ASSESSMENT OF THE HEALTH AND RESOURCES OF BANKHEAD NATIONAL FOREST, ALABAMA USING GIS AND REMOTELY SENSED DATA

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ABSTRACT

This paper discusses the uses of remote sensing and GIS data to monitor the health and resources of Bankhead National Forest (BNF), Alabama. The investigation focused on improving resource planning, eligibility determination of cultural and economic resources, and forest management, including understanding the disturbance regimes in the forest.

The purpose of the study is to show that environmental disturbance in the BNF is infused in the land use planning systems; how the systems have affected the forest productivity in the past thirty years (1974-2004); how the changes relate to cultural and socioeconomic stability of the area; and to certify that the forest health has not been compromised due to systems change.

The objective is the use of grounded theory research approach to promoted remote sensing and GIS data as instruments for data collection. Data analysis was done in: open, axial and selective coding procedures, to progressively collect and validate data correlations. It also used extensive ground truthing to obtain related measurements affecting the balance of the forest ecosystem. The goal or long-term objective is to be able to monitor the forest health by focusing attention on environmental interactions consisting of outbound---anthropogenic disturbance and inbound—natural disturbance now shaping the land use and the forest management. The goal also include developing a database from the coded data analysis, which constitutes benefits of ecological literacy, such as understanding socioeconomic activities, determination of eligibility of ground disturbance, and monitoring local economic resources and cultural development in the BNF.

INTRODUCTION

Land owners and residents of the BNF have expressed vexation and lack of public trust in the forest management due to environmental changes contributing various disturbance regimes in the forest ecosystem. The mistrust in management challenged *quality* and *share* of the land values, evoking conflicts among the stakeholders and land owners over socioeconomic and resource dividends statuses.

Ecological changes, due to man's ability to manipulate and modify natural systems like "rivers, slopes, ground water, shoreline" and live with the consequences, should not be underestimated (Hamblin, 1978).

"During the past decade, the BNF has experienced Southern Pine Beetle (SPB) infestations at epidemic levels". The epidemic peaked in the summer of 2000. About 10,000 acres of pine forest (loblolly pine) have been killed by this epidemic, which affected trees located within the Sipsey Wilderness area. The epidemic resulted in large acres of standing dead trees, increasing public safety hazard along trails and roads. The standing trees constitute increased forest fire fuel loads (National Forest in Alabama, 2003).

Since established by proclamation in 1936, the demands placed on the BNF include maintenance of "cultural, historical, archaeological, and ethno-botanical sites" and the economic stability of the area (WildLaw, 2003; Riddle, 2003).

The act of monitoring the forest health has more to do with forest management, geospatial planning, database development, and good forest management network, than mere formal remote sensing change detection procedures. For example, an extensive instrumental network is the major reason the medical profession is very stable and booming today. The study, methodically suppressed popular remote sensing approach of change detection but collected data that are significant to geospatial planning.

The internet resource of the month of June 2000 was GIS; where Maneesh Prasad noted the rapid growth of spatial planning in the Asia-Pacific Regions. He saw GIS applications used as integrator and bridge for many professions to enhance human involvements in managing the environment, land use changes, natural resources and emergencies (GeoWorld, 2000).

However, land use action was supported with RS and GIS geospatial planning techniques to express considerate processes that accord the communities and counties within the BNF the right to know how their environments are changing; why the needs for development exist; and why forests and other landmarks are protected and preserved (Catanese and Snyder, 1988). Campbell and Fainstein (1997) stressed the importance of historical roots of planning and justify them as part of land use development content.

METHODOLOGY

The study is on-going and based on the assumption that disturbance in the BNF is primarily due to lack of geospatial planning--failure to provide management with primary details and functional guidelines for decision-making on resource development.

The study used *grounded theory research approach* to emphasize interests in the levels and intensity of interactions in the BNF ecosystem. This was supported with multiple stages of data collection and three-level data coding analysis that were used to evaluate the forest disturbance pattern.

The study first acquired and processed time series TM satellite imagery of the study area from 1975 to 2005, and performed supervised classification—in 14 land classes, represented as k_i, (i = different land classes). The classification was to validate increased or relative abundance of transportation activities and related habitat, which was confirmed with the network or roads in the BNF.

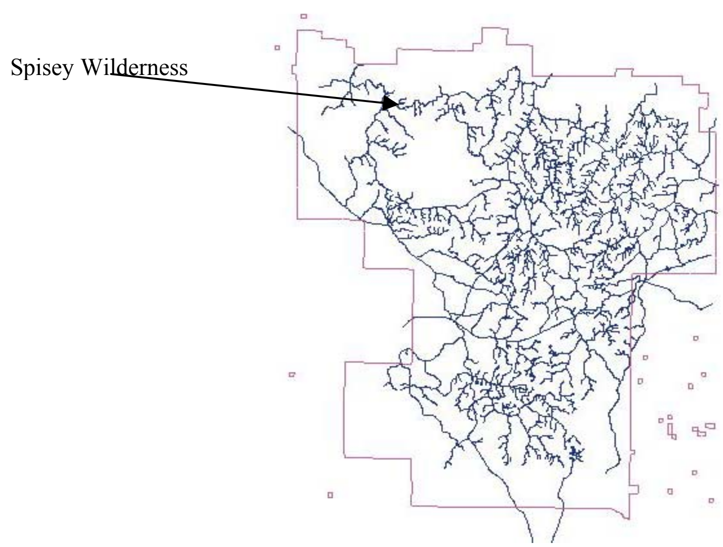

Figure 1. Bankhead road network (Source: U S Forest Service, Double Springs, AL, 2006).

Due to the relative abundance of transportation activities in the BNF, the study chose transportation as the *characteristic parameter* with variables that affect the balance of the forest ecosystem, among which traffic level of service, denoted as ***s*,** was selected as the dependent variable (DV) for ecosystem imbalance around the Spisey wilderness area. It relates to conditions around the Black Worrior Headwaters in the vicinity of Spisey Wilderness, surrounded by: the east and west High Town Path Historic Districts, Indian Tomb Hollow, Flint Creek, Brushy Fork, Carney Creek, and Kinlock Historic District (Irwin et al, 2002).

Two independent variables (IV) or c*haracteristic variables—terrain units* (t_{ms}) *and terrain unit subcategories* (u_{ms}) were chosen relative to **s**. The subscript-$_{ms}$ denotes machine space (all possible spaces designated to transportation). With regards to environmental health, MS is a datum of transportation casualties, with a cross section showing harsh changes in land use due to land use and landscape disturbance (LUSCD) in real time. The MS model used for this study is U. S. highway 33, running tangentially on the east of the Spisey Wilderness.

The transportation plans of this area are covered in sections 1, 2 and 5 of the BNF, according to the transportation plans adopted by the U. S. Forest Service in Double Springs, Alabama.

The variable k_i represents land development approach (land use classification system, levels 1 to 3), and 11 of the 14 land use classes that best relate to the DV were chosen, to include: transportation, urban, agriculture, forest, water, residential, commercial, industrial, institution, wetland, and barren land. The k_i serves as data location constants with noise images that reflect on the DV.

A differential equation in two IVs: $F(t_i, u_i, s, s_{ti}, s_{ui}, s_{titi}, s_{tiui}, s_{uiui}, \ldots) = 0$

Eqn. 1

was used to evaluate the relationships between the DV and the IVs; where $s_t = ds/dt$ and $s_u = ds/du$ are the different interaction values of the respective relationships. Alternatively, the study applied field work assessments and used aesthetical and ethical disciplines as bases to assign same interaction values (on a scale of 0 to 10%), while holding or eliminating t_i as arbitrary function. The location values of u_i are augmented in an interaction eligibility matrix (IEM), expressed in decimal values.

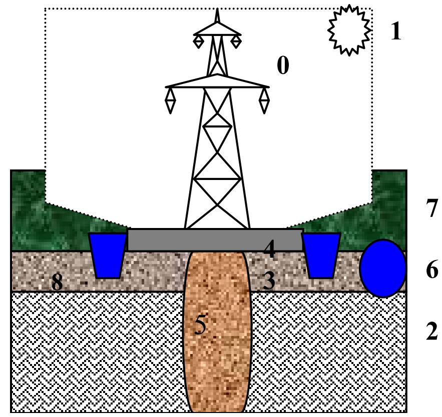

Figure 2a. Cross section of a MS showing terrain units

The **IV**$_1$ = terrain units (t_i) in **(2a) are:** [0]atmosphere, [1]climate, [2]geology, [3]subsoil, [4]land cover, [5]hydrologic system, [6]ROW, [7]mineral resources, [8]drainage, [9]vegetation, and [10]water.

The **IV**$_2$ = terrain units subcategories (u_i) in **(2b) and:** [0]air, [1]rainfall, [2]surface rock structure, [3]original rock structure, [4]landform, [5]topography, [6]soils, [7]soil moisture, [8]agricultural vegetation, [9]grass and top soil, [10]fauna, flora, and [11]wildlife

Figure 2b. Subcats/sensitivity levels of MS

For any suitable u_i that predicted LUSCD in the IEM, was based on the DV, which accounted for infinitely many different combinations of road operating conditions or interactions that develop with traffic *growth*, *distribution* and *circulation*. Traffic grows from stochastic process that develops into normal random distribution; such process like, the number of vehicles arriving a point, grows in real time, and has relaxation periods or values. Thus, the maximum value of the IEM represents maximum interaction with no relaxation. The study holds one-third of the sum of IEM entries to represent a *natural growth* (relaxation) in the trends of the ecological interactions, on the basis that the threshold of casualties in a MS is set approximately e^{-1} (≈ 27%). This matrix analysis involving Eqn 1., was repeated with u_i of t_i, and the relaxation values were augmented in a characteristic facility matrix (CFM). The CFM is the actual relaxation interaction matrix for the MS (values to 2 significant numbers).

The databank developed between IEM and CFM was used to create an ecological dependency matrix (EDM), a square matrix showing correlations of all terrain units' subcategories used in the evaluation of the IEM. The EDM also reveals relative ecological sensitivity of the selected area. The model was derived from the "Davenport Report" for the Pacific Gas and Electric Company, Santa Cruz, County (Robinette, 1973). And Maple software was used for numerical analysis involving large matrix manipulations.

DATA ANALYSIS

The analysis is composed of three stages representative of the open coding, for data-breakdown in the IEM; axial coding, for data reconfiguration in the CFM and selective coding for validation of data relationships in the EDM.

The IEM is an 11 x 11 matrix that can be compressed to a 2 x 11 matrix (See the columns of the IEM), and used to evaluate the function $F(t_i, u_i, s, s_{ti}, s_{ui}, s_{titi}, s_{tiui}, s_{uiui}, \ldots) = 0$, with $F(t_{ms})$ as the arbitrary function. The alternative approach (field note assessments) was used by adopting the IEM as an 11 x 11 matrix, and assigned interaction values with respect to s.

Table 1. Interaction eligibility matrix

(IEM)											
Subcats = Terrain units subcategories											
u_{ms}	k1	k2	K3	k4	k5	k6	k7	k8	k9	k10	k11
u11	1	3	0	2	6	4	6	4	1	1	2
u12	5	1	2	6	4	6	4	1	1	2	0
u13	3	4									
u14	2	3									
u15	6	8									
u16	4	6									
u17	9	4									
u18	7	4									
u19	3	7									
u110	7	2									
u111	3	7									
u1tot	50	49									
u21											
u22											
…											
u31											
u41											
un_x											

The IEM shows the limitations or casualties of the IV within the corresponding terrain unit. The subcategories interact with one another in a terrain unit to reveal the casualties associated with the DV in the MS, hence low and high values in the IEM respectively represents *casualties* and *dynamic interactions* in the MS.

The numerical analysis was based on selected MS terrain units--t_i, and correspondingly new terrain units' subcategories u_i, each time the process was repeated for different land classification--k_i. The CFM shows the possible land classifications--k_1 through k_{11} with the greatest casualty or interaction for s.

The entries in the IEM were numerical values scored on a scale of 0 to 10%, to determine the suitability of u_i to predict ground disturbance activities in k_i. It also shows the casualties (u_i with low scores) of MS resulting from LUSCD. The IEM is a non-relaxed interaction matrix in correspondence with t_i and u_i..

Table 2. Characteristic facility matrix

(CFM)
t_{ms} = MS terrain units

t_{ms}	k1	k2	k3	k4	k5	k6	k7	k8	k9	k10	k11
t11	17	16	y	z	..	..	..	..	..	..	..
t12											
t13											
t14											
t15											
t16											
t17											
t18											
t19											
t110											
t111											
t1tot											
t21											
t22											
…											
tT31											
t41											
…											
tn_x											

By adopting the computation that one-third of the sum of maximum interaction values of the IEM approximates the relaxation to e^{-1}, as casualty threshold for the IV, allowed for data transformation from IEM (non-relaxed matrix) to the CFM (a relaxed matrix). The entries in the CFM are calculated according to equation 2. **Eqn 2.** $y = \sum col_3 k_i/3$ …for all u_i (See Table 2). The process and calculations were repeated about 121 times to complete the entries of the CFM. The CFM shows the terrain with most possible casualties.

Sometimes, noise images ride on the interaction and facilitate u_i casualties, especially when t_i does not support s. Consequently, the interaction levels for u_i get lower. The noise image (ň) is an angular measurement such that: **(ň) =** $\cos\Omega$ **Eqn. 3.**
(Ω = a solid angle, of the radius r that describes the noise surface from the data plane). The surface of the noise image is an ***orthogram (õ)***, a sphere described by radius (r). The inverse distance decomposition (IDD) of the orthogram is ***solagram***—used to approximate data value in the sphere andits orbits around noise or error source (Nwaneri, 2004).

An interaction cut-off point was set for the CFM, and all values above it were used to create EDM, whose entries included all u_i used in the analysis, (See Table 3). When a subcategory u_i repeats, the one with greater interaction value is taken for the EDM. The cut-off is dependent on the details required by management; some management like numerical values to be entered and some prefer shading or (put x-marks) for all values above the cut-off point, to represent correlated or dynamically interactive u_i in the ecosystem.

Finally, a filter was inserted in the EDM to remove all self-interactions. This produces a square matrix with zero-diagonal entries, which may attract other useful matrix decompositions to validate data relationship common with triangular matrix manipulations.
The EDM shows terrain subcategories involved with ground disturbance activity, and one benefit of this process is database development, especially when extant data is unavailable.

MS was used in this study as the characteristic facility due to the fact that the fragmentation of the BNF is a result of transportation, where the majority of the roads are located on ridge tops, altering the original topography of the forest. In other word, remotely sensed imagery revealed a relative abundance of transportation activities (roads) in the NBF. Other consequences of terrain alteration are most likely to affect local drainage, plant and animal species, and their adaptation in the forest.

Table 3. Ecological dependency matrix

(EDM)

u_i = Sub matrices of different terrain units

u_i	u11	u12	u13	u14	u15	u16	u17	u18	u19	u110	u111	u21	unx
u11	0	5	3	2	6	4	9	7	3	7	3		
u12	3	0	x	x	x	x	x	x	x	x	x		
u13	0	x	0	x	x	x	x	x	x	x	x		
u14	2	x	x	0	x	x	x	x	x	x	x		
u15	6	x	x	x	0	x	x	x	x	x	x		
u16	4	x	x	x	x	0	x	x	x	x	x		
u17	6	x	x	x	x	x	0	x	x	x	x		
u18	4	x	x	x	x	x	x	0	x	x	x		
u19	2	x	x	x	x	x	x	x	0	x	x		
u110	2	x	x	x	x	x	x	x	x	0	x		
u111	2	x	x	x	x	x	x	x	x	x	0		
u21													
u22													
…													
u31													
u41													
u_{nt}													

The original BNF structure follows this pattern: Top ridge is moister with 29% chestnut, 13.5% red oak, 13.2% white oak, and 11.4% pine. The upper slopes are drier with 23.5% chestnut, 18.3% pine, 11.9% white oak, and 9.3% red oak. The middle slopes drains very well and has 20.2% white oak, 17.7% chestnut, 13.7% red oak, and 4% pine. The moister lower slopes drain the forest base and have 15.2% beech, 12.5% white oak, 9.8% chestnut, and 3.6% pine (Wills Jr., 1995). But now, the top ridge is mainly used for roads that distribute transportation effects/fallouts on the forest; in some cases, it alters the pattern above, and allows plant substitution. In this order, different plant communities are gradually being removed or share the consequences of different LUSCD regimes in the BNF.

The choice of s for suitable DV that predicts LUSCD, for about 300 roads, in section 1, 2 and 5 of the transportation plan, is evidently significant with a “D” average. This may be one of the major problems affecting the health of the forest, especially when the entire forest is considered as a neighborhood.

The partial differential equation approach develops similar degree of generality in form, due to the fact that the solution involves arbitrary function of the independent variable instead of arbitrary constant, as with ordinary deferential equation. Secondly, its geometrical interpretations are a setting of 3-dimensional Euclidean space, which is equivalent to geospatial concepts and treatments of regions, surfaces and their neighborhoods. This is a gateway to boundary conditions and a focus on space harmony. When the harmony is disturbed, the LUCC suffers most consequences along with other species taking refuge on land. These species become casualties of disturbance as they come in different levels of stability and sensitivity (Dannemeyer, 1968).

Further matrix manipulations are possible with the EDM, such as *LU*--decompositions.

CONCLUSION

The D-average scored for s for the 300 roads evaluated with GIS was considered typical of BNF’s approximately 800 roads. This statistic dominated and formed the conduit of roads that fragment the forest. The “D” score is considered high for the forest environments, and has caused portions of the forest ecosystem to become casualties of LUSCD.

Improvements derived from road closure, as practiced by the forest rangers, are not significant enough provided the MS exists and serve same purpose--constant ground disturbance in the BNF. This indication also shows that a lower s will not serve the best interest of the timber industry that draws raw materials from the forest. Then a self-absorbing situation occurs, where the economy depends on the timber industry, and logging roads create routes that penetrate and infiltrate the forest exotic species and sites, just by mere fragmentation. Consequently, roadless forest is recommended by this study as the only means to build wide-enough forest corridors that would allow good rhythms of wildlife movement and adaptation in the BNF. Seeing that the study is on-going, this recommendation is not final but would be totally supported if it can strongly demonstrate or minimize the proposition that timber logging does not generate more money and economic activities in the region than tourism (Irwin, et al, 2002; Barnhill, 2002).

In general, MS is not an ordinary space--it is a cross section of harsh changes in a natural land use system; it is *the variable to control in monitoring the health of the BNF because* it is dynamically dependent on voluntary/involuntary transportation of materials commissioned in geospatial planning.

The study now charges the forest management to develop a land use program consistent and compatible with the BNF master plan, including the transportation plans; such that it will show consistency in details and specifications that account for the physical, cultural, and spiritual aspects of the forest, and also support the values of the landowners.

Machine space causes huge LUSCD with high echelon of environmental and ecological casualties, which force species migration and isolation, causing unstable habitat. Thus, potential problems and consequences of LUSCD will continue to develop and fragment the BNF.

Inbound disturbance from nature was muted in this study because its consequences are relatively minimal, with the exception of the Southern Pine Beetle (SPB), which also was due to sprodynamic activities (SDA) assumed to be partly contributed by MS.

The forest health is therefore dependent on the integrity, disciplines, ethics, and details infused in its transportation plans for effective decision-making and good management.

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