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A Phytosociological Study of a Relict Hardwood Forest in Barren County, Kentucky

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A PHYTOSOCIOLOGICAL STUDY OF A RELICT HARDWOOD FOREST IN BARREN COUNTY, KENTUCKY

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A PHYTOSOCIOLOGICAL STUDY OF A RELICT HARDWOOD FOREST IN BARREN COUNTY, KENTUCKY

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Introduction

Although general information is readily available concerning the structure and composition of deciduous forests, especially in the eastern part of the United States, there seems to be little specific information concerning forest composition in the Commonwealth of Kentucky. The lack of phytosociological studies prior to the development of the land, and the extent of land development in Kentucky, has led to a paucity of information regarding the natural forest vegetation of the Commonwealth. To the author's knowledge, there are few publications dealing with the vegetational composition of relict or virgin forests in Kentucky. It is apparent that there is a special need for studies of natural areas that have been relatively undisturbed by man. A small wooded area in Barren County, Kentucky, referred to as Bonayer Forest, was chosen for a detailed phytosociological analysis in 1971 after a preliminary investigation indicated that the forest might be representative of the natural vegetation of southcentral Kentucky.

This study was undertaken to describe the vegetational composition of the forest, to gain some insight into the successional development of the stand, to compare the tree composition of the forest with that of representative woodlots in the surrounding area, and to establish a record of Bonayer Forest as a basis for possible future studies of a structural or functional nature. An underlying aim of this investigation was to determine whether or not this

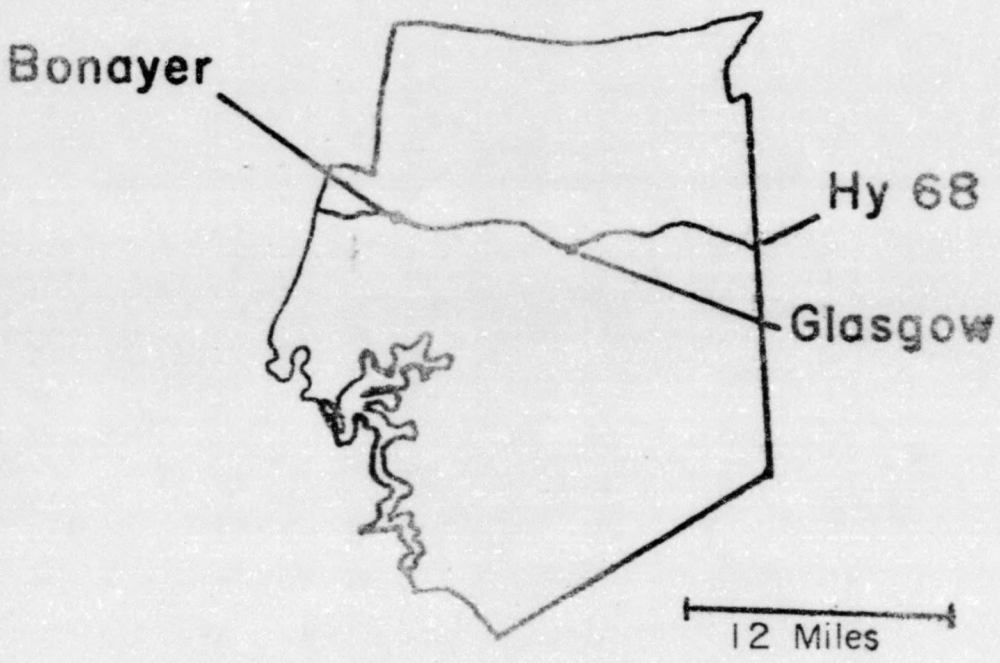
small forest is indicative of the vegetational composition that would be present in the region if it were undisturbed by man.

History and Description of the Study Area

The study area consists of approximately 14.5 acres (5.9 hectare) of mature hardwood forest in Barren County, Kentucky, 25 miles east of Bowling Green and six miles west of Glasgow (Fig. 1). This woods was part of a Revolutionary War Grant to the Reed family of Glasgow. To the knowledge of the last three Reed generations (approximately 125 years) there has been no timber removed except for dead chestnut trees after the chestnut blight epidemic in the late 1930's. Prior to 1971, the forest covered some thirty acres, but during that year, a part of the Cumberland Parkway cut through the woods, leaving less than half of the former stand. The woods may be the last remnant of typical forest vegetation in the more rolling or flatland areas of southcentral Kentucky. That this forest shows promise as an indicator of natural vegetation is expressed by its inclusion in Dr. Catherine Keever's inventory of the Central and Southeastern United States for the National Landmark Survey (personal communication).

Barren County is within the eastern and western Pennyroyal physiographic regions of Kentucky, which are parts of the Mississippian Plateau (McFarlan, 1943). The plateau is underlain by sedimentary rocks primarily of Mississippian age, with Devonian rocks in some areas. The topography of the county is predominantly one of a dissected plateau, and varies greatly. Bonayer Forest is on a nearly level section of land within an area of gently rolling topography.

Fig. 1. Map of Kentucky and map of Barren County. The study site is 0.9 mile east of Bonayer.


Bonayer
Hy 68
Glasgow
12 Miles

The closest weather recording station in Greensburg, Kentucky, 29 miles northeast of Bonayer indicates that the climate of Barren County is temperate, the growing season averaging about 180 days. The last freezing temperature in the spring occurs about April 22, and the first freezing temperature in the fall occurs about October 16. The average daily maximum temperature for a year is 69 F; the average daily minimum is 47 F. Annual precipitation is about 49 inches. October is often the driest month, but precipitation is generally well distributed throughout the year.

According to a soil survey of Barren County (Latham, 1969), the soils underlying Bonayer Forest have been classified as Dowellton and Taft silt loams. Both are nearly level, poorly drained, acid soils on upland flats. These soils were developed in residual or alluvial material that was derived chiefly from limestone and partly from sandstone or shale. The natural fertility of Dowellton and Taft silt loams is moderately low; organic matter content is low.

The surface layer of the Dowellton soil is a light grey, friable silt loam. Permeability through the subsoil is low due to a tight clay layer 12 to 20 inches below the surface. The water table remains near the surface for long periods.

The Taft soil has a surface layer of greyish-brown, mottled, very friable silt loam. A fragipan of two to three feet or more in thickness is present at a depth of 12 to 19 inches. The fragipan causes the upper subsoil to remain saturated with water during winter and part of spring.

The area now known as Barren County was settled following an order of the Virginia Convention in 1789, which declared that all the lands between the Barren and Green Rivers would be given to soldiers of the Continental Army. Barren County was formed from Warren and Green Counties in 1798 and originally included all of Metcalfe County, large parts of Hart and Monroe Counties, and a part of Allen County. The name of Barren County was derived from the term "barrens" given by the early settlers to a treeless grassland roughly corresponding to the area of karst topography in central Kentucky. According to Shaler (1884) the early settlers considered these lands to be worthless and unproductive since they did not support the magnificent forests that were expected of fertile land. The lack of trees may have been due to periodic fires set by the Indians to burn off old grass, thus providing better forage for buffalo and other large game. When the Indians no longer made regular hunting expeditions into Kentucky (about 1790), the grassland known as the Barrens was quickly restored (Shaler, 1884).

It is impossible to determine whether the present study site was a part of what was then the Barrens, or if it was part of the originally forested region which surrounded the Barrens. Franklin Gorin (1929), said:

> The country north, northwest, and northeast of Glasgow was mostly barrens, poorly watered and lightly timbered, but the rest of the county. . . was heavily timbered with oak, black and white walnut, ash, sugar maple, hackberry, cherry, poplar, chestnut, beech, buckeye, &c.

Bonayer Forest is located west and slightly north of Glasgow, so it would have been near the borderline between the wooded and barren regions as presented by Gorin. However, even if the study site was within the Barrens, it may have been reforested following 1790 (Shaler, 1884; Hussey, 1876). The history of Barren County, then, indicates that the study site may have been covered with forest vegetation for 180 or more years.

An early floristic survey was made of Barren and Edmonson Counties by John Hussey (1876), who listed species found in the area at that time. Barren County has been placed in the Western Mesophytic Forest Region by Braun (1964) and there appears to be no detailed analysis of forest vegetation in southcentral Kentucky other than limited data presented by Braun.

Materials and Methods

The quadrat method (Oosting, 1956) was the sampling technique used to determine species composition, relative density, and relative frequency of all size classes of vegetation as well as relative dominance (based on basal area) of tree species. At Bonayer 23 quadrats of 10 m X 10 m dimensions were placed on four transect lines with a 30 m interval between each quadrat. Seven additional 100 m square quadrats were placed at random in the remaining area (Fig. 2). The diameter breast height (dbh) of each tree species greater than two inches dbh was recorded for each 100 m^2 quadrat. Saplings and shrubs less than two inches dbh and greater than one foot in height were sampled in two 20 m^2 quadrats (2 X 10 m) placed within each 100 m^2 quadrat. Seedlings less than one foot in height were counted and identified to genus in four one m^2 (1 X 1 m) quadrats placed within each corner of the 100 m^2 quadrats.

In order to determine whether or not Bonayer Forest was different in tree composition than other forest stands in the locality, tree species were also sampled outside of the Bonayer Forest. However, since no one forest of sufficient size for comparative purposes was found, six wooded sites were chosen which were of similar topography and within a three mile radius of the Bonayer Forest. All of these stands had obviously been disturbed and appeared to consist of second or third growth woods. This composite of six sites, referred to as the Surrounding Area, was sampled

Fig. 2. Map of study area showing location of the 10 X 10 m sample quadrats.

by 20 quadrats randomly placed among the six sites. Within each of the 10 m X 10 m quadrats, species greater than two inches dbh were recorded.

To check the adequacy of sampling at Bonayer, species-area curves were drawn for trees, saplings and shrubs, and seedlings (Oosting, 1956). Sampling was considered to be adequate when a ten percent increase in area sampled yielded additional species equal to only five percent of the total present. This point indicated the minimum number of quadrats which should be used to obtain a representative sample of the vegetation.

Tree data was analyzed to provide mean dbh, mean density per acre, and mean basal area per acre of Bonayer Forest and of the Surrounding Area. Relative density, relative frequency, and relative dominance were calculated and summed to give importance values for each tree species (Curtis and McIntosh, 1951). Relative density plus relative frequency values were determined for saplings, shrubs, and seedlings.

Collections were made of all tree and shrub species found in the study area. Voucher specimens have been deposited in the Herbarium of Western Kentucky University. Plant nomenclature follows that of Gleason and Cronquist (1963).

To determine the approximate height of the canopy in the Bonayer stand, several random tree height measurements were taken using an Abney level.

When the State Department of Highways cut through a

section of the woods in 1971, stumps provided a record of annual growth rings. A random sample of the cut-over area was made and 18 tree stumps were analyzed to give an approximation of the age of the stand.

A soil sample of the first eight cm of soil was obtained from the center of each 100 m^2 quadrat in the Bonayer woods. A LaMotte Soil Test Kit was used to measure soil pH. Soil texture was analyzed by the hydrometer method of Bouyoucos (1936).

To gain some insight into the total productivity of the forest stand, falling leaves, stems, and fruits were collected during the period of October through February. Nearly all annual litter fall was expected during that period. At the midpoint of each transect line a one-half meter square box with a wire mesh bottom was placed to catch falling debris. Litter was periodically removed from the boxes, dried in a drying oven, and weighed to the nearest tenth of a gram.

Diversity values for trees in Bonayer Forest and the Surrounding Area were calculated using the Shannon-Weaver diversity formula (Wilhm and Dorris, 1968) which was programmed into a PDP8 computer. For the Bonayer data, three groups of 20 randomly chosen 100 m^2 quadrats were analyzed and the mean of these three diversity values was then comparable to that based on the 20 quadrats in the Surrounding Area. Another expression of diversity is the slope (b) of the regression $\log \hat{Y} = a + bx$ where $\hat{Y}$ is the number of individuals and x is the number of species (Williams, 1964).

The regression coefficient or slope (b) was determined for trees in Bonayer Forest.

A pilot study of the relationship between light intensity and the surface area of leaves was attempted. However, the study was terminated following May 27, 1972, due to mechanical failure of the light meter. Data which were obtained have been placed in the appendix.

Results

Species-area curves for trees (Fig. 3), saplings and shrubs (Fig. 4), and seedlings (Fig. 5) demonstrate that in all cases, samples were more than adequate for analysis of the vegetational composition of the forest. A minimum number of 18 of the 100 m^2 quadrats were necessary to characterize the tree species present at Bonayer; an additional 12 quadrats were used. Saplings and shrubs were sampled in 60 of the 20 m^2 quadrats, whereas 24 quadrats would have been sufficient. The 120 one m^2 quadrats used to sample seedlings were in excess of the minimum number of 52 quadrats for this stratum of vegetation. Although not presented here, a species-area curve for trees in the Surrounding Area showed that the minimum number of 100 m^2 quadrats needed was 12, so the 20 quadrats placed in the Surrounding Area also constituted an adequate sample for analysis.

In the Bonayer Forest 24 tree species are included in the sample of 30 quadrats. When tree species found at Bonayer are ranked according to importance values (Table 1), the four most predominant species (and their importance values) are Quercus alba L. (61.3), Nyssa sylvatica Marsh. (29.1), Carya ovata (Mill.) K. Koch (26.8), and Liquidambar styraciflua L. (22.1). Q. alba has a much greater relative dominance (38.9) than any other tree species at Bonayer. Cornus florida L. is the most abundant understory tree with a relative density of 8.4.

Fig. 3. Species-area curve of trees from Bonayer Forest. The arrow indicates the minimum number of 10 X 10 m quadrats which must be used in order to adequately sample tree composition.

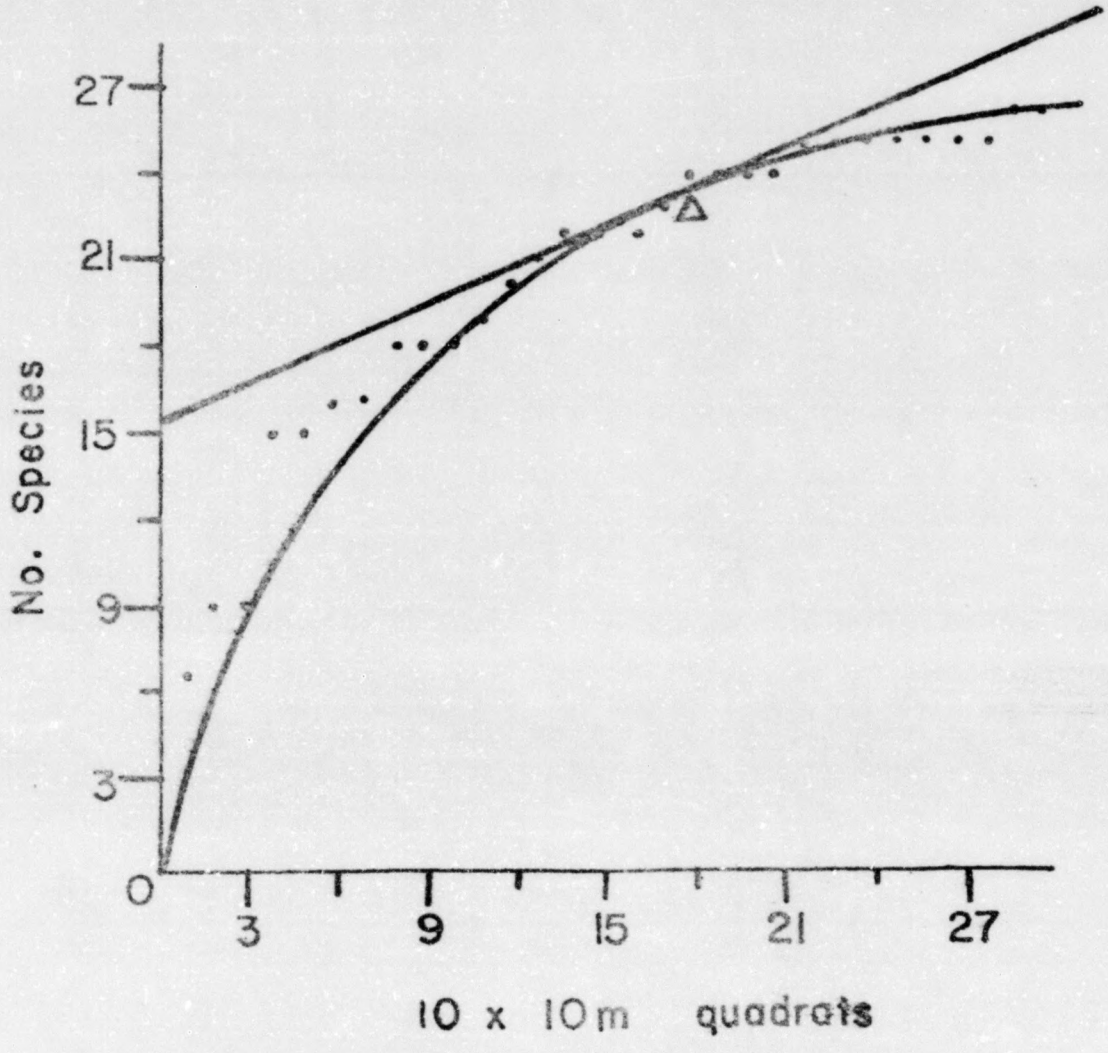

27
21
15
9
3
0
No. Species
3
9
15
21
27
10 x 10m quadrats

Fig. 4. Species-area curve of saplings and shrubs from Bonayer Forest. The arrow indicates the minimum number of 2 X 10 m quadrats which must be used in order to adequately sample sapling and shrub composition.

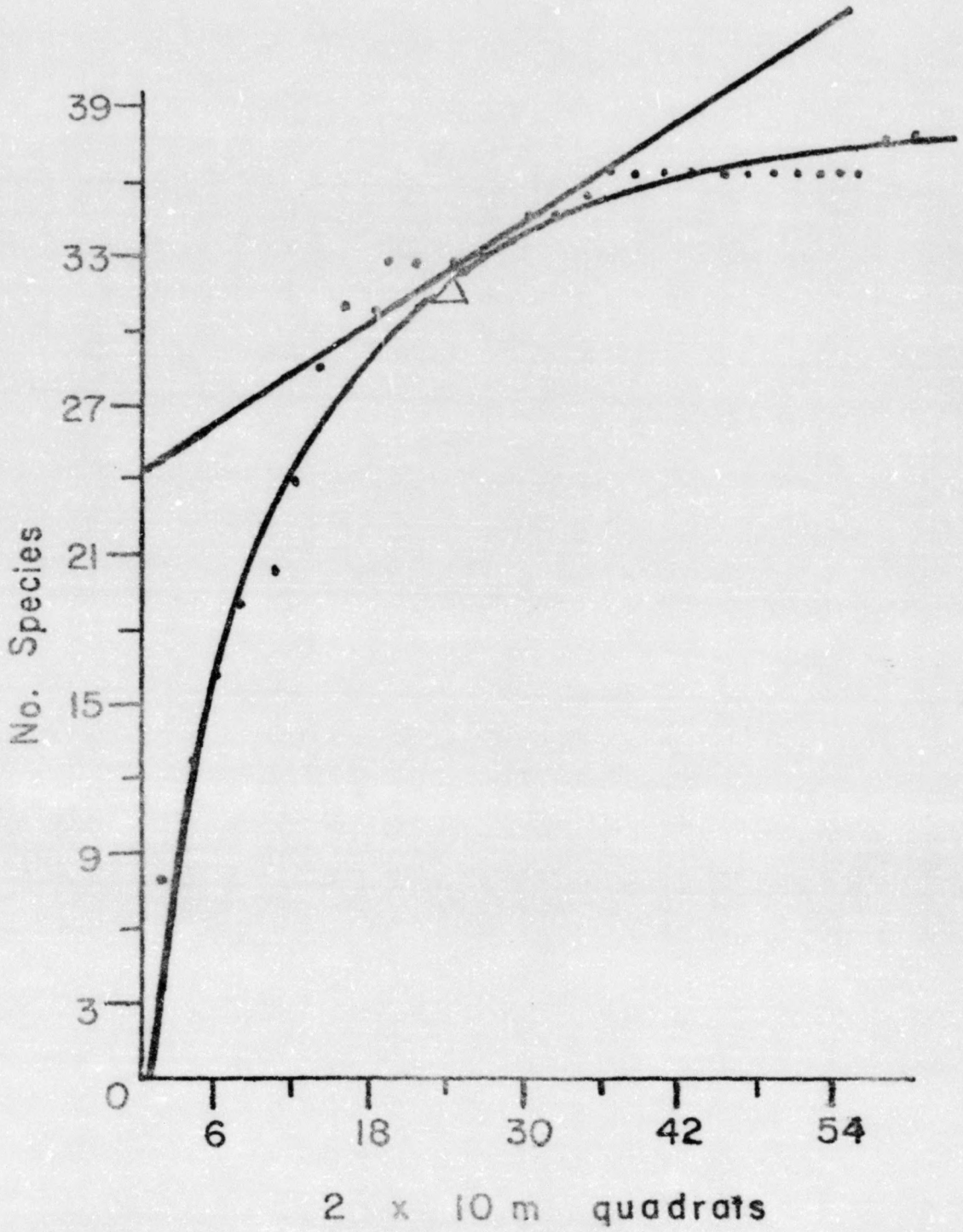

39
33
27
21
15
9
3
0
No. Species
6
18
30
42
54
2 x 10 m quadrats

Fig. 5. Species-area curve of seedlings from Bonayer Forest. The arrow indicates the minimum number of 1 X 1 m quadrats which must be used in order to adequately sample seedling composition.

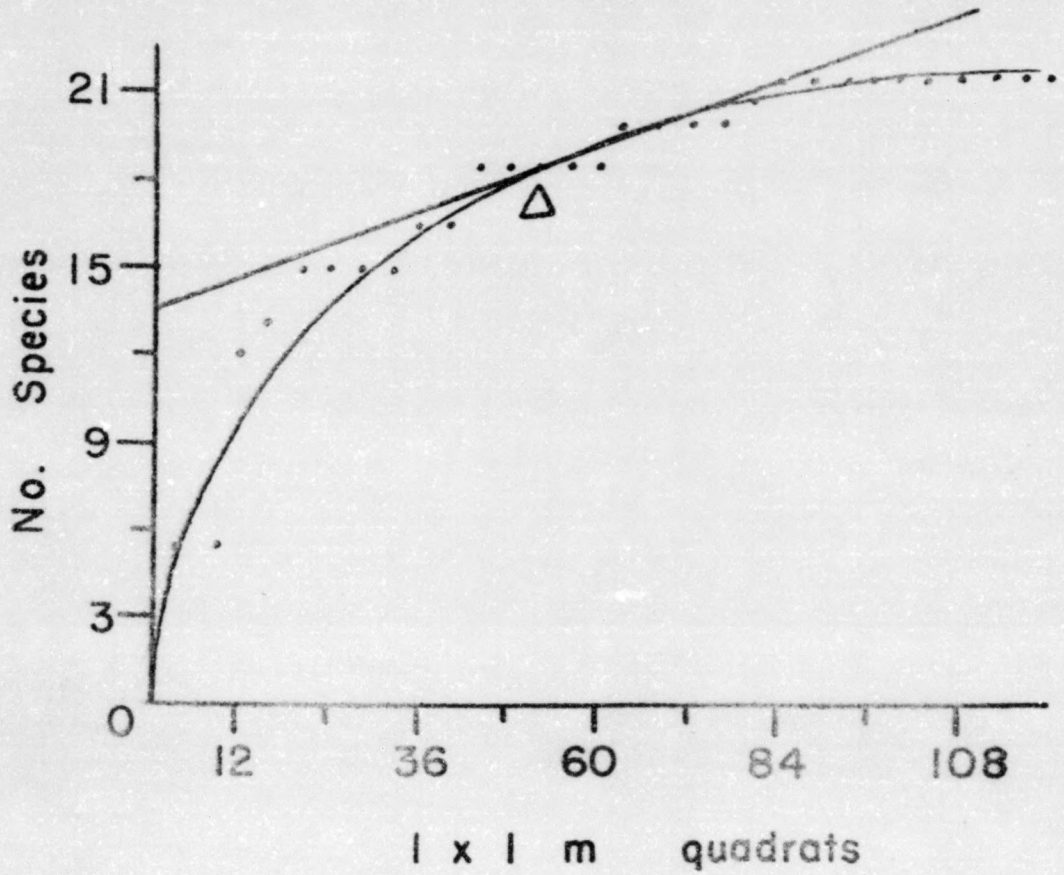

21
15
9
3
0
No. Species
12
36
60
84
108
1 x 1 m quadrats

Table 1. The number (N), relative density (RD), relative frequency (RF), relative dominance (RDo), and importance value (IV) of trees over two inches dbh in Bonayer Forest.[1]

Species	N	RD	RF	RDo	IV
Quercus alba L.	24	11.2	11.2	38.9	61.3
Nyssa sylvatica Marsh.	27	12.6	9.8	6.7	29.1
Carya ovata (Mill.) K. Koch	24	11.2	10.5	5.1	26.8
Liquidambar styraciflua L.	18	8.4	8.4	5.3	22.1
Liriodendron tulipifera L.	9	4.2	6.3	9.8	20.3
Cornus florida L.	18	8.4	7.7	1.1	17.2
Fagus grandifolia Ehrh.	8	3.7	5.6	7.7	17.0
Sassafras albidum (Nutt.) Nees.	15	7.0	4.9	1.5	13.4
Carpinus caroliniana Walt.	13	6.1	6.3	.6	13.0
Quercus velutina Lam.	8	3.7	3.5	5.4	12.6
Acer rubrum L.	8	3.7	4.2	4.2	12.1
Carya tomentosa (Poir.) Nutt.	8	3.7	3.5	1.0	8.2
Ulmus alata Michx.	6	2.8	3.5	1.3	7.6
Acer saccharum Marsh.	6	2.8	2.8	.8	6.4
Carya glabra (Mill.) Sweet	5	2.3	2.1	2.0	6.4
Quercus sp.	1	.5	.7	5.1	6.3
Fraxinus americana L.	4	1.9	2.1	.4	4.4
Fraxinus nigra Marsh.	4	1.9	1.4	.7	4.0
Quercus coccinea Muenchh.	2	.9	1.4	1.0	3.3
Prunus serotina Ehrh.	2	.9	1.4	.4	2.7
Ulmus rubra Muhl.	1	.5	.7	1.0	2.2
Fraxinus pennsylvanica Marsh.	1	.5	.7	.1	1.3

Table 1 (continued).

Species	N	RD	RF	RDo	IV
Amelanchier arborea (Michx. f.) Fern	1	.5	.7	.0	1.2
Oxydendrum arboreum (L.) DC.	1	.5	.7	.0	1.2

[1]Basal area equals 138.5 sq. ft.

The total of 214 trees which were recorded at Bonayer correspond to a density of 289 stems per acre. The trees have a mean dbh of 7.0 inches and a total basal area of 138.5 sq. ft. per acre. Diameter size class distribution of the ten most common tree species in the Bonayer Forest (Table 2) shows a generally even distribution of trees over several size classes. Quercus alba is present in all five size classes and is the only species that is so evenly distributed. Liquidambar styraciflua, Liriodendron tulipifera L., and Fagus grandifolia Ehrh. are each distributed over four different size classes. Only two species, Cornus florida and Carpinus caroliniana Walt. are restricted to the smallest size group of 2 - 4.9 inches dbh. In these data eight individuals of four different species show dbh's of 23.0 inches or greater.

When saplings and shrubs are ranked according to relative density plus relative frequency values, three genera appear as important understory trees in Bonayer Forest (Table 3). These are Cornus florida (11.4), Carpinus caroliniana Walt. (10.1), and Fraxinus spp. (10.0). Euonymous americanus L. is by far the most important shrub in the woods due to its high density of 6,357 individuals per acre and its frequency of 98.3%. Other common shrubs are Smilax sp., Corylus americana Walt., Lindera benzoin (L.) Blume., and Asimina triloba (L.) Dunal. It is interesting to note that a few Castenea dentata (Marsh.) Borkh. root sprouts are present in the woods.

Table 2. Diameter class distribution of the ten most common tree species in Bonayer Forest showing the number of trees in each class.[1]

Species	Size Classes				
	2-4.9	5-10.9	11-16.9	17-22.9	23.0+
Quercus alba L.	2	8	3	6	5
Carya ovata (Mill.) K. Koch	15	7	2		
Nyssa sylvatica Marsh.	17	7	3		
Liquidambar styraciflua L.	12	3	2	1	
Cornus florida L.	18				
Liriodendron tulipifera L.	1	4	3		1
Fagus grandifolia Ehrh.	4	2		1	1
Carpinus caroliniana Walt.	13				
Sassafras albidum (Nutt.) Nees.	12	3			
Acer rubrum L.	5	2			1

[1]Data based on 214 trees.

Table 3. The number (N), relative density (RD), relative frequency (RF), and relative density plus relative frequency (RD&RF) values for saplings and shrubs in Bonayer Forest.[1]

Species	N	RD	RF	RD&RF
Saplings				
Cornus florida L.	142	4.3	7.1	11.4
Carpinus caroliniana Walt.	128	3.9	6.2	10.1
Fraxinus spp.	108	3.3	6.7	10.0
Acer spp.	67	2.0	6.2	8.2
Nyssa sylvatica Marsh.	90	2.7	5.4	8.1
Carya spp.	62	1.9	6.0	7.9
Sassafras albidum (Nutt.) Nees.	66	2.0	5.1	7.1
Liquidambar styraciflua L.	58	1.8	4.2	6.0
Prunus serotina Ehrh.	34	1.0	3.8	4.8
Fagus grandifolia Ehrh.	30	.9	3.6	4.5
Quercus velutina Lam.	28	.8	3.3	4.1
Liriodendron tulipifera L.	45	1.4	2.5	3.9
Quercus alba L.	31	.9	2.7	3.6
Ulmus spp.	17	.5	2.0	2.5
Castenea dentata (Marsh.) Borkh.	7	.2	1.3	1.5
Morus rubra L.	6	.2	.7	.9
Juniperus virginiana L.	2	.1	.4	.5
Cercis canadensis L.	1	.0	.2	.2
Ostrya virginiana (Mill.) K. Koch	1	.0	.2	.2

Table 3 (continued).

Species	N	RD	RF	RD&RF
Shrubs				
Euonymous americanus L.	1883	57.2	10.7	67.9
Smilax sp.	218	6.6	7.8	14.4
Corylus americana Walt.	83	2.5	3.6	6.1
Lindera benzoin (L.) Blume.	56	1.7	3.8	5.5
Asimina triloba (L.) Dunal.	68	2.1	1.6	3.7
Aralia spinosa L.	36	1.1	1.8	2.9
Vaccinium stamineum L.	10	.3	1.1	1.4
Vitis spp.	6	.2	.5	.7
Amelanchier arborea (Michx. f.) Fern.	5	.2	.5	.7
Rhamnus carolinianus Walt.	1	.0	.2	.2
Lonicera japonica Thunb.			.9	

[1]Data gathered from 60 2 X 10 meter quadrats.

Relative density plus relative frequency values for seedlings in Bonayer Forest (Table 4) show that Quercus spp. (43.0), Acer spp. (25.9), and Liquidambar styraciflua (23.8) are the most predominant tree seedlings, while Smilax sp. (12.2) and Lindera benzoin (8.6) are the most common shrub seedlings.

Woody vines present at Bonayer and their frequencies in the seedling stratum are Parthenocissus quinquefolia (L.) Planch. (36.7), Lonicera japonica Thunb. (10.8), Rhus radicans L. (10.8), and Vitis spp. (3.3). Herbaceous plants noted in the Bonayer woods are Aralia racemosa L., Arisaema triphyllum (L.) Schott., Athyrium thelypteroides (Michx.) Desv., Boehmeria cylindrica (L.) Sw., Chimaphila maculata (L.) Pursh., Commelina communis L., Desmodium sp., Houstonia sp., Impatiens biflora Wlat., Mitchella repens L., Onoclea sensibilus L., Osmunda regalis L., Panicum sp., Podophyllum peltatum L., Polystichum acrostichoides (Michx.) Schott., Sanicula canadensis L., Smilacina racemosa (L.) Desf., Thelypteris hexagonoptera (Michx.) Weatherby., and Uvularia perfoliata L.

Tree data from six stands in the vicinity of Bonayer Forest (Table 5) give the total of 22 species which are included in the sample of the Surrounding Area. Of these, 17 species are common to both Bonayer Forest and the Surrounding Area. Surprisingly, Cornus florida, an understory tree, has the second highest importance value (43.4) in the Surrounding Area. This is due to its high relative density

Table 4. The number (N), relative density (RD), relative frequency (RF), and relative density plus relative frequency (RD& RF) values for tree and shrub seedlings in Bonayer Forest.[1]

Species	N	RD	RF	RD&RF
Tree seedlings				
Quercus spp.	238	28.9	14.1	43.0
Acer spp.	105	12.8	13.1	25.9
Liquidambar styraciflua L.	103	12.5	11.3	23.8
Liriodendron tulipifera L.	73	8.9	8.6	17.5
Nyssa sylvatica Marsh.	31	3.8	6.0	9.8
Carya spp.	29	3.5	6.0	9.5
Carpinus caroliniana Walt.	30	3.6	5.3	8.9
Sassafras albidum (Nutt.) Nees.	30	3.6	4.8	8.4
Fraxinus spp.	28	3.4	4.5	7.9
Cornus florida L.	26	3.2	4.0	7.2
Ulmus spp.	15	1.8	3.5	5.3
Prunus serotina Ehrh.	14	1.7	2.8	4.5
Amelanchier sp.	2	.2	.5	.7
Morus rubra L.	2	.2	.2	.4
Fagus grandifolia Ehrh.	1	.1	.2	.3
Unknown seedlings	6	.7	1.0	1.7
Shrub seedlings				
Smilax sp.	43	5.2	7.0	12.2
Lindera benzoin (L.) Blume	27	3.3	5.3	8.6
Corylus americana Walt.	10	1.2	.5	1.7
Aralia spinosa L.	8	1.0	.5	1.5

Table 4 (continued).

Species	N	RD	RF	RD&RF
Vaccineum stamineum L.	2	.2	.5	.7

[1]Data gathered from 120 one meter square quadrats.

Table 5. The number (N), relative density (RD), relative frequency (RF), relative dominance (RDo), and importance value (IV) of trees over two inches dbh in the Surrounding Area.[1]

Species	N	RD	RF	RDo	IV
Liriodendron tulipifera L.	32	15.6	8.9	24.4	48.9
Cornus florida L.	44	21.5	14.8	7.1	43.4
Quercus velutina Lam.	16	7.8	8.9	17.8	34.5
Nyssa sylvatica Marsh.	20	9.8	9.9	9.9	29.6
Acer rubrum L.	14	6.8	7.9	9.3	24.0
Liquidambar styraciflua L.	13	6.3	6.9	5.1	18.3
Carya ovata (Mill.) K. Koch	11	5.4	8.9	1.2	15.5
Quercus alba L.	9	4.4	4.0	3.0	11.4
Sassafras albidum (Nutt.) Nees.	10	4.9	4.0	2.4	11.3
Prunus serotina Ehrh.	8	3.9	5.9	.9	10.7
Quercus borealis Michx. f.	3	1.5	2.0	6.4	9.9
Carya tomentosa (Poir.) Nutt.	4	2.0	3.0	4.4	9.4
Carya glabra (Mill.) Sweet	3	1.5	2.0	3.9	7.4
Fagus grandifolia Ehrh.	6	2.9	2.0	.8	5.7
Carpinus caroliniana Walt.	4	2.0	3.0	.6	5.6
Juglans cinerea L.	1	.5	1.0	2.2	3.7
Cercis canadensis L.	2	1.0	2.0	.3	3.3
Fraxinus americana L.	1	.5	1.0	.1	1.6
Ulmus alata Michx.	1	.5	1.0	.1	1.6
Acer saccharum Marsh.	1	.5	1.0	.0	1.5
Morus rubra L.	1	.5	1.0	.0	1.5
Rhamnus carolinianus Walt.	1	.5	1.0	.0	1.5

[1]Basal area equals 127.6 sq. ft.

(21.5) and frequency (14.8) within the stands. The most important overstory trees in the Surrounding Area are Liriodendron tulipifera L. (48.9), Quercus velutina Lam. (34.5), Nyssa sylvatica (29.6), and Acer rubrum L. (24.0). Liriodendron tulipifera has the greatest relative dominance (24.4) of any species in the Surrounding Area. In comparing the four most important overstory species in the two forest areas only one, Nyssa sylvatica, is among the most important canopy species in both Bonayer and the Surrounding Area.

For the Surrounding Area 205 individuals with a mean dbh of 6.0 inches are included in the sample quadrats. These figures give a density of 4.5 stems per acre and a total basal area of 127.6 sq. ft. for trees in the Surrounding Area. Diameter class distribution of the ten most common tree species in the Surrounding Area (Table 6) shows a less even distribution over the various size classes than did the Bonayer data. No trees are present in the 23.0 inches or greater classification, and only two tree species, Liriodendron tulipifera and Quercus velutina are represented in four different size classes. Cornus florida is represented by 44 individuals, but they are restricted to the two smallest size classes, 2 - 4.9 and 5 - 10.9 inches dbh.

Both forest areas show high Shannon-Weaver diversity values for tree species. A value of 3.685 was computed for the Surrounding Area; a diversity of 4.057 was found for Bonayer Forest. Linear regression analysis of tree

Table 6. Diameter class distribution of the ten most common tree species in the Surrounding Area showing the number of trees in each class.[1]

Species	Size Classes 2-4.9	5-10.9	11-16.9	17-22.9	23.0+
Cornus florida L.	31	13			
Liriodendron tulipifera L.	12	12	6	2	
Quercus velutina Lam.	7	3	2	4	
Nyssa sylvatica Marsh.	7	9	4		
Acer rubrum L.	8	4		2	
Carya ovata (Mill.) K. Koch	10	1			
Liquidambar styraciflua L.	6	5	2		
Prunus serotina Ehrh.	8				
Quercus alba L.	7	1	1		
Sassafras albidum (Nutt.) Nees.	5	5			

[1]Data based on 205 trees.

species data from Bonayer Forest yielded a regression coefficient or slope (b) of 0.0759, which is another measure of diversity. When used in this manner, the smaller the slope the greater the diversity or the more species encountered per given number of individuals.

Table 7 lists the diameter and number of annual rings counted for eighteen Quercus alba (white oak) cut from Bonayer during highway construction. There was great variation in the number of rings counted for similar sized trees, but this analysis did provide information as to the age of the trees. Of the eighteen white oaks cut during highway construction, eight had stump widths ranging from 20 to 31 inches and showed from 81 to 184 years of growth. The largest stump analyzed was 46.0 inches in diameter with 207 annual rings.

Among the 24 white oaks that fell within the 10 X 10 m quadrats the range of dbh was 2.1 - 31.2 inches. Of these white oaks, eight (33%) were of the size class 2.1 - 9.5; eight (33%) measured 10.1 - 18.8; seven showed dbh's of 20.8 - 28.0. One white oak measured 31.2 inches. A few large white oaks measured outside the quadrats gave dbh's of: 33.0, 29.5, 26.5, 24.5, and 19.3.

Eleven random tree height measurements gave an average of 93.4 feet for an approximation of canopy height. The dbh was recorded for seven of the trees, but not for the remaining four. The species, dbh, and height of the seven trees were as follows: one Fagus grandifolia with a dbh of 15.7 inches and a

Table 7. Growth ring analysis of 18 white oak stumps.

Diameter (inches)	Number of Rings
10.5	69
12.0	80
13.5	71
14.5	63
15.5	147
17.0	108
20.0	163
21.5	158
24.0	81
28.0 (double trunk)	84
28.5	132
29.0	136
30.0	184
31.0	156
35.0	139
39.0	172
41.0	181
46.0	207

height of 74.5 feet, two Liquidambar styraciflua with dbh's of 21.0 and 23.3 inches corresponding to heights of 81.4 and 79.5 feet, two Liriodendron tulipifera with dbh's of 14.9 and 14.0 inches corresponding to heights of 93.6 and 87.9 feet, two Quercus alba with dbh's of 28.0 and 31.0 inches corresponding to heights of 120.0 and 86.5 feet. The three remaining Liriodendron tulipifera had heights of 98.0, 101.0, and 104.0 feet. One Quercus alba measured 101.0 feet in height.

The productivity of Bonayer Forest, as determined by collection of litter, seemed to be low, with very little organic matter being added to the forest floor annually. Collections from the four litter boxes averaged 251 grams of leaves, stems, and fruits which were deposited per meter square of forest floor. Of that total, leaf litter accounted for 229 grams; stems, 15 grams; and fruit material, eight grams.

Soil analysis of 30 soil samples (Table 8) gave a range of pH from 4.5 to 5.8 with a mean of 5.1. The average sand, silt, and clay content of the first eight cm of soil was 11.3 percent, 59.8 percent, and 28.9 percent, respectively. The majority of the soil samples (22) fall within the silty clay loam texture class, seven samples are classified as silt loam, and the remaining sample is sandy clay loam (Foth and Jacobs, 1964). There is no apparent difference in vegetation which may be correlated with differences in soil texture or soil pH within the Bonayer stand.

Table 8. Texture and pH of thirty soil samples from Bonayer Forest.

	Sample	%Sand	%Silt	%Clay	pH
Line I	0m	6.8	66.0	27.2	4.8
	30m	8.2	54.9	36.9	5.5
	60m	17.0	55.0	28.0	5.4
	90m	6.9	58.9	34.2	5.2
	120m	12.8	59.1	28.1	5.0
	150m	9.5	59.9	30.6	5.2
Line II	0m	6.0	59.5	34.5	5.6
	30m	13.0	61.0	26.0	5.5
	60m	10.9	52.9	36.2	4.6
	90m	12.7	60.7	26.6	5.0
	120m	12.9	63.1	24.0	4.5
	150m	53.0	23.0	24.0	5.2
Line III	0m	5.2	63.9	30.9	5.2
	30m	8.1	67.4	24.5	5.4
	60m	1.0	68.3	30.7	5.3
	90m	10.2	61.0	28.8	5.8
	120m	14.3	61.0	24.7	5.2
	150m	16.0	55.9	28.1	5.0
Line IV	0m	9.9	57.1	33.0	4.6
	30m	12.4	58.9	28.7	4.8
	60m	5.2	64.8	30.0	5.0
	90m	3.6	67.2	29.2	5.2
	120m	8.7	67.9	23.4	5.0
	150m	4.4	66.3	29.3	4.6
	Q25	9.1	62.9	28.0	4.6
	Q26	9.9	60.8	29.3	4.8
	Q27	12.9	58.5	28.6	5.2
	Q28	12.7	58.7	28.6	5.2
	Q29	17.9	56.8	25.3	4.8
	Q30	9.1	61.1	29.8	5.4

Discussion and Conclusions

Data in Table 1 indicate that Bonayer Forest may be characterized as an oak forest, primarily due to the importance of Quercus alba in the stand. Q. alba has the second highest density as well as the highest frequency and dominance of any species found at Bonayer. Other oaks included in the Bonayer data are Q. velutina, Q. coccinea Muenchh., and one individual of an unidentified species. Together the oaks have an importance value of 81.9 which makes up 27.3% of the total importance value (300) for all species. Accessory species which follow oak in importance in the Bonayer stand are Nyssa sylvatica, Carya ovata, Liquidambar styraciflua, and Liriodendron tulipifera. The understory of the Bonayer Forest is characterized by the presence of Cornus florida.

Diameter size class distribution of the ten most common tree species in the Bonayer Forest (Table 2) indicated that reproduction is taking place since canopy species are also present in the smaller size classes. The generally even distribution of trees over several size classes is evidence that the forest has not been disturbed in the recent past. Cornus florida and Carpinus caroliniana are both restricted to only the smallest size class, but this is to be expected, since these trees are typical understory species.

When overstory tree species present in each size class (trees, saplings, seedlings) are grouped into their respective genera and subsequently compared, a high degree of

similarity is evident between the composition of the canopy and the younger growth in Bonayer Forest (Table 9). Genera which are typically restricted to the understory (Cornus, Carpinus, Fraxinus, Sassafras) and would not be expected to replace dead or dying canopy trees have been omitted from these data. The six most important genera of trees present in the canopy of Bonayer Forest are Quercus, Carya, Nyssa, Liquidambar, Liriodendron, and Acer. Of these six genera, five are present in this relative position in the sapling layer, and all six are present in the seedling layer. In the sapling stratum, Liriodendron is not among the six most important genera since both Prunus and Fagus have higher relative density plus relative frequency values (Table 5). It is not unusual for Liriodendron to be less important in the sapling stage than in the canopy because it is shade intolerant and does not survive well under a closed canopy. The relative importance of the different genera is not the same throughout the seedling, sapling, and tree stages, but many factors affect the numbers, growth, and survival of seedlings so that the relative importance of different genera often changes over time. Nevertheless, it is obvious from an examination of the seedling and sapling composition at Bonayer that the same genera are present in these younger stages as are present in the canopy, indicating that the tree composition of Bonayer Forest will probably be much the same in the future.

Euonymous americanus (strawberry bush) has a greater

Table 9. Comparison of the six most important tree, sapling, and seedling genera in Bonayer Forest.

Trees		Saplings		Seedlings	
Genus	IV	Genus	RD&RF	Genus	RD&RF
Quercus	83.5	Acer	8.2	Quercus	43.0
Carya	31.4	Nyssa	8.1	Acer	25.9
Nyssa	29.1	Carya	7.9	Liquidambar	23.8
Liquidambar	22.1	Quercus	7.7	Liriodendron	17.5
Liriodendron	20.3	Liquidambar	6.0	Nyssa	9.8
Acer	18.5	Prunus	4.8	Carya	9.5

relative density plus relative frequency value (67.9) than any other sapling or shrub in Bonayer Forest (Table 5). Its unexpected density of 6,357 individuals per acre and frequency of 98.3% cannot be explained by reference to the literature, since apparently no research has been published on this species. Euonymous americanus deserves further study to determine the reason for its great abundance in Bonayer Forest.

Tree data from the Surrounding Area (Table 5) show both similarities and differences in composition when compared to data of Bonayer Forest. In the Surrounding Area, Liriodendron tulipifera and Quercus velutina are the most dominant tree species in contrast to the Bonayer stand, where Quercus alba is the most dominant. When all the oaks in the data of the Surrounding Area (Q. velutina, Q. alba, Q. borealis Michx. f.) are grouped, their collective relative dominance value (27.2) and importance value (55.8) are higher than those of Liriodendron. The Surrounding Area, then, may be characterized as oak-tulip poplar with Cornus florida, Nyssa sylvatica, Acer rubrum L., Liquidambar styraciflua, and Carya ovata as accessory species. It is apparent that oaks are dominant in both Bonayer Forest and the Surrounding Area; Nyssa sylvatica, Liquidambar styraciflua, and Carya ovata are accessory species common to both. Comparison of the seven most important genera in the Bonayer Forest and the Surrounding Area (Table 10) shows that the same seven genera (Quercus, Carya, Nyssa, Liquidambar,

Table 10. Comparison of the seven most important tree genera in the Bonayer Forest and in the Surrounding Area.

Bonayer Forest		Surrounding Area	
Genus	IV	Genus	IV
Quercus	83.5	Quercus	55.8
Carya	31.4	Liriodendron	48.9
Nyssa	29.1	Cornus	43.4
Liquidambar	22.1	Carya	32.3
Liriodendron	20.3	Nyssa	29.6
Acer	18.5	Acer	25.5
Cornus	17.2	Liquidambar	18.3

Liriodendron, Acer, Cornus) are the most important in both areas. This similarity in fundamental composition is to be expected of two forest areas in the same locality.

Two primary differences in composition between Bonayer and the Surrounding Area seem to indicate that Bonayer is a more mature and less disturbed forest stand than any stand in the Surrounding Area. One difference is that the importance values of Quercus alba and Q. velutina are approximately reversed in the two forest areas. In the Bonayer data Q. alba has an IV of 61.3, Q. velutina an IV of 12.6; in the Surrounding Area Q. alba has an IV of 11.4, Q. velutina an IV of 34.5 (Table 1, 2). A second difference between the two areas is that Liriodendron is much more predominant in the Surrounding Area than it is in the Bonayer Forest. Among the seven most important genera in the Bonayer data, Liriodendron ranks fifth with an IV of 20.3; in the data of the Surrounding Area Liriodendron approached Quercus in status with an IV of 48.9 (Table 10). Both these differences are probably the result of selective cutting which has occurred in the Surrounding Area, removing the larger Q. alba, opening up the canopy so that shade intolerant Liriodendron and Q. velutina have become more prominent. Bonayer Forest shows no indication of previous disturbance by cutting. The composition of the Surrounding Area, in the absence of further disturbance, will probably approach that of the Bonayer Forest in time.

Diameter size class distribution of the ten most common

tree species in the Surrounding Area gives further evidence that the stands in the Surrounding Area are younger and more disturbed than the Bonayer stand (Table 6). This is obvious in the fact that no trees are present in the 23.0 inches or greater size class whereas eight trees were included in this size class in the Bonayer data (Table 2). The Surrounding Area shows a less even distribution of trees over the various size classes. In the Bonayer sample, Quercus alba was represented in all five size classes, but it is present in only the first three classes in the sample of the Surrounding Area. This suggests that the larger Q. alba have been cut out of the Surrounding Area.

Growth ring analysis of Quercus alba trees cut during highway construction gives an estimation of the age of Bonayer Forest. From 81 to 184 annual growth rings were counted for eight white oak stumps with dbh's of 20 - 31 inches. One-third of the white oaks included in the sample data showed dbh's within this same range, implying an equal age for these living trees. It follows, then, that Bonayer Forest has been in existence for over 150 years.

According to ecological theory, quality, larger size, high diversity, and stability are typical of mature systems, while the opposite characteristics, quantity, small individuals, low diversity, and greater production are typical of young systems. Comparison of tree data from the Surrounding Area, from Bonayer Forest, and from a virgin forest in Indiana support the statement that numbers of individuals

decrease and size of individuals increase as a system matures. Lindsey, Barton, and Miles (1958) found that in an impressive virgin forest called Donaldson's Woods, some trees reached up to 52 inches in dbh, the mean dbh was 11.4 inches, there were 123 stems per acre, and there was a basal area of 125 sq. ft. per acre. Going from younger to more mature, the Surrounding Area, Bonayer Forest, and Donaldson's Woods show increasing mean dbh's of 6.0, 7.0, and 11.4, respectively. Similarly, the three forest areas exhibit decreasing numbers of individuals, or 415, 289, and 123 stems per acre, respectively. It seems that basal area of a stand is not necessarily correlated with maturity since the basal area of the Surrounding Area (127.6 sq. ft.) is almost identical to that of Donaldson's Woods (125 sq. ft.), while the basal area of Bonayer Forest is greater than the other two (138.5 sq. ft.). This comparison of the three forest areas suggests that although Bonayer Forest is more mature than the Surrounding Area, it does not exhibit a mean dbh and density which are characteristic of a virgin forest.

In general, high species diversity is considered to be characteristic of mature systems. According to the Shannon-Weaver diversity index, Bonayer Forest shows a slightly higher tree species diversity (4.057) than does the Surrounding Area (3.685). Since an almost equal number of species was present in both samples, the low diversity value for the Surrounding Area is due primarily to less evenness in the apportionment of individuals among the

species. Linear regression analysis of tree species data from the Bonayer Forest gave a slope (b) of 0.0759, where lower slope values signify higher diversity. Monk and McGinnis (1966), in a study of forest community types in Florida, found that known successional communities such as sandhills, cypress heads, and flatwoods gave slopes ranging from 0.1275 to 0.2262, while known climax communities such as the southern mixed hardwoods gave slopes of 0.0554 to 0.1160. The slope of 0.0759 calculated for the Bonayer Forest falls within the range of slopes which Monk and McGinnis found to be characteristic of known climax types. This indicates that Bonayer Forest has a high diversity typical of climax communities.

The small amount of litter deposited on the forest floor could be used to support the idea that the Bonayer Forest is a stand that has neared homeostasis. Although the litter samples were limited in number, the amount collected in the litter traps seemed to be consistent with the appearance of litter on the forest floor. The value of 251 grams of litter per meter square in 1972-73 is much less than the 600 grams per meter square of litter deposition obtained by Bray and Gorham (1964) for warm temperate forests between 34 - 38 degrees North latitude. This is evidence that the Bonayer Forest has low productivity, or that the community energetics are such that the gross production to standing crop biomass ratio (P/B ratio) is low. A low P/B ratio is typical of a mature system, one which is

approaching homeostasis.

A species list compiled by Hussey (1876) from collections in the western part of Barren County, in the cave region, and in Edmonson County contains all of the tree species present in the Bonayer data, as well as 22 of the 32 different species or genera of shrubs, woody vines, and herbs. Hussey stated that on the more level parts of Barren County, trees were still small in size and few in species, which he felt was evidence of the recent introduction of forest growth into the region. He noted that the largest trees in this section of Barren County were oaks 15 inches in diameter. This may be contrasted to white oaks which attained enormous development along the Green River, forming "immense trunks, reaching to a height of eighty feet, where they still seem to be three feet in diameter". Most of the species present in the Bonayer Forest, then, are identical to those found in the region nearly 100 years ago. The difference in size between trees in Barren County and elsewhere at that time may explain why trees in the Bonayer Forest do not approach the tremendous size expected of a virgin forest.

Bonayer Forest is included within the Mississippian Plateau of the Western Mesophytic Forest Region as discussed by Braun (1964). The Western Mesophytic Forest Region is designated as a transition region characterized by a "mosaic pattern of climax vegetation types" rather than a single climax type. Braun indicates the dominance of oak forest over much of the Mississippian Plateau. Accessory species

which vary from place to place may include sugar maple, beech, tuliptree, chestnut, hickories, white ash, and occasional other species. In sampling the canopy trees at one location in Barren County, Braun found that oaks formed 50% of the canopy with maple and beech the next most frequent. If all trees greater than 12 inches dbh in the Bonayer data are considered, oaks form 51.5% of the canopy with tuliptree (Liriodendron tulipifera) as the next most frequent. The designation of Bonayer Forest as an oak forest is, therefore, consistent with generalizations and specific data presented by Braun.

This study has provided evidence that Bonayer Forest is typical of what the vegetational composition would be in south central Kentucky if this area were left undisturbed by man. The composition of the forest is oak (Quercus) with black gum (Nyssa sylvatica), shagbark hickory (Carya ovata), sweetgum (Liquidambar styraciflua), and tulip poplar (Liriodendron tulipifera) as accessory species. Bonayer Forest is similar in composition to stands in the Surrounding Area, but is a more mature forest system. The same genera of trees are present in the younger growth stages as are present in the canopy, indicating that the canopy trees are replacing themselves and that the Bonayer Forest represents a climax vegetation type.

Summary

1. Bonayer Forest may be characterized as an oak forest, primarily due to the importance of Quercus alba in the stand. Accessory species are Nyssa sylvatica, Carya ovata, Liquidambar styraciflua, and Liriodendron tulipifera. Cornus florida is prevalent in the understory.

2. A high degree of similarity is evident between the tree composition of the canopy and the younger growth in the Bonayer Forest.

3. Euonymous americanus (strawberry bush) has an unexpected density of 6,357 individuals per acre and a frequency of 98.3%.

4. The same seven genera of trees are the most important in both the Bonayer Forest and the Surrounding Area. Quercus alba is the most dominant tree in the Bonayer Forest; Liriodendron tulipifera and Q. velutina are the most dominant in the Surrounding Area.

5. Growth ring analysis of Quercus alba stumps implies an age in excess of 150 years for the Bonayer Forest. Eleven random tree height measurements give an average of 93.4 feet.

6. The soil under Bonayer Forest is primarily silty clay loam, with an acid pH and low permeability. There were no differences in vegetation which could be correlated with slight changes in pH and soil texture within the stand.

7. The Bonayer Forest shows a mean dbh of 7.0, a density of 289 trees per acre, and a basal area of 138.5 sq. ft. per acre.

8. Bonayer Forest has a high tree species diversity with a Shannon-Weaver diversity index of 4.057 and a linear regression coefficient or slope (b) of 0.0759.

9. A low productivity value of 251 grams of litter per meter square was obtained for Bonayer Forest in 1972-73.

Appendix I. Relationship between light intensity and surface area of dogwood (*Cornus florida* L.) leaves.

For a pilot study of the relationship between light intensity and surface area of leaves, four dogwood trees (*Cornus florida* L.) were chosen at random within the Bonayer Forest. Leaf prints of ten leaves on each tree were recorded on light-sensitive blueprint paper on April 23 and May 4, 15, and 27 of 1972. The blueprint paper was then developed over ammonium hydroxide and the surface areas of the leaves calculated by measuring the prints with a planometer. Light intensity at each tree was measured with a light meter. The study was terminated following May 27 due to a mechanical failure of the light meter.

Data obtained in this study are presented in Table A1. Average leaf areas are based on measurements of 40 *Cornus florida* leaves. As expected, an inverse relationship exists between leaf surface area and percent incident light. It seems that understory trees would have a selective advantage if they attained full leaf development early in the season before leaf development in canopy trees causes a reduction of light intensity. Leaf area and light intensity may warrant further study to determine if or in what manner they are related to phenological patterns in canopy and understory species.

Table A1. Relationship between light intensity and surface area of dogwood (*Cornus florida* L.) leaves.

Date	Avg. Leaf Area, cm^2*	% incident light
4-23	4.2	24
5-4	9.6	14
5-15	12.9	--
5-27	13.4	2

*Average of 40 leaves.

LITERATURE CITED

Bouyoucos, G. J. 1936. Directions for making mechanical analyses of soils by the hydrometer method. Soil Sci. 42:225-229.

Braun, E. Lucy. 1964. Deciduous forests of Eastern North America. Hafner Publishing Co. New York. 596 p.

Bray, J. R. and E. Gorham. 1964. Litter production in forests of the world. In: Adv. Ecol. Res. (J. B. Cragg, ed.) 2:101-157.

Curtis, R. T. and R. P. McIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecol. 32:476-496.

Foth, H. D. and H. S. Jacobs. 1964. Laboratory manual for introductory soil science. Wm. C. Brown Co. Dubuque. 82 p.

Gleason, H. A. and A. Cronquist. 1963. Manual of vascular plants of Northeastern United States and adjacent Canada. D. Van Nostrand Co. Princeton. 810 p.

Gorin, Franklin. 1929. Times of long ago. Barren County, Kentucky. J. P. Morton Co. Louisville. 131 p.

Hussey, John. 1876. Report of the botany of Barren and Edmonson Counties. Ky. Geol. Sur. 1:27-58.

Latham, Earle E. 1969. Soil survey of Barren County, Kentucky. U. S. Government Printing Office. Washington, D. C. 85 p.

Lindsey, A. A., J. D. Barton, Jr., and S. R. Miles. 1958. Field efficiency of forest sampling methods. Ecol. 39:428-444.

McFarlan, A. C. 1943. Geology of Kentucky. University of Kentucky. Lexington. 531 p.

Monk, C. D., and J. T. McGinnis. 1966. Tree species diversity in six forest types in north central Florida. J. Ecol. 54:341-344.

Oosting, Henry J. 1956. The study of plant communities. W. H. R. Freeman Co. San Francisco. 440 p.

Shaler, N. S. 1884. Kentucky, a pioneer commonwealth. Houghton, Mifflin Co. New York. 433 p.

Wilhm, J. L. and T. C. Dorris. 1968. Biological parameters for water quality criteria. BioScience 18(6):477-481.

Williams, C. B. 1964. Pattern in the balance of nature, and related problems in quantitative ecology. Academic Press. New York. 324 p.

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