Spatial Patterns of Vegetation Response to Catastrophic Disturbance

A Preliminary Proposal For Long-term Research at the Pisgah Forest

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Introduction

Most studies of post-disturbance vegetation dynamics have focussed either on broad-scale or on local patterns of plant response and recovery; few have investigated an intermediate scale where spatial patterns of stands or communities are important (however, cf. Bonnicksen and Stone 1982). Examples of broad-scale information relating to wind-damage include: regional summaries of forest loss (NETSA 1941); landscape or forest-wide summaries of damage and resulting vegetation (Gould 1960, Jensen 1939, Fox Forest notes; Canham and Loucks 1984), and summary statistics derived from averaging point samples in communities (Spurr 1956, Hibbs 1979, 1983, Brake and Post 1941, Foster 1988). At the smaller scale studies include; dynamics of single stands (Falinski 1978, Henry and Swan 1974, Oliver and Stephens 1979, Foster 1988), studies of gap dynamics (Hibbs 1982, Runkle 1981, 1982), and physiological, morphological and architectural analyses of individual species or cohorts of species (Sipe unpubl., Hibbs unpubl.).

Ecologists recognize that vegetation development following disturbance is spatially heterogeneous (Whittaker and Levin 1977, Levin and Paine 1974). For example, Pickett *et al.* 1988 (NSF grant) discuss the patchiness of environmental conditions in the post-tornado landscape and the influence that various factors such as survivorship, herbivory, seed bed conditions, propagule availability, and secondary damage exert on vegetation development. However, studies that summarize results, average data or integrate patterns over large areas obscure this heterogeneity and provide a false sense of a neat, well-defined progression. As an example, results in Foster (1988) from the Harvard Pisgah tract summarize the changes in composition and structure of the vegetation over 50 years. Age-structure data shows two distinct cohorts or response classes: hardwoods, with the exception of beech, all date to the hurricane, whereas hemlock and beech include many stems pre-dating the storm. This clumping of data hides the fact that there are discrete stands of pure hemlock that survived the storms, areas of mixed hemlock and hardwood that includes survivors and new saplings, and stands of hardwoods that all date to the storm.

Proposal For New Studies at the Pisgah Tract

As an extension of the past and current work at Pisgah I propose to look at the patchiness of the vegetation resulting from the processes of hurricane damage, and regrowth operating on the pre-hurricane vegetation. Specifically, I seek to describe the vegetation pattern in terms of spatial characteristics (patch size, shape, discreteness), composition (understory, overstory), floristic richness and structure (density, basal area, size distribution, age-structure, vertical stratification). Subsequently, the pattern will be related to: pre-hurricane overstory vegetation, deduced from size and composition of downed wood, surviving trees and extensive classification of old-growth forest; site conditions including soil depth, downed wood microtopography, moisture; landscape features, such as exposure (topex value), slope position, aspect, slope, surface shape (convex, concave); storm damage judged by surviving forest and downed wood, tip-up mounds.

Significance of the Research

This work will expand on existing and past research at Pisgah and the Harvard Forest and will address a spatial scale that has been overlooked in the past and yet is complentary to ongoing studies at both places (Schoonmaker unpubl., Sipe unpubl.). Since the scale and questions are similar to the proposed study by Pickett *et al.* (1988) of the recent Tionesta blow-down the two studies will serve as continual feedback on each other, providing guidance for questions asked at the recent blowdown and insight into early processes that may be difficult to deduce at the older hurricane site. The study will address what I interpret as important emerging areas in ecology: notably the interaction between communities, landforms and disturbance processes (Swanson *et al.* 1988). The work will also provide a field context and empirical baseline information for experimental studies proposed at the Harvard Forest LTER.

Why Pisgah

Most sites in southern and central New England were significantly altered by agricultural practices by the early 1900's. As a consequence, at the time of the hurricane the structure and composition of most of the forests in this region were much different than under presettlement conditions. The altered structure affected the way in which the storm damaged the forest and altered the site (e.g. size of windthrow mounds, amount of downed wood). Following the storm much of the damaged timber was salvaged (NETSA 1941) with coincident modification of site conditions by removal of downed wood, scarification of the ground, burning of woody debris and piling of slash.

At Pisgah the historical situation is quite different and presents the opportunity for studying the disturbance process in a site that has not been directly altered by human activities before or after the storm. The large size of the pre-disturbance trees provide disturbance patterns (e.g. soil wind-throw mounds and downed boles) that would be difficult to find elsewhere in New England and yet were undoubtedly characteristic of presettlement old-growth forest conditions. The structure of the vegetation and disturbance are similar to that at Tionesta, thereby strengthening opportunities for that comparison. Finally, considerable information is known about the old-growth forest, disturbance history and post-hurricane vegetation dynamics at Pisgah. The site is secure for research and preserved for the long-term examination of natural processes.

Methods

Coordinate Grid System

A grid system will be established to serve as a reference for both landform characterization and the identification and mapping of vegetation pattern. The grid will be 30 m, giving 14 columns and 12 rows for a density of approximately 170 points (see Figure 1). The coordinates will be parallel and perpendicular to the northwest and southwest borders. For convenience coordinate designations follow LOTUS 1-2-3 worksheet format (Table 1) and will be alphabetical for columns (A.. CF) and numeric for rows (1.. 72) with A1 starting in the upper left (northeast corner). Every seventh letter and number will be used for the 30-m grid to accommodate finer-scale mapping on a 5-m GIS grid (see Figure 1 and *GIS* section).

The coordinate system will be established in the field using simple surveying instruments. End points along the western (columns) and northern (rows) sides will be marked with metal pipe labelled with lead tags. The interior 30-m points will be marked with 1" PVC pipe labelled with marking paint.

Topographic Survey

Work at the Pisgah tract has been hampered by the lack of a good map showing landscape features and topography of the fairly complex terrain. In order to improve this situation and to provide the physiographic context for the proposed research on forest patch characteristics, a basic topographic map will be compiled.

The topographic benchmark will be a local one to provide relative relief and will be tied into absolute elevation on USGS maps in an approximate way. Starting at A1 the relative elevation will be established by surveying to the adjacent points to the southeast (e.g. G1) and southwest A7, see Fig. 1). By following columns point-by-point a topographic map will be gradually compiled, referenced to point A1.

The advantages of this technique are: (1) it is a rapid method, (2) it is easily managed by a two-person crew and (3) it is suitable for dense woods in rough terrain where long straight shots are difficult. The disadvantages that must be considered are: (1) the point-to-point accuracy is ~ +/- 50 cm, (2) there is no back-sighting to allow for estimate of error or to correct cumulative errors, and (3) the map will not be accurately referenced to an absolute benchmark. To reduce the problems of precision it will be possible to check the extent of errors by calculating elevations of a point through various routes. The major objective in compiling the map is to provide a guide to relative measures of topography, exposure, physiographic placement, etc., and this should be achieved in this exercise.

Landform Survey and General Mapping of the Area

The objective of these measurements is to map prominent features of the landscape to supplement the topographic map. These include: physiographic features such as wetlands, boggy hollows and ridgetops; distinctive landform features such as large windthrows, big snaps, and exposed ridgetops; and research activities such as the plot locations from Figure 3. The survey will be undertaken by walking the transect lines (columns) and noting locations and extent of the features listed above. The final map will provide additional overlays that can be encoded on the GIS or used in conjunction with the topography to produce a base map.

GIS

The establishment of a GIS at Pisgah will serve a number of important functions for the proposed research and for future activities. These include: (1) maintenance of long-term records of research activities and results; (2) generation of new maps from existing overlays to show (a) derived features such as slope, aspect and exposure, (b) combinations of features such as the overlays of physiographic and vegetation overlays, and (c) new perspectives obtained from three-dimensional perspective maps that can be rotated and viewed from any direction; (3) the possibility for detailed stem mapping and spatial analysis and (4) modelling exercises to explore prospective changes in the mapped landscape.

The GIS will be based on a 5-m grid system using 84 columns and 72 rows for a total of 6048 cells. This level of resolution was chosen as it is felt to be appropriate for the current questions and needs and because it provides a manageable number of cells for both encoding and computing.

Future needs for greater resolution can be accommodated for particular parts of the grid or the entire area. Encoding will be done on LOTUS 1-2-3 and on a digitizing table utilizing Arc-Info software (see Equipment and Costs), which have been found to be efficient, rapid, and consistently accurate.

The initial overlays to be encoded directly include: property boundary, topography, physiographic features, research plots and vegetation stands (see *Vegetation Analysis* below). From the topographic overlay various maps that will be derived include: slope, aspect, drainage and exposure. The latter will be calculated for each stand by tabulating the number of grid cells that fall into the East to South (direction of the strongest wind) viewshed of the stand. This number will be assigned a relative value from 1 to 10 based on the range of values calculated. For each stand a separate assessment of topographic relief or roughness will also be calculated.

Vegetation Analysis

Vegetation stands will be identified and mapped using a modified cruise technique that will assess overstory and understory components. Each column line will be followed and stand borders will be identified based on changes in vegetation structure (height, density, evenness) and composition. Borders will be followed over to adjacent column lines so that intervening areas are accounted for. If necessary row lines may also be followed in order to fill out the map and resolve boundary problems. Field maps will be copied and then encoded on the GIS with each stand receiving a distinct number.

Vegetation will be sampled in 20 x 20 m plots. Initially one plot will be sampled in each stand and will be located using a grid-point (30-m grid) as a corner. Diameter measurements will be collected for each stem so that basal area and density can be calculated. Canopy height and density will be recorded and downed wood will be tallied by diameter (top and bottom), length, decay class and mound size. Species lists and relative abundance will be recorded for herbs. Regeneration will be recorded in 5 2 x 2 m plots located in the corners and center of the larger plot.

Once the vegetation sampling is completed a community analysis will be performed using DCA and TWINSPAN to identify vegetation assemblages and species and stand relationships. This step will serve to reduce the number of sampling units (by grouping stands) for further analyses.

Additional Data Collection

In addition to characterizing the stands on vegetational criteria it is planned to examine age-structure, regeneration patterns and other stand features. Some of the necessary data will have been collected in the vegetation sampling; e.g. for size distribution studies, analysis of regeneration density. Other information will need to be collected and much of this (e.g. age-structure) can be done most efficiently by assemblages rather than for each stand. In particular I would like to date trees in each assemblage in order to characterize age-structure and to look for patterns of response to past disturbances. In order to describe patterns of regeneration I would like to sample the distribution of seedlings in relationship to soil disturbance and other factors.

Equipment and Costs

Basic requirements for this project include: field supplies, a field crew, one laboratory research assistant, and digitizing computer equipment.

Field supplies such as metal pipe and PVC pipe have been assembled by J. Edwards. Surveying equipment is currently available at the Harvard Forest. The field crew will consist of D. R. Foster and an assistant. The same assistant could manage the data encoding. Total time would be approximately 3-6 months.

Digitizing equipment is presently incomplete at the Forest. The basic computer facilities are available and a digitizing table (~ $5-8,000) and software (~ $5-10,000) is partially covered by the NSF facilities grant.

Grid Coordinate System for Pisgah

Column Designations

30-m Column Number	30-m Pt.	* * * *	5-m pts		* * * *	
1	A	B	C	D	E	F
2	G	H	I	J	K	L
3	M	N	O	P	Q	R
4	S	T	U	V	W	X
5	Y	Z	AA	AB	AC	AD
6	AE	AF	AG	AH	AI	AJ
7	AK	AL	AM	AN	AO	AP
8	AQ	AR	AS	AT	AU	AV
9	AW	AX	AY	AZ	BA	BB
10	BC	BD	BE	BF	BG	BH
11	BI	BJ	BK	BL	BM	BN
12	BO	BP	BQ	BR	BS	BT
13	BU	BV	BW	BX	BY	BZ
14	CA	CB	CC	CD	CE	CF

Row Designations

30-m Row Number	30-m Pt.	* * * *	5-m pts		* * * *	
1	1	2	3	4	5	6
2	7	8	9	10	11	12
3	13	14	15	16	17	18
4	19	20	21	22	23	24
5	25	26	27	28	29	30
6	31	32	33	34	35	36
7	37	38	39	40	41	42
8	43	44	45	46	47	48
9	49	50	51	52	53	54
10	55	56	57	58	59	60
11	61	62	63	64	65	66
12	67	68	69	70	71	72

7/87

Pisgah
Permanent Plot Locations