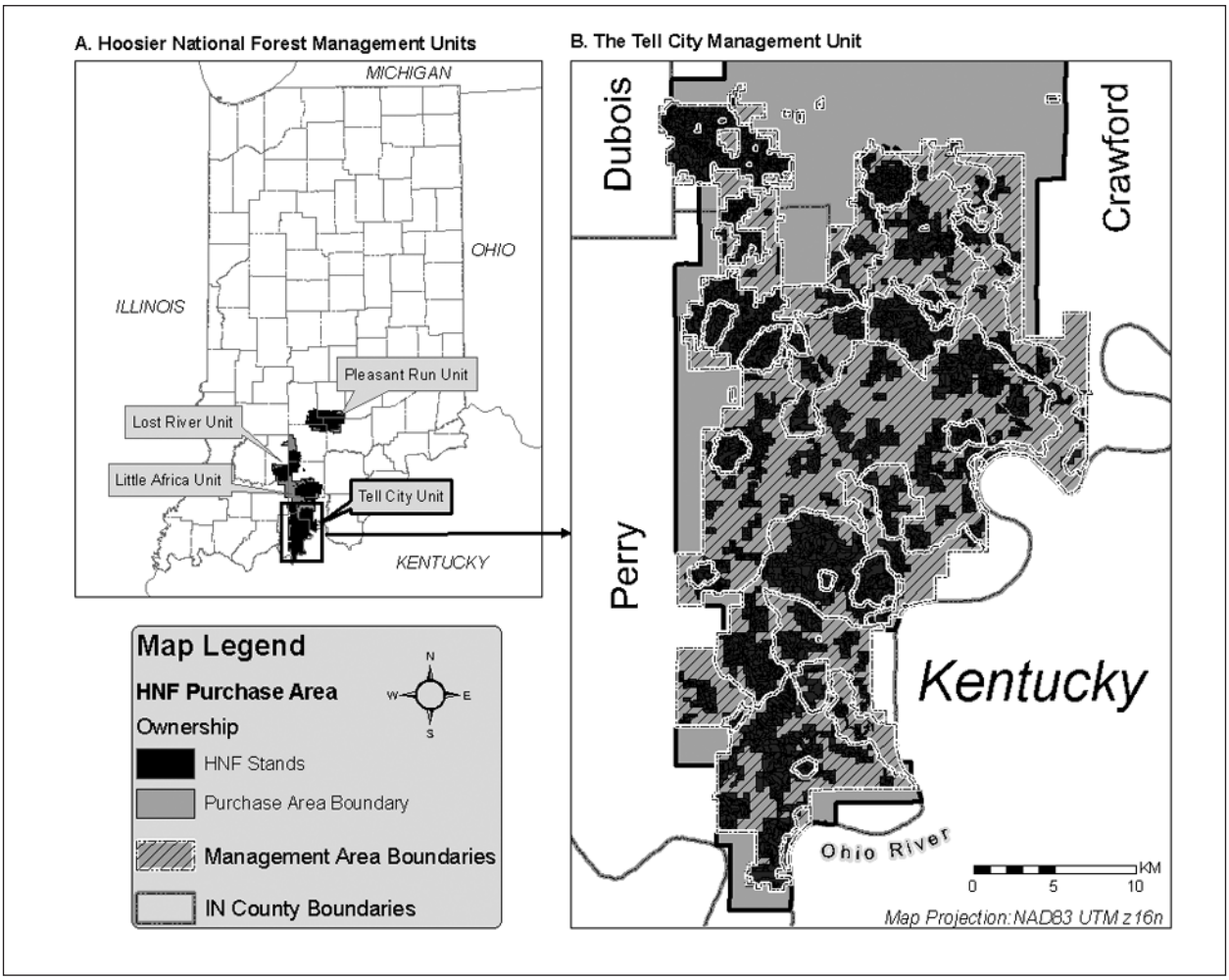

Figure 1.—Geographic units of management within the study area: (A) The Hoosier National Forest in Indiana, and (B) Tell City Management Unit.

METHODS

This analysis used two primary and four tertiary electronic dataset inputs: (1) The HNF stands represent the geographic unit for comparisons between conifer stands and forest goal values. Stand cover types were also an input for forest goal values; (2) Delineated conifer stands represent the most current (2005) and spatially accurate (to within ~ 5 m horizontal accuracy) extent of conifer stands; (3) Ecological land type phase (ELTP) units describe local ecological conditions and are used to characterize ecological goals in constructing forest goal surface values; (4) Management areas; (5) Cave density; and (6) Riparian extent were also utilized to construct forest goal value layers. General spatial summary statistics for all data inputs are presented in Table 2.

DIGITAL LANDSCAPE CHARACTERIZATION

Management Areas and Units

Figure 1 illustrates many levels of geographic management boundaries. Management units (black areas in Figure 1A; USDA FS 2007a) divide the forest latitudinally into four major geographic sections. The purchase area boundary (gray in Figure 1A and B; USDA FS 2007b) defines the congressionally designated geographic

Table 2.—Summary spatial statistics for polygon datasets within the Tell City Management Unit. All area values are in hectares.

	Data Layer	Count	Total Area	Mean Area	STD. Dev. Area
1	*Forest Stands	4,258	32,744	8	8
2	*Delineated Conifer Stands	496	5,192	10	12
3	*Study Area ELTPs	7,947	32,357	4	12
4	Management Areas	74	6,965	941	2,570
5	Cave Density	1	1,366	1,366	0
6	Riparian Areas	1	7,516	7,516	0

* Datasets clipped to HNF stands extent.

area within which HNF authorities can purchase lands to meet forest objectives. Management area boundaries (white dashed outline and hash areas in Figure 1A; USDA FS 2007a) segment the landscape by ecological and social values as they relate to forest goals defined in the HNF Plan (pp. 3-25 – 3-51). Management areas include private and HNF properties.

Properties owned by the HNF are divided into stands (dark areas in Figure 1B) based on forest cover type and local site conditions. Stands were created by the USDA Forest Service[3] in 1998 to represent the smallest geographic unit for which management decisions are made. Thirty-two forest types are identified in the TCU. Forest goal values and conifer fraction were evaluated for each stand in the TCU as the primary unit of analysis for this study. Stand type was also used as an input for calculating forest goal values based on stand descriptions and forest types as they relate to goals and conditions described in the HNF Plan.

Delineated Conifer Stands

Conifer stands for the HNF were delineated from high-resolution infrared aerial imagery as part of a project conducted for HNF[4]. Within the TCU, 496 conifer stands were identified (see Table 3 for spatial summary statistics). The high-resolution imagery (1 m pixel size) and manual accuracy assessment provided a high level of confidence in the final output for stand size, shape, and location. However, it was not possible to perform species identification with this dataset; stands are simply identified as “conifers”.

Landscape Classification

Ecological classification systems define expected ecological conditions on the landscape by ecosystem productivity or expected response to management activity (Bailey 1983). The introduction of the National Hierarchical Framework of Ecological Units (NHFEU) established a system for the spatial segmentation of ecosystems in the United States (Cleland and others 1997). The NHFEUs range from continental ecoregions to stand-sized land units called Ecological Land Types (ELTs) and smaller ELTPs.

An ecological classification system created for the HNF defines 16 ELTPs for the TCU (Zhalnin 2004, Zhalnin and Parker 2009). ELTP descriptions are based on statistical comparisons between topographic conditions and forest types across sampling sites in management units (Zhalnin and Parker 2009).

[3] Stands dataset on file with the Hoosier National Forest Stands, Bedford, IN (contact authors).
[4] Image Matters Inc. May 24, 2009. “Report on Phase II Results of Conifer Stand Delineation of the Hoosier National Forest.” Contact author Jeff Ehman.

Table 3.—Input dataset attribute contributions to forest goal value surfaces.

Input Layer (Attribute)	Forest Goal	Positive Impact Areas	Negative Impact Areas
HNF Stands (Cover type)	FG 1	Cover type includes a listed species	Nonnative forest cover type
	FG 2	Specified habitat type	Single species
ELTP (ELTP)	FG 1	Ciffs	--
	FG 2	Match forest cover type	--
Cave Density	FG 1	> 0 caves/square km	--
	FG 2	> 0 caves/square km	--
Management Area	FG 1	Description supports T/E	Support recreation development
	FG 2	Natural and diverse character	--
Riparian	FG 1	--	--
	FG 2	100-ft riparian buffer	--

Forest Goal (FG) Value Layers

Spatially explicit values associated with forest goals were derived for the study area. Forest goal value layers were created by linking forest goal descriptions listed in the HNF Plan with available spatial data layer attributes. First, the eight forest goals listed in the Plan (see Table 1) were analyzed for relationships to forest cover type. It was determined that only FG 1 (Conservation of Threatened and Endangered Species Habitat) and FG 2 (Maintain and Restore Sustainable Ecosystems) were directly impacted by the presence of conifers. Next, available spatial datasets were selected based on relationships with goal descriptions. Spatial attributes were ranked by whether their relationship was positive, neutral, or negative (1, 0, -1, respectively) in achieving FG 1 or 2.

Spatial data inputs used to derive forest goal surfaces were selected based on availability, scale, and interpretability toward forest goals. Forest goal value surface input data layers were as follows: the HNF stands dataset, HNF Management Areas (USDA FS 2007a), ecological land types for the HNF (Zhalnin 2004), Indiana streams (U.S. Geological Survey and U.S. Environmental Protection Agency 2008a), Indiana water bodies (U.S. Geological Survey and U.S. Environmental Protection Agency 2008b), and cave densities (Indiana Geological Survey 1997). Layer inputs were summed across the study area, converted to positive integers, divided by polygon area, then normalized to derive spatially explicit (per unit area) independent index values ranging from 0 to 1 for forest goals 1 and 2. Descriptions of spatial data inputs and attribute rankings are presented in Table 3.

The value layers for FG 1 were constructed under the following assumptions related to threatened and endangered (T/E) species. The U.S. Department of Interior, Fish and Wildlife Service has identified five federally listed species with part or all of their range within the HNF: Indiana bat (*Myotis sodalis*), Gray bat (*Myotis grisescens*), rough pigtoe mussel (*Pleurobema plenum*), and eastern fanshell mussel (*Cyprogenia stegaria*) (all listed as endangered) and the bald eagle (*Haliaeetus leucocephalus*) (listed as threatened) (HNF Plan p. C-1). Forest cover types described in the HNF stands containing any favored roosting tree species (HNF Plan p. 3-3) of the Indiana or Gray bat were ranked positively and nonnative forest cover types were ranked negatively. Cave locations (cave density) and ecological conditions favoring bat habitat (e.g., ELTP cliffs) were ranked positively. No sites specifically noted for the fanshell mussel, rough pigtoe mussel, or the bald eagle are present in the TCU. Management areas described in the HNF Plan as containing habitat directly related to T/E listed species were ranked positively and areas designated for the development of recreational activities were ranked negatively for FG 1.

FG 2 calls for the maintenance of ecosystems that are diverse in species variety, genetic make-up, and ecological processes; the enhancement of sustainability through provision of a variety of habitats focusing on native species, cave, and riparian ecosystems; and the use of prescribed burning to restore natural conditions (HNF Plan pp. 2-3 – 2-4). Forest stands containing nonnative species or pure stands (forest types listed as a single species) are ranked negatively. The value layer for FG 2 was constructed under these assumptions: Forest stand types matching FG 2 habitats listed in the HNF Plan or that matched expected ELTP descriptions were ranked positively based on expected ecosystem quality. Forest stands listed as single-tree cover types were ranked negatively. Areas where cave density is greater than 1 per square kilometer were ranked positively. Management areas described in the Plan as possessing enhanced habitat or character were ranked positively for FG 2. Due to greater diversity associated with lakes and streams, riparian areas were also ranked positively for FG 2. See Table 3 for a summary of FG value rankings.

STATISTICAL ANALYSIS

The impact of conifer stands on HNF goals was measured at the stand level by examining the relationship between FG 1 and FG 2 and conifer fraction. Figure 2 illustrates the method for calculating forest goal values and conifer fraction for each stand polygon. For stands with a conifer fraction greater than zero, an arcsine transformation was applied and index values were regressed with conifer fraction. Index values for stands with zero conifer fraction were compared to other stands using a Mann-Whitney rank sum test of FG value.

RESULTS AND DISCUSSION

FOREST GOAL VALUE ANALYSIS

Histogram distributions and descriptive statistics for FG 1 and FG 2 are presented in Figures 3A, B. Both distributions reflect a tri-modal statistical artifact of the original integer-based ranking. Index values for FG 1 are more widely distributed throughout the study area, whereas FG 2 values are more concentrated (also reflected in standard deviations). On average, FG 1 values were slightly higher than FG 2, suggesting stands in the TCU may be better suited for preservation of T/E habitat than for sustainability. Comparing the distributions of both classes suggests FG 1 objectives may be met over a larger number of stands; the FG 2 objectives are targeted to more specific stands.

Relationships between FG values and conifer fraction are presented in Figure 4. Forest stands are plotted as points by respective arcsine-transformed forest goal values (Y-axis) and arcsine-transformed conifer fraction (X-axis). Both forest goal indices are inversely correlated with conifer fraction within TCU stands (regression slope statistically < 0). Although the data clouds are dispersed, a trend is evident: forest stands with a higher conifer fraction tend to have lower FG values. Results from the Mann-Whitney rank sum test comparing stands with and without conifers show no significant difference for FG 1 ($p = 0.244$) but do show a significant difference for FG 2 ($p < 0.001$).

Statistical analysis results were convoluted due to the methods used to rank and combine inputs in forming FG index values. The regression analysis demonstrates a trend where lower conifer fraction is associated with higher forest goal values. Furthermore, the non-parametric Mann-Whitney test indicates that FG 2 was significantly different between stands with and without conifers. These results indicate that removal of conifers could improve the value of stands in the TCU for achieving forest goals. However, further analysis is necessary to confirm this assumption.

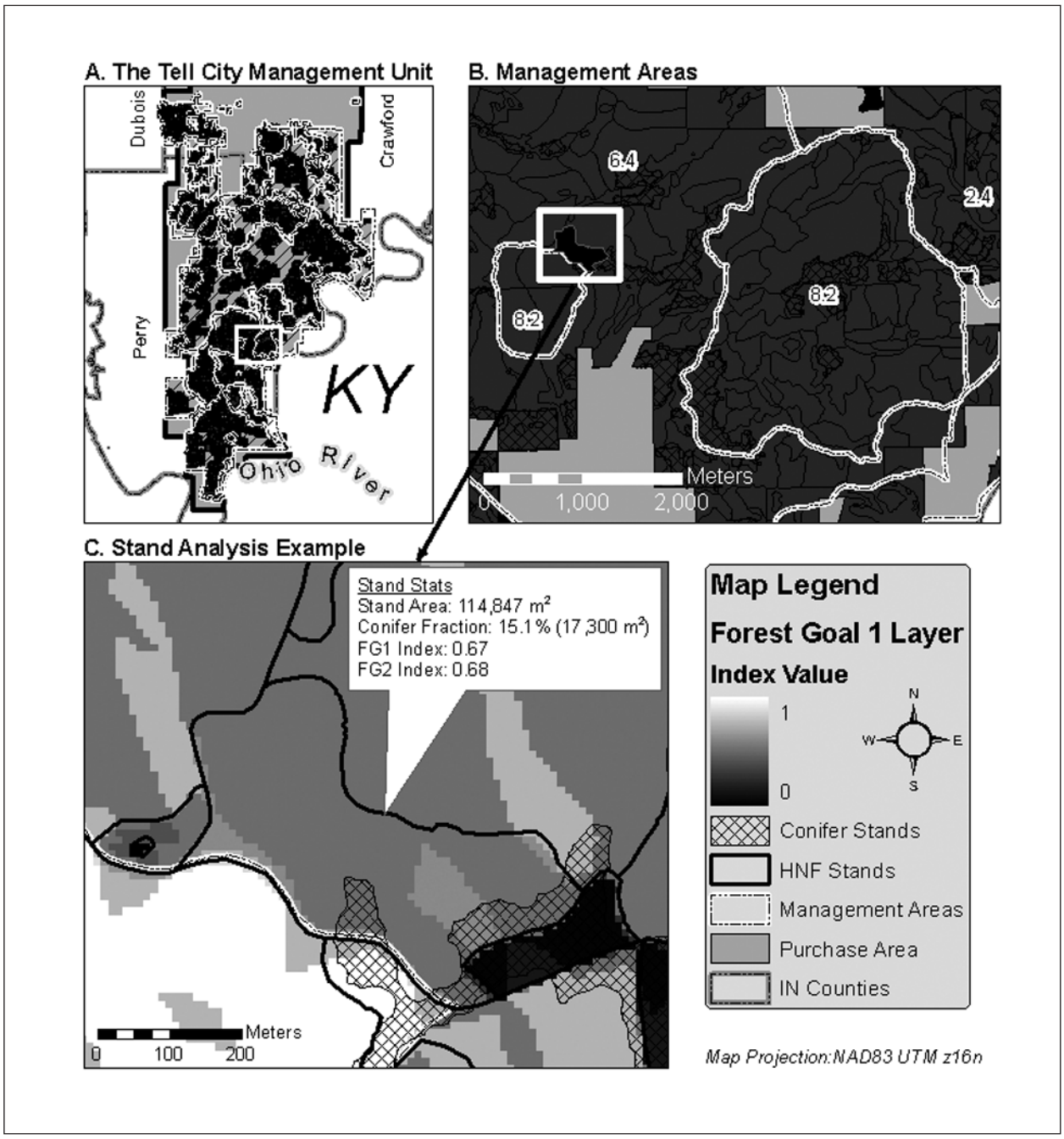

Figure 2.—Example of stand level analysis performed in this study. Multiple scales are displayed to illustrate (A) the TCU study area, (B) relative management areas, and (C) the calculation of stand-level statistics.

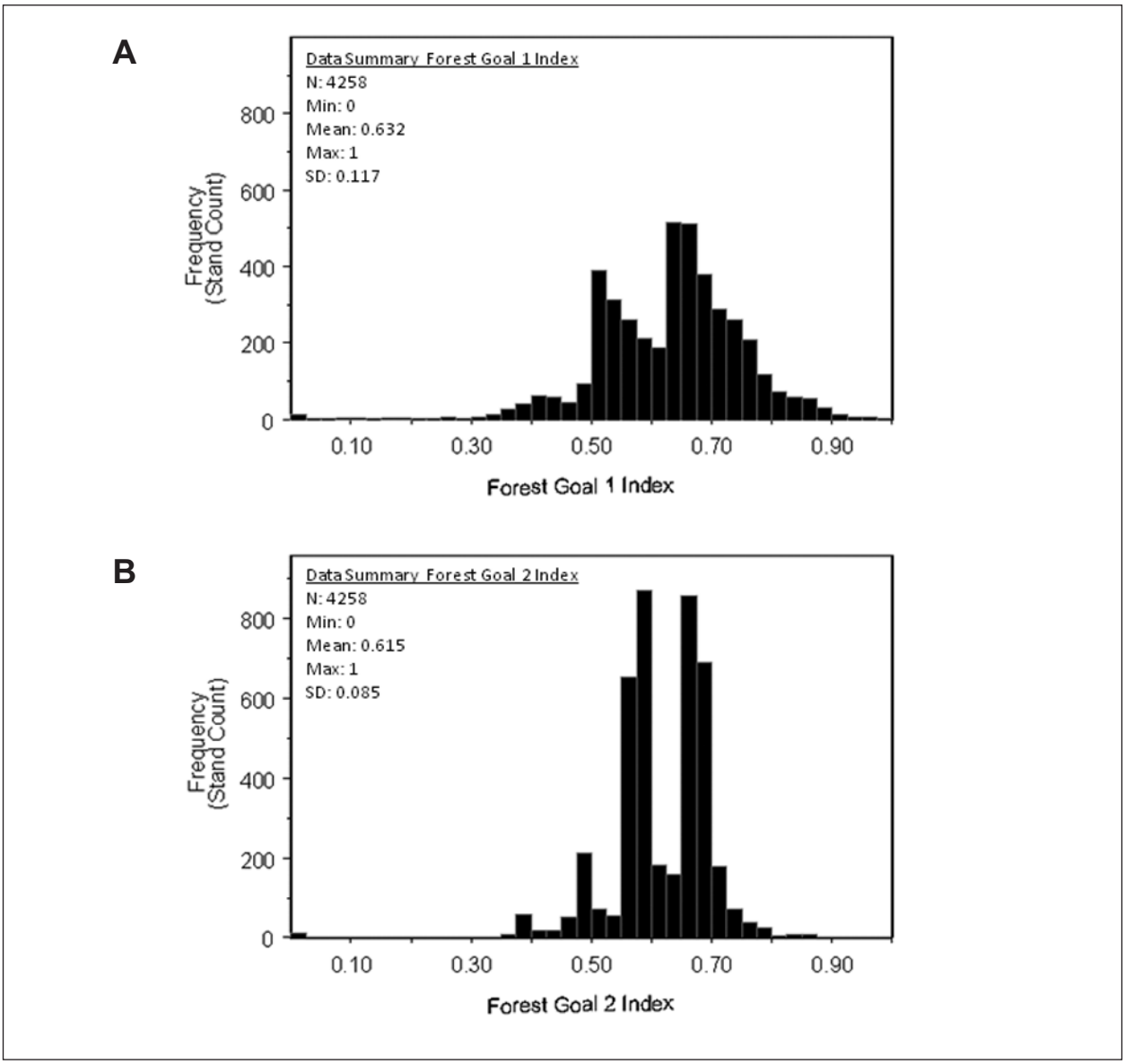

Figure 3.—Frequency distributions and descriptive statistics of forest goal indices across forest stands in the TCU.

CONCLUSIONS

Although this analysis concludes that an inverse relationship exists between land values for some forest goals and the presence of conifers, we do not argue that conifers are "bad" for the forest. Evergreen species provide some ecological and social benefits over hardwoods through year-round ground cover supporting watershed function (FG 3) and desired greenness through the winter (FG 5). Incorporating layers created for additional forest goals could increase the applicability of this analysis. However, a comprehensive study to create spatial layers for all eight forest goals would require extensive data sampling over many disciplines and many spatial scales, and the links between complementary and opposing objectives could confuse rather than resolve the issue of managing conifers. The reasons for examining FG 1 and FG 2 are described above. Sensitivity analysis of inputs and input ranks could quantify the utility of the forest goal evaluation by relating threshold goal values with records of actual management treatments.

Some conifers are native to the study area but were not distinguishable from nonnatives due to remote-sensing processing limitations. As science improves, spatial analysis methods offer possibilities of enhancing

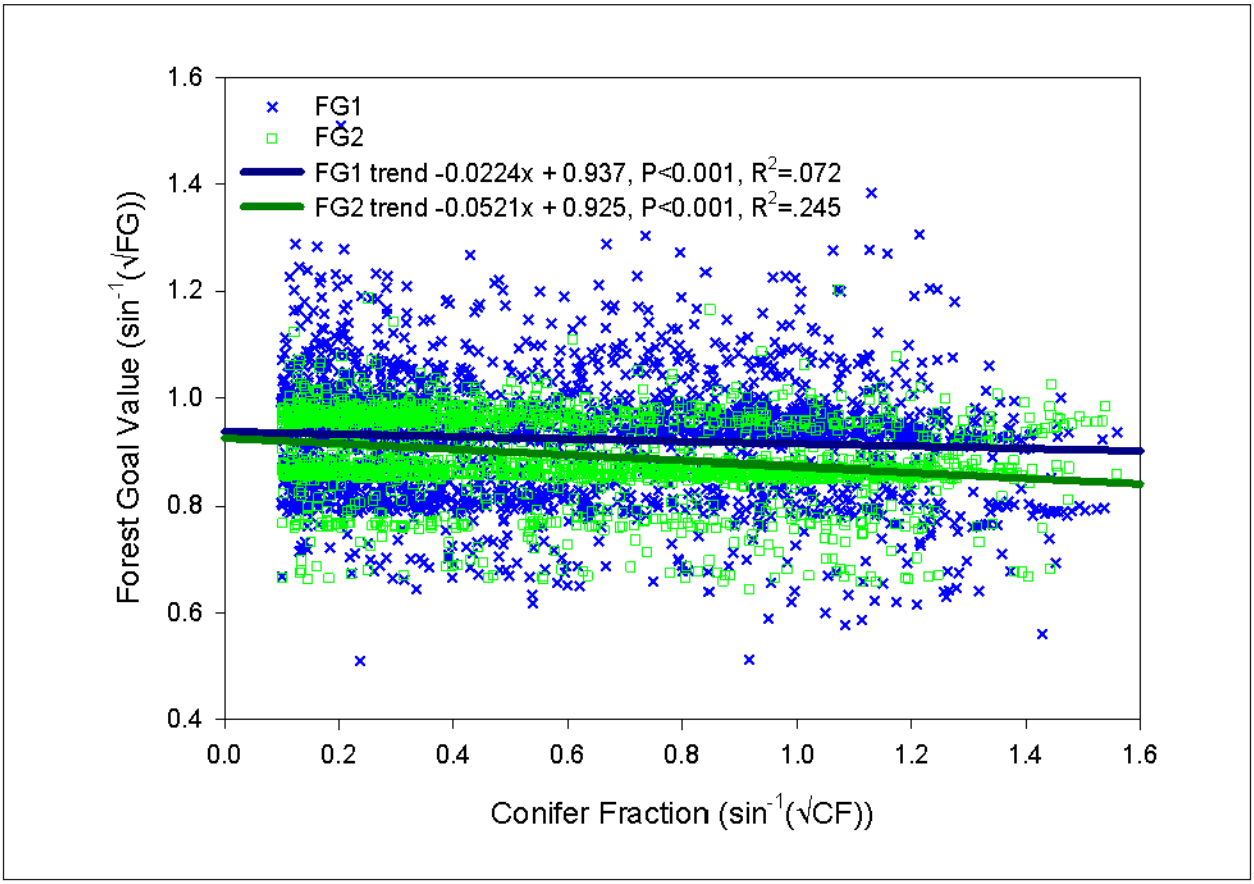

Figure 4.—Forest goal value and conifer fraction plot. Points represent polygons in the TCU. Trend lines represent the results of the linear regression. Data are left transformed to more clearly show the inverse relationship between conifer fraction and forest goal value.

both the identification of stand characteristics such as species and size, and other management considerations important for effective allocation of precious resources.

The primary purpose of this analysis was to demonstrate that forest-wide, spatially explicit information on forest conditions can ultimately inform management decisions. Conifer fraction can be tied with negative or positive landscape impacts, relative to specific management objectives. As spatially explicit management information is developed (e.g., where fire may be used), incorporating information about social (e.g., management area goals) and physical (e.g., presence of conifers) resources will ultimately lead to better informed decisions (e.g., where can minimal burning have maximum impact). This information may be especially important in the HNF, where managers may opt to purchase land to meet their objectives.

The HNF Plan produced in 2006 outlines forest goals that reflect a paradigm shift in forest management in the Central Hardwoods region by defining multiple-use objectives influenced by national, regional, and local stakeholder interests, over purely local objectives. This analysis demonstrates how management actions in the past and present can be linked to future decisions. At the time of planting, fast-growing non-native conifer species provided erosion control on locally degraded sites, and pulp wood for regional markets. Climate-related shifts in species range could change the definition of what is native and therefore the desirability of conifer stands in the HNF. This analysis could provide a value-based assessment of adaptation/mitigation strategies by modeling the ranks of forest types according to expected future conditions.

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