The Missouri Ozark Forest Ecosystem Project

The Effects of Forest Management on the Forest Ecosystem

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Abstract: The effects of forest management on non-timber resources are of growing concern to forest managers and the public. While many previous studies have reported effects of stand-level treatments (less than 15 ha) on various stand-level attributes, few studies have attempted to document the influence of forest management on the biotic and abiotic characteristics of entire management areas, comprising many stands on hundreds of hectares.

The Missouri Ozark Forest Ecosystem Project (MOFEP) was initiated by the Missouri Department of Conservation in 1990 as a long-term study of typical forest management practices on the plant and animal components of those forests. The study is led by the Department's Wildlife and Forestry Divisions, with cooperation from the University of Missouri.

The study area, located in the Ozark Region of southeastern Missouri, consists of mature upland oak-hickory and oak-pine forest communities. The study design includes three replications of three forest management systems: evenaged, unevenaged and non-manipulative or control. Management units (i.e. replications) range in size from 266 to 527 ha (657 to 1,302 acres), with a total study area of 3,725 ha (9,200 acres). Initial forest treatments will begin in October 1994.

Pre-treatment data is now being collected to investigate the effects of forest management on the composition and spatial distribution of woody and herbaceous vegetation, forest interior birds, reptiles and amphibians, tree canopy insects, forest litter invertebrates, small mammals, tree genetics and nutrient cycling.

INTRODUCTION

Non-timber resources are of growing concern to forest mangers and the public. To the present, most forest managers and scientists have concentrated their efforts on manipulating and studying stands, generally less than 15 ha (37 acres), to achieve or determine a particular result. Therefore, a great deal is known about plant and animal species within the confines of the stand boundaries. Conversely, little is known about the effects of stand level management on the entire ecosystem in which that stand lies.

The Missouri Ozark Forest Ecosystem Project (MOFEP) was initiated by the Missouri Department of Conservation in 1990 with an overall goal of understanding how forest management affects forest ecosystems. Project objectives are:

1. Identify a location and define a design that facilitates the analysis of the effects of forest management on major components of a Missouri Ozark forest ecosystem.

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2. Use information acquired to refine forest management practices in Missouri.

To achieve these objectives, a number of studies have been designed and implemented. Staff from the Conservation Department's Forestry and Wildlife Divisions along with cooperators from several Missouri universities and the U.S. Forest Service are presently conducting research on the MOFEP compartments. These researchers are collecting pretreatment information on the composition and spatial distribution of woody and herbaceous vegetation, forest interior birds, reptiles and amphibians, tree canopy and forest litter invertebrates, small mammals, vegetation diversity and nutrient cycling.

Each of these studies has its own specific objectives. This paper will characterize the vegetation on the MOFEP compartments, and use the forest interior bird project as an example of one of many studies associated with MOFEP. The objectives of these two studies are to determine how evenaged, unevenaged, and non-manipulative forest management affect:

1. Plant species diversity and woody plant composition, structure, growth, quality, health, and condition.

2. Rates of nest parasitism, nest predation, and reproductive success of forest interior songbirds, and densities of selected songbirds.

A recent report on forestry research (National Research Council, 1990) recommends that interdisciplinary forest ecosystem research be increased. This approach is taken in MOFEP.

A long-term ecological study like MOFEP has never been conducted in Missouri. A limited number of landscape level research efforts are currently being pursued in the United States and Canada. Hubbard Brook Experimental Forest (Likens, 1988), H. J. Andrews Experimental Forest (Franklin, 1989, for example) and the Vermont Monitoring Cooperative (Scherbatskoy, pers. comm.) in the United States and Kejimkujik (Elder and Martin, 1989) in Canada all involve ecosystem level research. The Missouri Ozark Forest Ecosystem Project is unique among these because of its location and design.

In addition to a characterization of the MOFEP compartments, this paper will address some of the problems associated with a large-scale, long-term project.

METHODS

Study Area

The Missouri Ozark Forest Ecosystem Project is made up of nine compartments, ranging in size from 260 to 527 ha (657 to 1,302 acres) that are located in Carter, Reynolds, and Shannon Counties in the southeastern Missouri Ozarks (Figure 1). Collectively, these counties are 84% forested with large contiguous blocks separated only by roads and streams (Spencer et al. 1992). Agricultural activity is limited to bottomland corridors along primary and secondary streams.

Geologically, the MOFEP management units are underlain mainly by Ordovician age dolomite with areas of Cambrian age dolomite and Precambrian igneous rock also present (MO Geol. Survey, 1979). Ordovician and Cambrian age dolomites exhibit an aggregate thickness of 3,800 and 2,000 feet, respectively (U.S. Geological Survey, 1961).

Weathering of the Ordovician and Cambrian age dolomites has resulted in a deep mantle of leached, very cherty residuum on the MOFEP compartments (Gott, 1975). The residuum is more than 30.5 m (100 feet) thick with rock outcrops present along streams and steep slopes. Water drains freely through this residuum into subsurface solution channels.

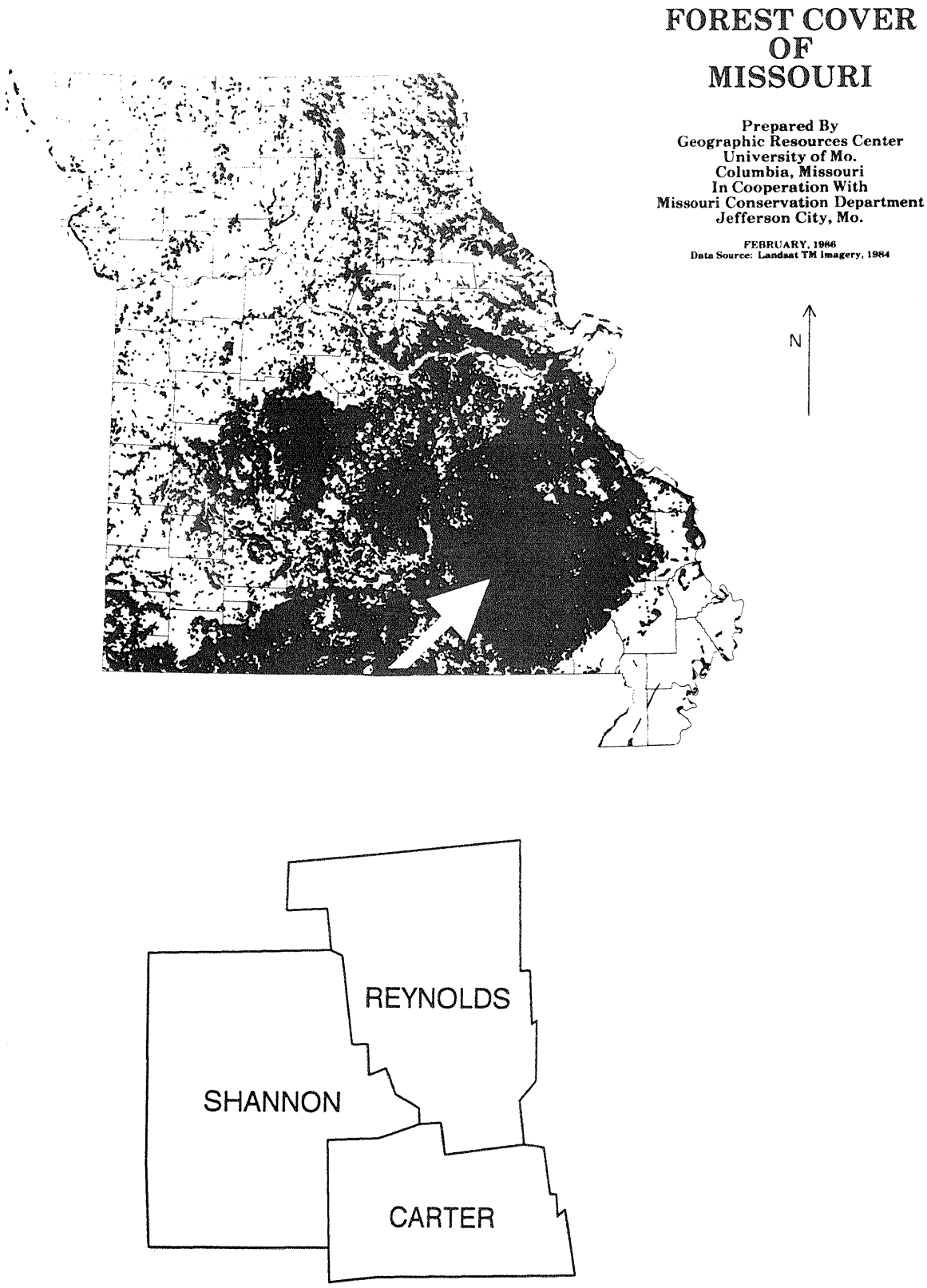


Figure 1.—Missouri Ozark Forest Ecosystem Study site location.

Mean annual temperature is 13.3° C (56° F), and mean annual precipitation is 112 cm (44 inches). Soils on the compartments were formed mostly in residuum. The common series are Viburnum, Midco, Gepp, Bardley, Viraton, Poynor and Clarksville (SCS unpublished data). A brief description of these series are provided below:

Viburnum Series - The Viburnum series consists of deep, somewhat poorly drained soils on uplands of the Salem Plateau. These soils formed in thin loess, cherty loamy and clayey sediments, and cherty red clays. Permeability is moderately slow. Slopes range from 1 to 15 percent.

Midco Series - Midco series consists of deep, somewhat excessively drained, cherty soils that occupy the bottom land. They formed in recent alluvium derived largely from upland soils underlain by cherty dolomite and sandstone. The permeability of the soils is moderately rapid. Slope gradients range from 1 to 4 percent.

Gepp Series - The Gepp series consists of deep, well drained, moderately permeable soils that formed in clayey residuum weathered from dolomite and cherty limestone bedrock. These nearly level to steep soils are on uplands in the Ozark Highlands.

Bardley Series - The Bardley series consists of moderately deep, well drained, moderately permeable soils that formed in cherty sediments and residuum from dolomite interbedded with some limestone and sandstone. These soils are on upland ridges, side slopes and nose slopes. Slope gradients range from 2 to 100 percent.

Poynor Series - The Poynor series consists of deep, well drained, moderately permeable soils on uplands formed in residuum from cherty dolomite and clayey shales or cherty limestone. Slope ranges from 2 to 60 percent.

Clarksville Series - The Clarksville series consists of deep, somewhat excessively drained soils formed in residuum and locally transported colluvial-alluvial materials from cherty dolomite or cherty limestone on steep side slopes and narrow ridgetops. Permeability is moderate. Slopes range from 1 to 60 percent.

Viraton Series - The Viraton series consists of deep, moderately well drained soils on foot slopes. These soils formed in loamy and clayey colluvium washed from the adjacent uplands and have a fragipan. Permeability is moderate above the fragipan and very slow in it. Slopes range from 3 to 9 percent.

Management areas within MOFEP are collectively comprised of 13 different Ecological Landtypes (ELT) (Table 1). The ELT of a given area is an index of the capability of that land to support various natural resources (Miller, 1981). The predominant potential productivity class for the compartments is 3.7 to 5.9 cubic meters (131 to 208 cubic feet) of growth per ha (2.47 acres) per year (Spencer et al. 1992). The majority of MOFEP compartments are in the black oak (*Quercus velutina* Lam.) - scarlet oak (*Quercus coccinea* Muenchh.) forest type and range in site index from 51 to 80 (black oak, base age 50) (Hahn, 1991). The individual ELT's and their relative abundance are summarized in Table 2.

Overall Study Design

The Missouri Ozark Forest Ecosystem Project comprises three replications of three treatments in a randomized complete block design. Each treatment area is a standard compartment, 266 to 527 ha (657 to 1,302 acres), in the Missouri Ozarks. All compartments are in the Lower Ozark section of the Ozark Natural Division of Missouri (Thom & Wilson, 1980). All contain mature second growth oak-hickory forest, and no timber harvesting has occurred during the past 20 years. Each compartment was subdivided into from 69 to 74 stands for management purposes.

Table 1.—Description of Ecological Landtypes for the 13 present on MOFEP[1]

ELT	Land form	Aspect	Percent slope	Soil series	Vegetation[2] community
3	High Flood Plain, Low Terrace	Neutral	0-4	Midco	Mesic bottomland forest
5	Upland Waterway	Neutral	0-4	Midco	Dry bottomland forest
7	Toe Slope	All	0-14	Viraton	Mesic forest
11	Ridge	Neutral	0-8	Clarksville Poynor Gepp	Dry chert forest
15	Flat	Neutral	0-8	Viburnum	Dry chert forest
17	Side Slope	South and West	8-99	Clarksville Poynor Gepp	Dry chert forest
18	Side Slope	North and East	8-99	Clarksville Poynor Gepp	Dry-mesic chert forest, Dry-mesic sand forest
19	Side Slope	South and West	8-99	Bardley	Glade savanna
20	Side Slope	North and East	8-99	Bardley	Dry mesic limestone forest
21	Side Slope	All	5-99	Gepp	Dolomite glade Limestone glade
22	Side Slope	All	5-99	Gepp	Xeric limestone forest
23	Side Slope	All	5-99	Gepp	Dry limestone forest

[1]From: Miller, 1981.

[2]From: Nelson, 1985.

Table 2.—Area (and percent) of management compartment in hectares by ELT

ELT	1	2	3	4	5	6	7	8	9	Total
3	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.5)	0 (0.0)	2 (0.0)
5	0 (0.0)	0 (0.0)	8 (2.5)	34 (6.8)	22 (8.2)	15 (3.3)	39 (7.8)	26 (7.9)	22 4.7)	166 (4.4)
6	0 (0.0)	15 (2.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	15 (0.4)
7	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	9 (1.8)	3 (0.8)	6 (1.3)	18 (0.5)
11	79 (20.7)	117 (22.1)	31 (10.0)	82 (16.7)	39 (14.7)	68 (15.4)	83 (16.5)	48 (14.3)	73 (15.4)	619 (16.6)
15	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	27 (5.4)	32 (9.6)	0 (0.0)	59 (1.6)
17	130 (34.3)	225 (42.7)	108 (35.1)	230 (46.6)	103 (38.8)	212 (47.9)	199 (39.6)	98 (29.4)	237 (50.1)	1542 (41.4)
18	171 (45.0)	170 (32.3)	103 (33.5)	147 (29.9)	95 (35.6)	148 (33.4)	135 (26.9)	87 (26.0)	135 (28.5)	1190 (32.0)
19	0 (0.0)	0 (0.0)	27 (8.8)	0 (0.0)	7 (2.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	34 (0.9)
20	0 (0.0)	0 (0.0)	30 (9.8)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	30 (0.8)
21	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.2)	18 (5.3)	0 (0.0)	19 (0.5)
22	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	11 (3.3)	0 (0.0)	11 (0.3)
23	0 (0.0)	0 (0.0)	1 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	9 (1.8)	10 (2.9)	0 (0.0)	19 (0.5)
Totals	380	527	307	493	266	442	502	334	473	3725

One replication (three compartments) is located on Carr Creek and Cardareva State Forests (numbers 1-3). A second replication is located on Cardareva, Paint Rock and Deer Run State Forests (number 4-6). The final replication is located on Peck Ranch Wildlife Management Area (numbers 7-9) (Figure 1). The treatments will be implemented beginning in the Fall of 1994.

The three treatments are as follows:

1. Evenaged management (EAM) will be practiced according to Missouri Department of Conservation (MDC) Forest Land Management Guidelines (1986), with a rotation length of 80 - 100 years resulting in a regulated harvest of 10% - 12.5% per entry, and a 10 year re-entry period. This is Management Level II in the 1986 Guidelines and approximates the treatments applied to most MDC administered forest land between 1970 and 1986. Under this management level, 10% of each compartment will be left uncut as "old growth", with an objective size class balance of approximately 10% regeneration, 20% small trees, 30% pole timber, and 40% sawtimber. Stand prescriptions will follow Roach and Gingrich (1968). Stands range from one to ten ha (2.5 to 25 acres) in size. In general, total area designated with a silvicultural prescription of regeneration will be restricted to approximately 10% - 12.5% of the compartment, with those stands in greatest need of regeneration selected first. Remaining stands needing regeneration will be deferred to a later entry if possible. Immature stands with site index 55 (base age 50 yrs.) and greater will be given intermediate treatments according to Roach and Gingrich (1968). Glades, food plots, ponds, and other amenities, will be managed according to 1986 guidelines.

2. Unevenaged management (UAM) will be applied under the guidelines of MDC (1986) with stand treatments following Law & Lorimer (1989). Approximately ten percent of each compartment will be designated as "old growth" with no cutting; the remaining 90% will be treated on a 10 year cycle, entered the same years as the EAM treatment. Each compartment will be divided into management units of 8 to 32 ha (20 to 80 acres), and objectives set for largest diameter tree (LDT), residual basal area (RBA), and q-value. The LDT objective will be equal to the desired sawtimber size objective for an identical site under EAM. An overall RBA equivalent to B-level stocking will be chosen, with adjustments made where necessary for anticipated logging damage, etc. Q-value objectives should be in the range of 1.3 - 1.7. A size class distribution identical to that under the EAM treatment would be preferred. For example, a mean poletimber diameter of 21.5 cm (8.5 inches) and sawtimber diameter of 39.4 cm (15.5 inches) (mid points of ranges, assuming 51 cm (20 inch) maximum), with both size classes at B-level stocking, a typical EAM 405 ha (1000 acre) compartment would have 1,784 square m (19,200 square feet) of poletimber basal area and 2,751 square m (29,600 square feet) of sawtimber basal area. According to Law & Lorimer (1989) this is equivalent to a q-value of 1.5.

3. Non-manipulative management (NMM). No cutting for harvest, improvement, or salvage would be permitted. Natural catastrophic events including tornadoes, fire, insect, disease or natural mortality will be treated as if on any other state owned forest land, except that salvage harvests would not occur. Wildfires will be controlled and areas will not be exempted from controls applied to surrounding areas in the event of a large-scale damaging insect outbreak. This treatment will somewhat resemble "old growth" management, and will serve as a control in this project.

The overall study design will allow for analysis of treatment effects within ELT's. For this reason vegetation plots will be randomly assigned within ELT's. A total of 644 permanent plots have been installed to determine adequacy of experimental design (Table 3). The plots will be remeasured after the initial treatment is completed, and at 5 year intervals thereafter. A 0.2 ha (0.49 ac.)

circular plot is used to sample trees 11.4 cm (4.5 in.) dbh and larger and to document the total number of den trees. Four line intercepts 17.2 m (56.4 feet) in length are located within each 0.2 ha (0.49 ac) plot to document the coverage of down dead woody material. Four circular 0.02 ha (0.05 ac.) plots are located within the larger plot to sample woody plants between 3.5 cm (1.5 in.) and 11.2 cm (4.4 in.) dbh. One 0.004 ha (0.01 ac) plot is placed within each 0.02 ha plot (0.05 ac), sharing the same plot center, to sample vegetation taller than 1.0 m (3.3 feet) and less than 3.5 cm (1.5 inches) dbh. Four one square m (10.8 square feet) plots will be located within each 0.02 ha (0.05 ac) plot to sample vegetation less than 1.0 m (3.3 feet) in height. Plot establishment and measurement follow guidelines of Curtis (1983).

Most stands within each compartment contains at least one permanent plot. Stand boundaries do not cross ELT boundaries but one ELT can contain several stands. Table 2 shows the area and percentage of each ELT present in each compartment. The number of permanent vegetation plots within each ELT is proportional to the amount of each ELT present within a compartment (Table 2,3).

Table 3.—Number of vegetation plots by compartment and major ELT

	Compartment									
ELT	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
11	13	15	7	10	8	6	10	8	12	89
17	27	31	30	29	26	37	27	19	31	257
18	33	22	22	24	22	25	23	22	21	214
Other	0	5	13	11	13	3	11	21	7	84
Total	73	73	72	74	69	71	71	70	71	644

RESULTS

Ecological landtypes 11, 17 and 18 comprise the 90% of the MOFEP compartments (Table 2). Therefore, summaries of basal area and stem counts of the six most abundant species growing on the MOFEP sites are limited to these three (Tables 4-9). Across all ELT's black oak (*Quercus velutina* Lam.) accounted for the greatest amount of basal area, ranging from 40% on ELT 11 to 27% on ELT 17. Other species making up the remainder of the total basal area and their relative dominance are summarized in Tables 5, 7 and 9. The total number of stems for each species by compartment is provided in Tables 4, 6 and 8. Diameter class distributions of the six most common species are presented in Figure 2.

Table 4.—Number of trees per hectare by management compartment and dominant species - ELT 11

	Pinus echinata	*Carya* spp.	*Quercus alba*	*Quercus coccinea*	*Quercus stellata*	*Quercus velutina*	*Quercus* spp.	Other spp.	Total
Compartment 1	0.00[1]	0.00	50.00	0.00	0.00	50.00	0.00	0.00	
	190.00[2]	215.00	180.00	170.00	90.00	375.00	10.00	25.00	
	31.92[3]	80.38	109.23	50.00	32.69	157.69	1.15	8.46	471.54
	56.81[4]	58.18	44.29	55.53	28.77	103.49	3.00	8.75	
Compartment 2	0.00	20.00	25.00	0.00	0.00	60.00	0.00	0.00	
	60.00	230.00	320.00	155.00	60.00	290.00	5.00	95.00	
	13.00	122.33	109.33	66.67	11.33	162.67	0.67	25.67	511.67
	20.86	60.26	86.81	46.16	16.53	60.23	1.76	27.96	
Compartment 3	5.00	45.00	85.00	20.00	0.00	70.00	0.00	0.00	
	55.00	90.00	215.00	100.00	40.00	190.00	5.00	10.00	
	23.57	72.86	149.29	48.57	17.86	132.14	1.43	2.86	448.57
	18.87	14.39	46.76	27.34	15.51	48.72	2.44	3.93	
Compartment 4	0.00	30.00	40.00	5.00	0.00	55.00	0.00	0.00	
	205.00	230.00	135.00	285.00	35.00	200.00	5.00	30.00	
	54.00	111.50	93.50	85.00	16.00	128.50	2.00	12.50	503.00
	64.63	78.46	37.79	84.89	12.20	52.02	2.58	11.12	
Compartment 5	0.00	40.00	30.00	5.00	5.00	35.00	0.00	0.00	
	125.00	220.00	155.00	105.00	120.00	185.00	15.00	90.00	
	31.88	131.88	85.00	27.50	54.38	110.63	3.75	29.38	474.38
	45.59	64.97	46.90	32.51	39.14	52.27	5.18	34.17	
Compartment 6	0.00	90.00	30.00	0.00	5.00	45.00	0.00	0.00	
	205.00	230.00	130.00	35.00	80.00	160.00	20.00	65.00	
	54.17	144.17	78.33	11.67	35.83	109.17	3.33	23.33	460.00
	88.11	46.63	40.82	12.52	35.97	46.95	8.16	24.43	
Compartment 7	0.00	0.00	0.00	0.00	15.00	40.00	0.00	0.00	
	275.00	65.00	60.00	330.00	160.00	315.00	45.00	10.00	
	46.50	16.50	29.50	117.50	61.00	138.00	9.00	2.00	420.00
	82.43	19.44	23.27	107.30	39.21	85.90	14.49	3.50	
Compartment 8	0.00	25.00	5.00	5.00	15.00	85.00	0.00	0.00	
	35.00	85.00	60.00	75.00	85.00	285.00	75.00	5.00	
	13.13	48.75	21.88	41.25	45.00	138.13	23.75	0.63	332.50
	12.52	21.00	17.92	27.61	23.30	63.92	28.75	1.77	
Compartment 9	0.00	15.00	0.00	5.00	0.00	55.00	0.00	0.00	
	70.00	115.00	140.00	135.00	110.00	300.00	75.00	10.00	
	14.58	53.75	42.50	41.67	47.92	125.83	12.50	2.92	341.67
	20.39	31.20	43.30	37.01	31.08	62.88	25.09	3.96	

[1] Minimum
[2] Maximum
[3] Mean
[4] Standard deviation

Table 5.—Basal area (sq M/ha) by management compartment and dominant species - ELT 11

	Pinus echinata	*Carya* spp.	*Quercus alba*	*Quercus coccinea*	*Quercus stellata*	*Quercus velutina*	*Quercus* spp.	Other spp.	Total
Compartment 1	0.00[1]	0.00	0.84	0.00	0.00	1.76	0.00	0.00	
	8.79[2]	5.95	5.83	6.65	8.10	17.70	0.19	2.38	
	1.64[3]	2.44	2.90	2.42	2.07	9.69	0.03	0.32	21.51
	2.65[4]	1.70	1.35	2.43	2.28	5.08	0.07	0.67	
	8%	11%	13%	11%	10%	45%	0%	1%	100%
Compartment 2	0.00	0.43	1.05	0.00	0.00	2.85	0.00	0.00	
	2.19	8.04	7.73	10.64	7.16	13.04	0.25	4.91	
	0.52	2.98	3.46	3.91	0.91	9.12	0.03	1.19	22.12
	0.73	1.70	2.12	3.23	1.85	2.85	0.08	1.49	
	2%	13%	16%	18%	4%	41%	0%	5%	100%
Compartment 3	0.36	1.77	2.86	1.29	0.00	5.60	0.00	0.00	
	3.42	4.68	12.16	3.77	2.76	16.32	0.38	0.18	
	1.44	2.90	5.56	2.40	1.28	9.11	0.10	0.04	22.84
	1.26	1.01	3.40	0.93	1.02	3.48	0.17	0.07	
	6%	13%	24%	10%	6%	40%	0%	0%	100%
Compartment 4	0.00	0.67	0.83	0.22	0.00	2.41	0.00	0.00	
	9.13	6.85	4.56	17.53	3.00	14.33	0.72	1.20	
	2.88	3.00	3.08	5.86	0.86	8.47	0.10	0.30	24.55
	3.14	2.02	1.18	4.99	0.92	3.62	0.22	0.39	
	12%	12%	13%	24%	4%	35%	0%	1%	100%
Compartment 5	0.00	0.85	1.18	0.27	0.80	3.50	0.00	0.00	
	5.37	7.79	9.29	4.52	6.41	12.77	0.95	3.15	
	1.36	3.89	4.00	1.58	2.93	7.36	0.20	0.84	22.16
	2.01	2.51	2.71	1.32	2.03	3.06	0.34	1.23	
	6%	18%	18%	7%	13%	33%	1%	4%	100%
Compartment 6	0.00	1.92	1.44	0.00	0.13	3.41	0.00	0.00	
	5.29	9.29	5.64	3.72	6.16	15.53	1.27	3.16	
	1.53	5.21	3.22	0.93	2.41	9.96	0.21	0.72	24.19
	2.41	2.53	1.92	1.41	2.54	5.23	0.52	1.22	
	6%	22%	13%	4%	10%	41%	1%	3%	100%
Compartment 7	0.00	0.00	0.00	0.00	0.95	2.46	0.00	0.00	
	19.52	1.85	4.79	15.88	7.01	21.92	1.26	0.15	
	3.29	0.49	1.22	5.98	2.90	8.21	0.28	0.03	22.40
	5.83	0.57	1.42	5.14	1.99	6.13	0.42	0.05	
	15%	2%	5%	27%	13%	37%	1%	0%	100%
Compartment 8	0.00	1.23	0.30	0.26	0.62	7.89	0.00	0.00	
	2.53	4.31	2.23	10.34	5.10	15.70	3.14	0.14	
	0.85	1.95	1.15	4.98	2.36	11.05	1.02	0.02	23.38
	0.90	1.01	0.65	3.74	1.34	2.63	1.29	0.05	
	4%	8%	5%	21%	10%	47%	4%	0%	100%
Compartment 9	0.00	0.20	0.00	0.13	0.00	3.20	0.00	0.00	
	4.78	6.58	4.61	15.03	8.48	24.72	5.28	0.57	
	0.82	2.31	1.73	3.27	3.73	9.54	0.80	0.10	22.30
	1.35	1.96	1.60	4.16	2.57	5.46	1.72	0.17	
	4%	10%	8%	15%	17%	43%	4%	0%	100%
Grand Mean	1.59	2.80	2.92	3.48	2.16	9.17	0.31	0.39	22.83
Percent Mean	7%	12%	13%	15%	10%	40%	1%	2%	100%

[1] Minimum
[2] Maximum
[3] Mean
[4] Standard deviation

Table 6.—Number of trees per hectare by management compartment and dominant species - ELT 17

	Pinus echinata	*Carya* spp.	*Quercus alba*	*Quercus coccinea*	*Quercus stellata*	*Quercus velutina*	*Quercus* spp.	Other spp.	Total
Compartment 1	0.00[1]	0.00	25.00	25.00	0.00	25.00	0.00	0.00	
	290.00[2]	115.00	305.00	480.00	55.00	220.00	45.00	25.00	
	88.70[3]	33.15	107.59	166.11	15.00	109.63	7.04	5.56	532.78
	73.97[4]	29.36	62.38	117.97	17.97	59.71	11.71	6.70	
Compartment 2	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	
	280.00	190.00	310.00	190.00	70.00	385.00	120.00	160.00	
	39.84	58.87	104.84	83.87	11.94	118.23	16.13	26.13	459.84
	59.90	46.36	73.17	49.34	17.73	81.86	33.58	32.75	
Compartment 3	0.00	5.00	10.00	5.00	0.00	15.00	0.00	0.00	
	185.00	110.00	210.00	495.00	145.00	370.00	60.00	55.00	
	46.50	39.33	98.17	112.50	19.33	137.00	5.00	13.00	470.83
	44.47	29.99	50.15	98.35	32.37	83.49	11.82	13.43	
Compartment 4	0.00	0.00	10.00	10.00	0.00	5.00	0.00	0.00	
	220.00	140.00	230.00	430.00	70.00	185.00	60.00	50.00	
	65.52	50.69	101.38	100.17	18.79	75.17	5.69	13.28	430.69
	60.12	38.03	58.05	77.55	17.86	46.24	12.59	13.65	
Compartment 5	0.00	5.00	5.00	5.00	0.00	10.00	0.00	0.00	
	200.00	105.00	200.00	160.00	120.00	250.00	30.00	55.00	
	48.46	47.88	112.31	63.65	34.23	98.46	5.96	24.80	435.76
	52.30	26.73	54.17	39.26	35.99	59.56	8.00	16.61	
Compartment 6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	545.00	135.00	435.00	190.00	170.00	125.00	15.00	185.00	
	99.86	56.08	119.32	62.30	32.70	55.54	2.30	25.95	454.05
	116.40	34.62	83.81	44.22	43.09	37.63	3.65	34.40	
Compartment 7	0.00	0.00	5.00	15.00	0.00	0.00	0.00	0.00	
	245.00	90.00	120.00	450.00	140.00	240.00	50.00	25.00	
	59.07	19.63	50.00	148.70	36.67	37.96	6.48	4.44	362.96
	63.20	23.33	38.41	93.26	32.23	62.93	12.31	5.77	
Compartment 8	0.00	0.00	0.00	0.00	0.00	35.00	0.00	0.00	
	220.00	90.00	140.00	205.00	210.00	175.00	135.00	25.00	
	34.74	25.00	23.16	36.05	39.47	102.37	30.00	5.26	296.05
	57.87	24.66	39.76	60.34	46.81	38.17	38.37	6.56	
Compartment 9	5.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	
	90.00	140.00	200.00	230.00	90.00	160.00	115.00	45.00	
	23.57	32.58	75.16	89.52	17.74	75.97	7.58	6.29	328.41
	19.67	32.25	53.67	62.59	19.10	47.41	21.52	10.88	

[1] Minimum
[2] Maximum
[3] Mean
[4] Standard deviation

Table 7.—Basal area (sq M/ha) by management compartment and dominant species - ELT 17

	Pinus echinata	*Carya* spp.	*Quercus alba*	*Quercus coccinea*	*Quercus stellata*	*Quercus velutina*	*Quercus* spp.	Other spp.	**Total**
Compartment 1	0.00[1]	0.00	0.64	1.64	0.00	0.62	0.00	0.00	
	10.14[2]	3.41	7.12	12.07	4.19	9.49	2.02	1.50	
	3.20[3]	0.94	3.05	5.69	0.68	4.94	0.28	0.19	18.96
	2.53[4]	0.91	1.58	3.23	1.10	2.59	0.47	0.35	
	17%	5%	16%	30%	4%	26%	1%	1%	100%
Compartment 2	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	
	11.74	7.47	8.42	9.42	4.44	16.02	3.43	5.24	
	1.79	1.74	3.46	3.93	0.54	5.76	0.47	0.99	18.67
	2.41	1.58	2.14	2.69	0.98	3.66	0.99	1.28	
	10%	9%	19%	21%	3%	31%	3%	5%	100%
Compartment 3	0.00	0.06	0.16	0.48	0.00	0.37	0.00	0.00	
	12.79	4.56	8.82	14.33	7.17	15.04	2.41	2.44	
	2.74	1.38	3.34	4.69	0.95	7.41	0.23	0.57	21.31
	3.03	1.13	1.88	3.21	1.40	3.86	0.53	0.62	
	13%	6%	16%	22%	4%	35%	1%	3%	100%
Compartment 4	0.00	0.00	0.21	0.56	0.00	0.08	0.00	0.00	
	10.32	6.64	11.05	11.98	6.35	8.71	1.91	1.67	
	3.03	1.86	3.70	4.70	1.29	4.59	0.23	0.49	19.88
	2.64	1.62	2.34	2.86	1.40	2.79	0.52	0.51	
	15%	9%	19%	24%	6%	23%	1%	2%	100%
Compartment 5	0.00	0.26	0.07	0.09	0.00	0.42	0.00	0.00	
	9.42	3.37	12.17	7.22	7.06	11.25	1.57	1.86	
	2.76	1.58	4.51	3.18	2.23	5.20	0.28	0.64	20.37
	2.77	0.93	2.61	1.97	2.27	3.32	0.40	0.52	
	14%	8%	22%	16%	11%	26%	1%	3%	100%
Compartment 6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	19.15	5.50	12.77	15.52	9.01	11.50	1.12	4.70	
	3.99	1.82	4.36	4.77	1.99	4.59	0.14	0.68	22.34
	4.48	1.30	2.48	4.06	2.62	3.47	0.26	0.96	
	18%	8%	20%	21%	9%	21%	1%	3%	100%
Compartment 7	0.00	0.00	0.12	1.84	0.00	0.00	0.00	0.00	
	13.45	3.64	5.42	18.00	3.78	8.91	2.60	0.32	
	3.64	0.70	1.70	7.99	1.47	1.94	0.27	0.07	17.77
	3.80	0.88	1.52	3.21	1.09	2.99	0.55	0.08	
	20%	4%	10%	45%	8%	11%	2%	0%	100%
Compartment 8	0.00	0.00	0.00	0.00	0.00	1.86	0.00	0.00	
	9.98	3.06	10.09	12.22	8.85	15.83	6.44	1.66	
	1.73	0.78	1.13	2.74	1.78	7.17	1.33	0.16	16.83
	2.95	0.81	2.51	4.13	2.09	3.71	1.85	0.38	
	10%	5%	7%	16%	11%	43%	8%	1%	100%
Compartment 9	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	
	4.18	4.39	9.35	12.50	3.60	13.70	4.65	1.32	
	1.16	1.11	3.41	4.78	0.97	5.29	0.31	0.14	17.16
	1.17	1.07	2.47	2.83	0.99	3.65	0.89	0.30	
	7%	6%	20%	28%	6%	31%	2%	1%	100%
Grand Mean	2.67	1.32	3.18	4.72	1.32	5.21	0.39	0.44	19.26
Percent Mean	14%	7%	16%	25%	7%	27%	2%	2%	100%

[1] Minimum
[2] Maximum
[3] Mean
[4] Standard deviation

Table 8.—Number of trees per hectare by management compartment and dominant species - ELT 18

	Pinus echinata	*Carya* spp.	*Quercus alba*	*Quercus coccinea*	*Quercus stellata*	*Quercus velutina*	*Quercus* spp.	Other spp.	Total
Compartment 1	0.00[1]	5.00	25.00	25.00	0.00	25.00	0.00	0.00	
	200.00[2]	195.00	380.00	305.00	50.00	240.00	5.00	55.00	
	22.73[3]	65.30	125.61	109.55	5.91	108.94	0.15	17.58	455.76
	39.25[4]	46.69	73.86	71.17	12.71	55.63	0.87	14.95	
Compartment 2	0.00	15.00	50.00	15.00	0.00	20.00	0.00	10.00	
	85.00	190.00	180.00	210.00	45.00	200.00	35.00	75.00	
	13.18	90.68	99.09	100.23	2.27	87.50	2.05	36.14	431.14
	28.43	53.21	34.49	55.82	9.60	46.00	7.51	24.49	
Compartment 3	0.00	10.00	40.00	10.00	0.00	5.00	0.00	0.00	
	75.00	225.00	245.00	215.00	30.00	260.00	30.00	70.00	
	18.41	74.09	142.27	85.23	8.41	86.36	1.59	30.23	446.59
	25.09	47.45	66.76	54.61	12.09	63.62	6.43	21.46	
Compartment 4	0.00	20.00	40.00	5.00	0.00	10.00	0.00	0.00	
	75.00	240.00	275.00	180.00	80.00	160.00	75.00	115.00	
	13.13	95.42	123.96	75.63	13.33	69.17	8.75	36.04	435.42
	21.15	53.93	65.57	52.72	22.78	48.09	18.01	33.00	
Compartment 5	0.00	20.00	20.00	10.00	0.00	5.00	0.00	0.00	
	50.00	265.00	295.00	185.00	60.00	160.00	5.00	65.00	
	9.77	105.68	100.68	60.45	10.23	80.00	0.23	23.64	390.68
	12.49	64.20	64.26	42.84	15.70	42.37	1.07	18.97	
Compartment 6	0.00	10.00	40.00	10.00	0.00	0.00	0.00	5.00	
	135.00	250.00	285.00	150.00	20.00	120.00	5.00	140.00	
	13.20	72.60	140.40	66.00	3.20	48.00	0.40	50.80	394.60
	27.83	57.94	68.52	41.13	6.44	33.70	1.38	34.60	
Compartment 7	0.00	0.00	0.00	10.00	0.00	10.00	0.00	0.00	
	235.00	85.00	290.00	230.00	170.00	235.00	10.00	55.00	
	24.13	28.70	62.17	101.74	33.48	91.09	1.74	8.26	351.30
	49.03	22.57	65.21	62.86	36.94	57.19	3.57	11.93	
Compartment 8	0.00	0.00	15.00	20.00	0.00	5.00	0.00	0.00	
	165.00	95.00	210.00	215.00	115.00	220.00	15.00	90.00	
	15.45	28.86	91.82	99.09	26.36	91.14	2.05	18.86	373.64
	34.29	29.68	57.31	58.59	30.09	59.90	3.98	25.40	
Compartment 9	0.00	10.00	0.00	0.00	0.00	5.00	0.00	0.00	
	35.00	160.00	230.00	135.00	70.00	155.00	30.00	55.00	
	3.81	59.76	84.52	54.05	12.86	56.90	2.14	21.43	295.48
	7.73	44.54	59.47	33.64	22.06	42.29	6.63	15.50	

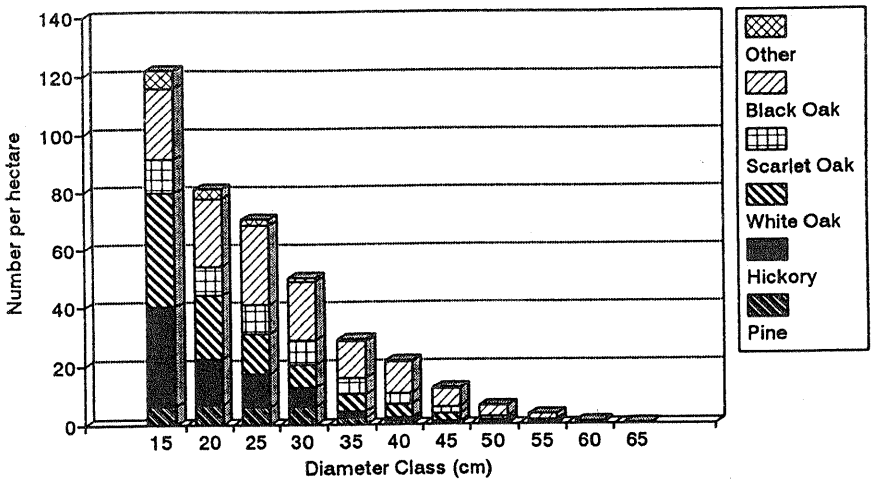
[1] Minimum
[2] Maximum
[3] Mean
[4] Standard deviation

Table 9.—Basal area (sq M/ha) by management compartment and dominant species - ELT 18

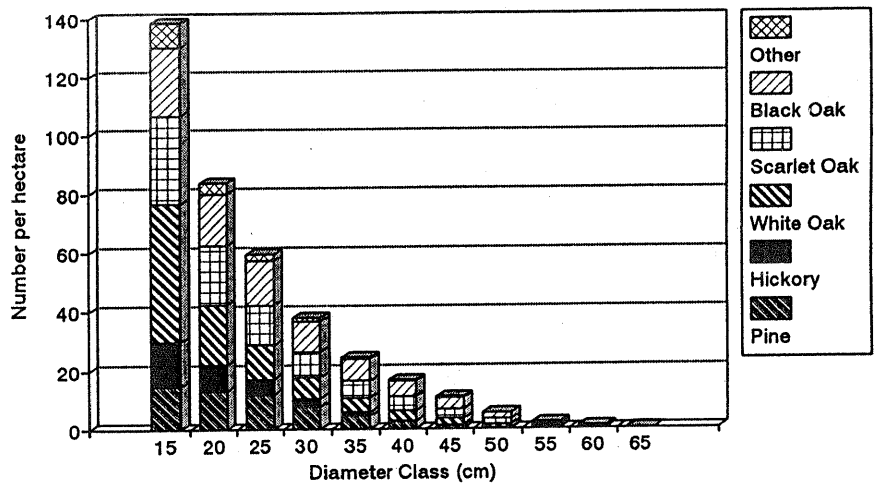
	Pinus echinata	*Carya* spp.	*Quercus alba*	*Quercus coccinea*	*Quercus stellata*	*Quercus velutina*	*Quercus* spp.	Other spp.	Total
Compartment 1	0.00[1]	0.05	0.69	0.76	0.00	1.01	0.00	0.00	
	10.26[2]	6.50	10.43	13.28	3.49	11.72	0.32	3.51	
	1.18[3]	2.14	3.92	5.43	0.32	6.35	0.01	0.63	19.98
	2.03[4]	1.61	2.26	3.03	0.77	3.06	0.06	0.82	
	6%	11%	20%	27%	2%	32%	0%	3%	100%
Compartment 2	0.00	0.20	1.58	0.72	0.00	1.03	0.00	0.10	
	4.63	6.39	7.80	15.78	3.25	12.90	1.19	3.00	
	0.55	2.98	3.29	5.62	0.18	6.16	0.06	1.08	19.94
	1.22	1.99	1.47	3.23	0.70	3.32	0.25	0.86	
	3%	15%	17%	28%	1%	31%	0%	5%	100%
Compartment 3	0.00	0.68	1.36	0.72	0.00	0.35	0.00	0.00	
	5.42	6.02	12.35	9.99	4.06	14.62	1.85	3.17	
	1.06	2.58	4.71	4.79	0.69	6.36	0.09	1.30	21.57
	1.49	1.73	2.22	2.57	1.18	3.79	0.39	0.95	
	5%	12%	22%	22%	3%	29%	0%	6%	100%
Compartment 4	0.00	0.64	1.08	0.37	0.00	0.47	0.00	0.00	
	3.51	9.13	10.17	11.40	5.30	12.19	2.02	4.73	
	0.68	3.20	4.44	4.31	0.86	5.02	0.25	1.30	20.06
	1.08	2.42	2.31	3.18	1.52	3.66	0.53	1.12	
	3%	16%	22%	22%	4%	25%	1%	6%	100%
Compartment 5	0.00	0.54	0.39	0.24	0.00	0.38	0.00	0.00	
	3.74	9.32	9.12	14.96	5.83	12.33	0.20	4.59	
	0.56	3.89	3.82	4.01	0.75	6.11	0.01	0.86	20.02
	0.86	2.47	2.40	3.21	1.34	2.67	0.04	1.16	
	3%	19%	19%	20%	4%	31%	0%	4%	100%
Compartment 6	0.00	0.11	0.90	0.47	0.00	0.00	0.00	0.05	
	4.72	10.22	11.41	13.96	1.63	10.89	0.12	5.89	
	0.59	2.70	6.13	6.06	0.25	5.12	0.01	1.59	22.45
	1.04	2.48	3.04	3.89	0.49	3.61	0.03	1.53	
	3%	12%	27%	27%	1%	23%	0%	7%	100%
Compartment 7	0.00	0.00	0.00	1.51	0.00	0.56	0.00	0.00	
	13.91	4.14	12.80	19.41	6.94	20.81	0.77	0.97	
	1.40	1.16	2.69	7.66	1.52	6.55	0.08	0.14	21.20
	2.85	1.04	3.30	4.74	1.76	5.06	0.20	0.27	
	7%	5%	13%	36%	7%	31%	0%	1%	100%
Compartment 8	0.00	0.00	0.19	1.69	0.00	0.21	0.00	0.00	
	8.72	5.40	12.07	19.79	8.27	16.12	0.61	3.50	
	0.85	1.26	4.30	8.15	1.52	6.27	0.09	0.49	22.93
	1.82	1.57	3.60	5.06	2.06	4.30	0.19	0.84	
	4%	6%	19%	36%	7%	27%	0%	2%	100%
Compartment 9	0.00	0.24	0.00	0.00	0.00	0.12	0.00	0.00	
	3.32	6.99	13.77	10.53	6.87	14.21	0.65	1.63	
	0.37	2.21	4.45	3.86	1.17	4.50	0.07	0.51	17.14
	0.75	1.53	3.64	3.18	2.05	3.77	0.17	0.51	
	2%	13%	26%	23%	7%	26%	0%	3%	100%
Grand Mean	0.80	2.46	4.19	5.54	0.81	5.83	0.08	0.88	20.59
Percent Mean	4%	12%	20%	27%	4%	28%	0%	4%	100%

[1] Minimum
[2] Maximum
[3] Mean
[4] Standard deviation

A. Ecological Landtype 11



B. Ecological Landtype 17



C. Ecological Landtype 18

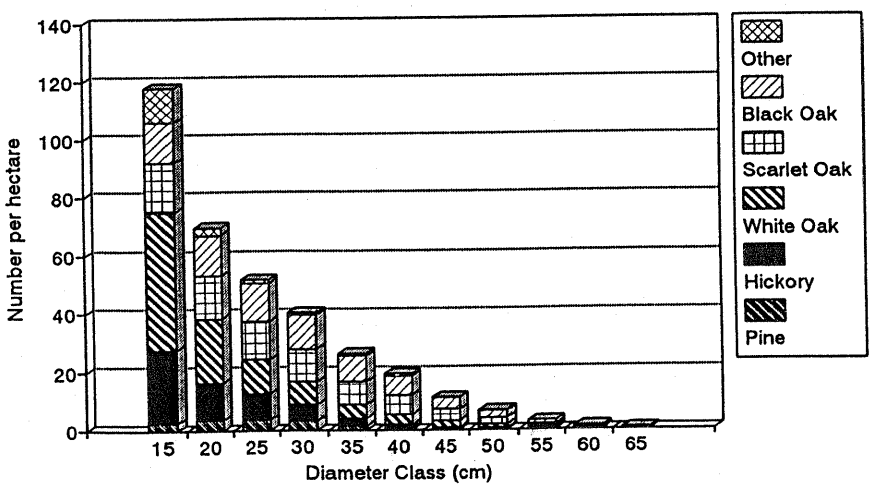


Figure 2.—Number of stems per hectare by size class and major species group. White oak includes post oak.

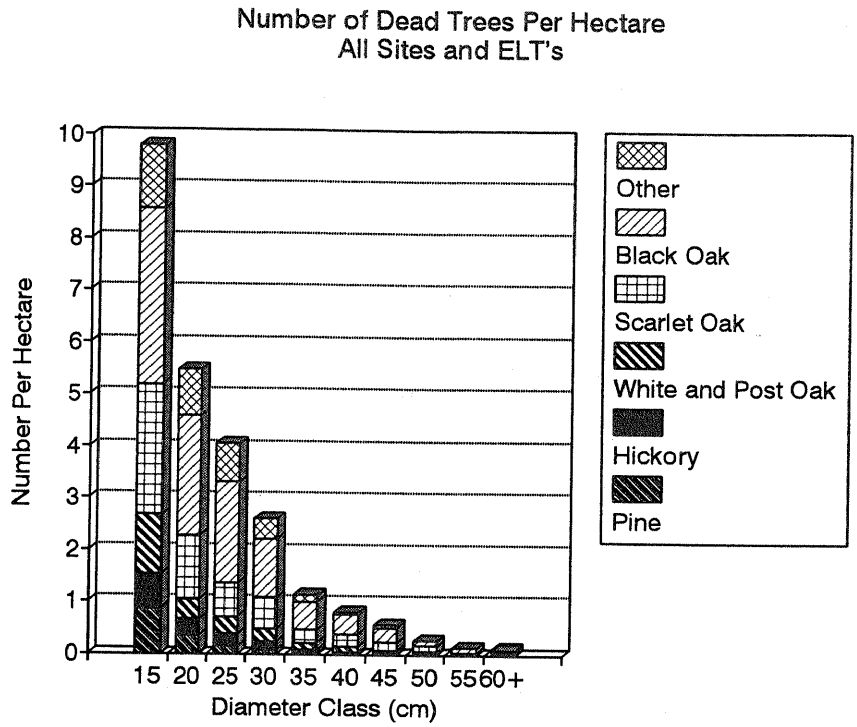


Figure 3.—Size class distribution of dead trees.

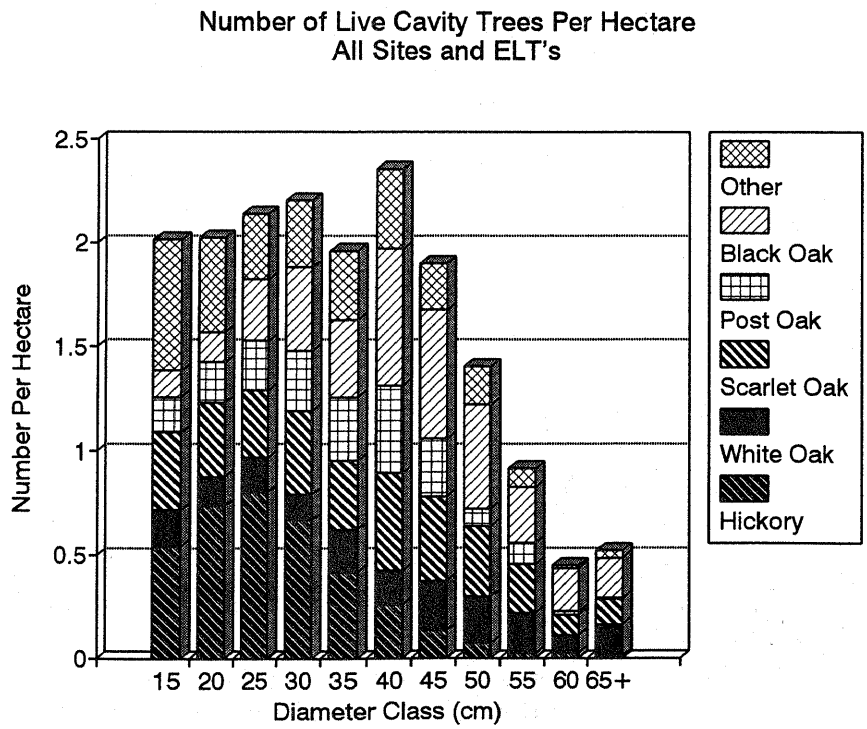


Figure 4.—Size class distribution of all live cavity trees.

Permanent plot establishment resulted in data base of 54,397 standing trees 11.4 cm (4.5 inches) dbh and larger of which 3,741 are dead (Figure 3). Of the 54,397 trees, 2,371 live (Figure 4) and 817 dead trees contain cavities. Additionally, 41,562 trees from 3.8 to 11.3 cm (1.5 and 4.4 inches) in diameter and 26,913 from one meter tall to 3.7 cm (3.1 feet and 1.5 inches) in diameter have been identified and measured. A total of 4,654 pieces of down dead woody material have been documented and over 330 different species of herbaceous plants have been identified and their coverage estimated.

As mentioned previously, a number of independent studies are currently in progress on MOFEP sites. Because of the long term nature of MOFEP, results from these studies from which management recommendations can be made will not be available for many years. However, the preliminary information obtained to date has proven to be very interesting. For example, investigators associated with the forest interior songbird study have collected two years of pretreatment information. Data collected in 1991 and 1992 suggested that nesting success rates were high, nearly 60% for some species and up to 80% for others, and the rate of nest parasitism by brown-headed cowbirds was low, as only eight were parasitized (Clawson, pers. comm.). Nest predation rates were also low, approximately 20%. Approximately 1800 birds have been netted and banded during 1991 and 1992. The results though preliminary, already have proved valuable in the international Partners In Flight program of conservation of neotropical migrant birds.

DISCUSSION

Committing the funding and resources to a long-term project like MOFEP exhibits both forward thinking and a commitment to the proper management of the resource on the part of the Missouri Department of Conservation. These traits were also exhibited by the core group of individuals who were initially involved in proposing MOFEP. A tremendous amount of work and diligence was needed to finally launch a project of this magnitude.

Implementing a long term study like MOFEP can at times be frustrating. The many concurrent interrelated studies demand detailed coordination. The Department Administration has assigned three permanent positions exclusively to MOFEP: a research forester and two assistant research foresters. The research forester is primarily responsible for the forest vegetation study but also serves as the local coordinator for all associated studies.

A large number of people, associated with various MOFEP studies, converge on a very small town in the Missouri Ozarks for three to four months each summer. During the first two to three weeks of the summer the research forester spends much time orienting summer workers to their new quarters and assignments. What would seem to be simple matters, like arranging transportation, can occupy considerable amount of the research forester's time. A research forester coordinating a project like MOFEP on site must be able to handle a multitude of problems that have nothing to do with conducting field research.

Public relations problems in a small town of 1,200 must be addressed. The convergence of many summer workers must be explained to the local people through newspaper articles, group presentations and personal communication. Without adequate explanation, rumors of why so many people associated with the "government" have landed in one small town can be very interesting.

Convincing the public of the authenticity of long term goals of a project like this is difficult. Critics, including the media, frequently believe that research is being conducted to justify current management practices. There is also a tendency for the public to draw premature conclusions. However, these problems can be addressed through diligent attempts to educate the public through the media. In MOFEP, this is being attempted through press releases, tours, exhibits, printed information, and public presentations.

Locating nine parcels of land at least 250 ha in size without previous manipulation for at least 20 years was also a difficult task. These parcels also needed to be within close proximity to each other to facilitate data collection. Fortunately, the heavily forested Ozarks provided the opportunity to conduct a replicated ecosystem level experiment.

The very nature of ecosystem level research requires a tremendous amount of data collection. Identifying and subsequently employing qualified individuals to collect information primarily during the summer months has proven to be very difficult. It is very important to advertise the need for data collectors several months prior to the job starting. Investigators associated with MOFEP have been successful in attracting students from many disciplines from all over the United States to work during the summer months on various projects.

CONCLUSION

Results obtained from MOFEP should help determine the effects of evenaged, unevenaged, and non-manipulative management on major living and non-living components of an oak-hickory forest. Additionally, this project will allow researchers to characterize, with great detail, the major components of an Ozark forest ecosystem and possibly determine how these components interact.

Additional benefits of establishing long term experiments may be significant, but not apparent to us today. Forest ecosystem researchers must be farsighted enough to anticipate problems which might be encountered perhaps 100 years in the future. At the same time, researchers must attempt to solve today's problems. Additional benefits of a long term experiment may be realized in the future when an issue such as gypsy moth, biodiversity, or global warming becomes critical.

LITERATURE CITED

Clawson, R.L. 1992. Personal communication.

Curtis, R.O. 1983. Procedure for establishing and maintaining permanent plots for silvicultural and yield research. USDA For. Serv. Gen. Tech. Rep. PNW-155, PNW For. and Range Exp. Stn. 56p.

Franklin, J. 1989. Toward a new forestry. Am. For. November/December: 37-44.

Gott, J. 1975. Soil survey of the Mark Twain National Forest Area, Missouri (Parts of Carter, Oregon, Ripley and Shannon counties.) USDA Forest Service, Rolla, Mo.

Elder, F.C. and H.C. Martin. 1989. Kejimkujik P - One in a family of integrated watershed studies. Water, air and soil pollution. Vol. 46 Nos. 1-4. pp. 1-12.

Hahn, J.T. 1991. Timber resource of Missouri. USDA For. Serv. N.C. For. Exp. Stn., Res. Bull. NC-119. 123 pp.

Law, J.R. and C.G. Lorimer. 1989. Managing unevenaged stands. In: Central Hardwoods Notes, F.B. Clark and J.G. Hutchison, editors. USDA For. Serv. N. C. For. Exp. Stn., St. Paul, MN. 6 pp.

Likens, P.C. 1988. Publications of the Hubbard Brook ecosystem study. Millbrook, New York. Institute of Ecosystem Studies, Cary Arboretum, Box AB, Millbrook, NY 12545, 124 p.

Miller, M.R. 1981. Ecological Land Classification Terrestrial Subsystem - A basic inventory system for planning and management of the Mark Twain National Forest. USDA Forest Service, Rolla, Mo. 56 p.

Missouri Department of Conservation. 1986. Forest Land Management Guidelines. Mo. Dept. of Cons. 86 pp.

Missouri Geological Survey. 1961. Stratigraphic Succession in Missouri. Mo. Dept. of Natural Resources. Rolla, Mo.

Missouri Geological Survey. 1979. Geologic Map of Missouri. Mo. Dept. of Natural Resources. Rolla, Mo.

National Research Council. 1990. Forestry Research - A Mandate for Change. National Academy Press, Washington D.C. 84 p.

Nelson, P.W. 1985. The Terrestrial Natural Communities of Missouri. M. Dept. of Nat. Res., Jefferson City, Mo. 197 p.

Roach, F.A. and S.F. Gingrich. 1968. Evenaged silviculture for upland central hardwoods. U. S. Dept. of Ag. Handbook 355, Washington, D. C. 39 pp.

Scherbatskoy, T. 1992. Personal communication.

Spencer, J.S. Jr., S.M. Roussopoulos, and R.A. Massengale. 1992. Missouri's Forest Resource, 1989: an Analysis. USDA For. Serv. Res. Bull. NC-139. 84 p.

Thom, R. H. and J. H. Wilson. 1980. The natural divisions of Missouri. In: Transactions of the Missouri Academy of Science. Vol. 14. pp 9-23.