GRADIENT ANALYSIS OF SECONDARY DECIDUOUS FOREST VEGETATION OCCURRING ON A SLOPE OF FORT ANCIENT, SOUTHWESTERN OHIO[1]

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Abstract. A gradient analysis was made of the woody vegetation of a secondary deciduous forest on a slope in southwestern Ohio. Coefficients of similarity showed greater variation in the vegetation between different slope eposures than between different slope elevations. Greatest vegetational differences between exposures were for the north-south comparison, while the west-south exposures had the highest similarity. Greatest elevational similarity was within the west exposure. This exposure supported a northern red oak community, while the north exposure supported a sugar maple-oak community, and the south exposure supported a chinkapin oak-northern red oak community. Individual species had different patterns of distribution, indicating a continuum in the distribution of plant communities.

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Fort Ancient State Memorial is situated above the east bank of the Little Miami River in Washington Township, Warren County, near Lebanon, Ohio. The boundaries of the park lie between 84° 5′ and 84° 7′ west longitude and 39° 23′ and 39° 26′ north latitude. The objective of this study was to determine variation in woody vegetation over the slope that extends southward along the river a distance of 800 m from near North Lookout Point. Inclination of the slope is approximately 23°; exposures are from north to west to south. Maximum elevation is 266 m at North Lookout Point, which is approximately 65 m above the river.

Fort Ancient was used by prehistoric Hopewell Indians and by more recent Indian cultures until it was abandoned in 1600 A.D. (Morgan, 1970). According to Moorehead (1890), one of the earliest written accounts of Fort Ancient occurred in 1810, when an article describing its Indian mounds and walls appeared in the magazine *Port Folio*. In 1880's concern grew over the preservation of the site (Wright, 1887; Moorehead, 1890), and on May 11, 1891, the Ohio Historical Society purchased 73 hectares of land as an archaeological preserve. Eight other land purchases have brought the total area owned and maintained by the Society to 277 hectares.

The vegetation of Fort Ancient was greatly affected by Indian occupancy of the area. Some recovery took place between 1600 and pioneer settlement, but there are many historical accounts of disturbance since then. Wright (1887) mentioned Harvard professor Frederic W. Putnam's concerns about damage from agriculture. Randall (1908) reported clearance and restoration of the Fort area with cultivation inside and outside. Farming is believed to have been halted in the park shortly thereafter, but other disturbances contined. For example, from December 1933 through October 1935 the Civilian Conservation Corps (CCC) planted trees in the park and built fences, erosion check dams, and lookout platforms (Morgan, 1970). These CCC activities are not thought to have significantly affected the hillside study site. Fires have burned over the study area, but photographs of damage from the most recent one (1944) indicate that at least that fire probably

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has had little impact on today's forest canopy.

As a result of disturbances, whether natural or artificial, the forest of the study site is secondary. According to Braun (1950) the study area is located on the boundary between the Beech-Maple Region and the mixed mesophytic forests to the south. More recently, Gordon (1969) included the area in his Oak-Sugar Maple Forest. These studies were quite general in their coverage, and consequently this is the first detailed analysis of vegetation in the Fort Ancient region.

METHODS

Three parallel study areas, each 2 m in width, were established along the contour from the north exposure through the west to the south exposure. The distance between the transects was approximately 40 m. The upper transect was 590 m in length, the middle transect 710 m, and the lower transect 800 m. Each was divided into contiguous 2 m × 10 m quadrats. Vegetation data were collected from August 3 to September 20, 1973. In each quadrat the species and diameter at breast height (dbh) were recorded for every woody individual ≥ 2.5 cm dbh. Compass readings of slope exposure were taken in the center of each quadrat. The nomenclature used is that of Braun (1961).

The slope was divided into three general exposures: south, 135° to 224°; west, 225° to 314°; and north, 315° to 44°. Importance values were calculated by summing the relative values for frequency, density, and basal area of the woody species for the group of quadrats under consideration. Comparisons were made between groups of quadrats by using the coefficient of similarity, $C=2w/a+b$, where w equals the sum of the lower of every pair of values and a equals the sum of values from one group and b equals the sum of values from the other group (Sörenson, 1948).

RESULTS AND DISCUSSION

The first question was whether the woody vegetation showed greater differences between slope elevation or slope

TABLE 1

Distribution of woody plant species by slope exposure.†

Species	North Exposure				West Exposure				South Exposure			
	BA*	D*	F*	V*	BA	D	F	V	BA	D	F	V
Acer saccharum	2.3	632	75	85	.7	160	26	25	.2	138	7	8
Tilia americana	7.0	132	30	43	2.0	55	8	15	—	17	3	2
Quercus borealis	8.9	104	17	42	13.1	176	27	72	9.4	483	48	84
Quercus muehlenbergii	1.8	94	15	19	4.1	172	25	38	6.5	793	76	88
Fraxinus americana	2.3	47	9	14	1.5	125	21	23	.4	276	31	22
Liriodendron tulipifera	3.7	19	2	13	—	—	—	—	—	—	—	—
Ulmus rubra	.9	38	8	10	.2	43	8	8	—	—	—	—
Ulmus americana	.9	47	6	9	.2	8	2	2	—	—	—	—
Fagus grandifolia	2.1	9	2	8	—	—	—	—	—	—	—	—
Carya cordiformis	1.0	28	6	8	—	12	2	2	—	34	7	3
Ostrya virginiana	.3	47	9	8	—	16	3	2	—	—	—	—
Cercis canadensis	.1	47	8	7	.7	614	62	69	.6	500	55	39
Aesculus glabra	.1	47	8	7	.2	31	5	5	.1	17	3	3
Sassafras albidum	.4	28	6	6	.4	125	16	17	1.0	397	48	35
Quercus alba	.7	19	4	5	2.2	8	2	9	.3	52	10	7
Prunus serotina	.3	19	4	4	.8	16	3	5	—	—	—	—
Cornus florida	—	19	4	3	—	16	2	2	—	—	—	—
Carya ovata	—	9	2	2	—	—	—	—	—	17	3	2
Carya tomentosa	1	9	2	2	—	—	—	—	—	—	—	—
Fraxinus quadrangulata	—	9	2	2	.5	23	5	5	.1	34	3	3
Amelanchier arborea	.1	9	2	2	—	—	—	—	—	—	—	—
Carpinus caroliniana	—	9	2	2	—	—	—	—	—	—	—	—
Crataegus mollis	—	—	—	—	—	23	4	3	—	17	3	2
Carya laciniosa	—	—	—	—	—	4	1	—	—	—	—	—
Asimina triloba	—	—	—	—	—	4	1	—	—	—	—	—
Vitis vulpina	—	—	—	—	—	—	—	—	—	17	3	2
Totals	33.0	1421	223		26.6	1631	223		18.6	2792	300	

*BA=basal area in m^2/hectare, D=density in individuals/hectare, F=frequency in percentages of 53, 128, and 29 quadrats for the north, west, and south exposures, respectively, and V=Importance Values calculated by summing the relative values of the first three parameters.

†Species are ordered according to Importance Values on the north exposure. Using this as a reference the reader can note changes in the community around the slope to the west and south exposures. Table 2 can be compared to table 1 on this basis.

exposure. Tables 1 and 2 present data for the three exposures and the three elevations, respectively. Coefficients of similarity calculated from these data are given in the upper portion of table 3. In most cases, the coefficients of similarity between different exposures are smaller than the coefficients calculated for the same parameters between the different slope elevations. In general, the upper and middle transects have the greatest similarity, followed by the middle-lower and upper-lower comparisons. For the slope exposures, the west-south comparison has the highest similarity values for most parameters, followed by the north-west and the north-south comparisons. There is greater variation between slope exposures than between slope elevations so an additional coefficient of similarity analysis was made to compare different elevations within each of the 3 exposures (lower portion of table 3). These data indicate that greatest similarity occurs within the west exposure.

Slope exposure is the key to explanation of the distribution of woody species within the study site. Table 1 indicates that the north exposure supports a sugar maple-oak community, the west exposure supports an oak community dominated by northern red oak (*Quercus borealis*), and the south exposure supports an oak community of chinkapin (*Quercus muhlenbergii*) and northern red oak. One dominant is sugar maple (*Acer saccharum*), a species which has its maximum importance value at the north exposure where its high density and low basal area indicate a potential increase in dominance in the future. From its peak importance on the north exposure, sugar

TABLE 2
Distribution of woody plant species by slope elevation.†

Species	Upper Elevation				Middle Elevation				Lower Elevation			
	BA*	D*	F*	V*	BA	D	F	V	BA	D	F	V
Acer saccharum	1.5	288	37	40	.8	253	35	19	.9	288	35	41
Tilia americana	4.3	136	17	34	3.8	106	15	23	1.3	50	8	13
Quercus borealis	7.1	119	17	45	13.5	204	34	64	13.0	256	29	85
Quercus muehlenbergii	4.5	169	27	41	4.8	338	42	48	2.7	200	20	35
Fraxinus americana	3.9	119	22	33	1.0	162	24	20	.3	100	14	15
Liriodendron tulipifera	—	—	—	—	—	—	—	—	2.4	13	1	12
Ulmus rubra	.4	68	12	11	.4	28	6	4	.2	19	4	4
Ulmus americana	—	—	—	—	.4	21	4	4	.6	25	3	6
Fagus grandifolia	—	—	—	—	—	—	—	—	1.4	6	1	7
Carya cordiformis	.6	42	7	8	—	—	—	—	.3	19	4	4
Ostrya virginiana	—	17	3	2	.1	21	4	3	.1	25	5	5
Cercis canadensis	.6	525	49	56	.7	521	49	48	.4	344	3	25
Aesculus glabra	—	17	2	2	—	28	4	3	.3	50	10	10
Sassafras albidum	.2	76	12	11	.7	134	15	15	.5	188	24	27
Quercus alba	.1	17	3	2	4.6	35	7	19	—	—	—	—
Prunus serotina	.3	25	5	4	1.3	21	4	7	—	—	—	—
Cornus florida	—	—	—	—	—	7	1	—	.1	31	4	4
Carya ovata	—	—	—	—	—	7	1	—	—	6	1	1
Carya tomentosa	—	—	—	—	.1	7	1	—	—	—	—	—
Fraxinus quadrangulata	.1	25	3	2	.4	21	4	4	5	19	4	5
Amelanchier arborea	.1	8	2	1	—	—	—	—	—	—	—	—
Carpinus caroliniana	—	—	—	—	—	—	—	—	—	6	1	1
Crataegus mollis	—	25	3	2	.1	21	4	3	—	6	1	1
Carya laciniosa	—	—	—	—	—	7	1	—	—	—	—	—
Asimina triloba	—	8	2	1	—	—	—	—	—	—	—	—
Vitis vulpina	—	—	—	—	—	7	1	—	—	—	—	—
Totals	23.7	1684	223		32.7	1949	256		25.0	1651	172	

*BA=basal area in m^2/hectare, D=density in individuals/hectare, F=frequency in percentages of 59, 71, 80 quadrats for the upper, middle, and lower elevations, respectively, and V=Importance Values calculated by summing the relative values of the first three parameters.

†See footnote table 1.

TABLE 3

Coefficients of similarity of plant communities.

	+/-*	BA*	D*	F*	V*	+/-	BA	D	F	V	+/-	BA	D	F	V
Quadrants	North-West Exposures					West-South Exposures					North-South Exposures				
	75	57	45	53	53	71	69	60	64	71	59	47	26	31	38
	Upper-Middle Elevations					Middle-Lower Elevations					Upper-Lower Elevations				
All	76	67	83	84	80	77	70	78	68	72	72	55	75	64	67
North Exposure	64	33	64	56	51	69	45	72	62	61	62	31	60	49	50
West Exposure	80	63	82	82	83	79	72	74	73	78	86	68	78	79	77
South Exposure	78	67	56	52	63	63	21	66	68	53	59	42	40	53	53

*Coefficients based on +/- (presence/absence), BA=basal area, D=density, F=frequency, and V=Importance Value data.

maple declines through the west to the south exposure. The same is true for American basswood (*Tilia americana*), while species such as American beech (*Fagus grandifolia*) and tuliptree (*Liriodendron tulipifera*) are common only on the north slope. Sugar maple, beech, and tuliptree reach their greatest importance values at the lowest slope elevation of the north exposure, the most mesic habitat of the study site; basswood is most important at the highest slope elevation. Other species increase in importance along the slope exposure gradient from north to south; these include northern red oak, chinkapin oak, and sassafras (*Sassafras albidum*). On the south exposure, red oak and sassafras are most important at the lowest elevation, while chinkapin oak peaks in dominance at the highest elevation. Still other species have maximum importance values on the west exposure; the most important of these is redbud (*Cercis canadensis*), a species which is nearly equal in importance at the three elevations within this exposure.

Greater detail on the nature of the distribution of individual species is revealed by pooling data from each ten successive quadrats along the face of the slope for each of the transects. Such analyses show patterns of changes in dominance for individual species that are not duplicated (except in the case of some species with very low importance values). This lack of similarity in the distribution of individual species reveals continuous variation along the slope exposure gradient. Thus, it may be concluded that although the vegetation of this Fort Ancient slope generally fits Gordon's (1969) classification of the area as an oak-sugar maple forest, there is a continuum in the distribution of plant communities along the slope with variation based primarily on slope exposure.

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