Mark Twain National Forest

Comparison of Measured Growth and Mortality Trends to Modeled FVS Projections Relative to Oak Decline Impacts as Observed Over Three FIA Inventory Cycles

Fall 2006

(Updated: Spring 2010)

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Mark Twain National Forest
Oak Decline Assessment

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1. Project Purpose

Background

In 2003, the Mark Twain National Forest contacted the U.S. Forest Service, Forest Health Protection (FHP) Staff, St. Paul Field Office, requesting assistance with data analysis in support of their forest plan revision efforts. They were particularly interested in being able to use Forest Inventory Analysis (FIA) data to predict the effects of oak decline on future forest health conditions. Refer to Appendix A to review the memo that details this request.

A Forest Service team was assembled to address their data needs. The team included a scientist from the Northern Research Station Disease Research Work Unit, analysts from FIA, and pathologists from FHP. The team originally intended to prepare an overarching product that would include an assessment of the oak resource in Southern Missouri, analysis of data on the cause of oak decline, and management implications/recommendations. The final product(s), however, ended up being a series of individual projects that supported the original data request. Refer to Appendix B.

In addition to the published products, the team developed a timeline of events that was particularly useful in visualizing the relationships between drought events, survey efforts, and periods of oak mortality. This table was not published, but is included here in Appendix C.

This project involved an analysis of FIA data from multiple survey cycles to evaluate oak decline. FIA data from re-measured stands was used to validate projections of tree growth and stand conditions as modeled by the Forest Vegetation Simulator (FVS). The results of this project were discussed with the Mark Twain National Forest staff in September 2006, and then presented at the Third Forest Vegetation Simulator Conference in February 2007. The conference proceeding paper can be found at:

http://www.fs.fed.us/fmsc/fvs/fvs_conference.shtml.

The purpose of this document is to capture extensive information on the methods used for data analysis. The process that was developed could be quite valuable for application to other projects.

Abstract from Third FVS Conference

Comparison of FVS Projection of Oak Decline on the Mark Twain National Forest to Actual Growth and Mortality as Measured Over Three FIA Inventory Cycles

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Abstract— *Oak decline has been recorded on oak forests throughout the Ozark Plateau of Missouri since the 1970s, but severe drought in the late 1990s, combined with the advancing age of the Ozark forests, has intensified the levels of crown dieback and mortality beyond historical levels. The purpose of this project was to determine whether the Forest Vegetation Simulator (FVS) model could accurately predict the effect of oak decline on the Mark Twain National Forest (MTNF). Forest Inventory and Analysis (FIA) data were used to benchmark mortality magnitude and to adjust FVS growth projections. Data from inventory cycles 3 (1976-1977), 4 (1986-1987), and 5 (1999-2003) were available for approximately 150 oak stands on the MTNF. These data were translated into FVS-ready format and projected with and without the Oak Decline Event Monitor (ODEM) addfile. Actual growth and mortality versus projected values were compared. In the absence of harvesting or other major disturbance, baseline mortality per size class in a healthy forest is generally constant and departure from this constant may indicate unsustainable forest conditions. We compared current mortality rates to calculated mortality rates between inventory cycles 3 and 4 (i.e. prior to the latest decline events) to indicate whether mortality rates increased between inventory periods. This paper describes the FVS adjustments and methodology used; assesses the usefulness of FIA data and application of the ODEM addfile for this project; and, discusses how FVS tools and comparison of baseline mortality rates could be used to predict future trends in Missouri oak forests.*

2. FIA Data Sources

Cycle 3 and 4: Periodic Inventory

The Mark Twain National Forest is located in south-central Missouri and encompasses approximately 1.5 million acres. Refer to the following graphic:

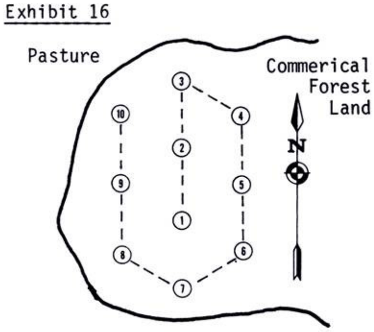
In Missouri, the 3rd FIA periodic inventory was collected from 1969-1972. Subsequently, data for the Mark Twain National Forest (MTNF) was also gathered in 1976-1977. The 4th FIA periodic inventory cycle for Missouri was completed in 1989 with most of the data on the MTNF collected from 1986-1987. Both the 3rd and 4th inventory data were gathered in accordance with a 10-point sample design distributed over approximately an acre of ground around plot center (NCRS 1969, NCRS 1986).

Plot Design, Item 16.

The pattern of sample points is designed to obtain a uniform distribution of points over approximately 1 acre. Measured distances between sequential points is 70 horizontal feet.

Exhibit 16

From Point	to Point	Azimuth
1	2	0°
2	3	0
3	4	120
4	5	180
5	6	180
6	7	240
7	8	300
8	9	0
9	10	0

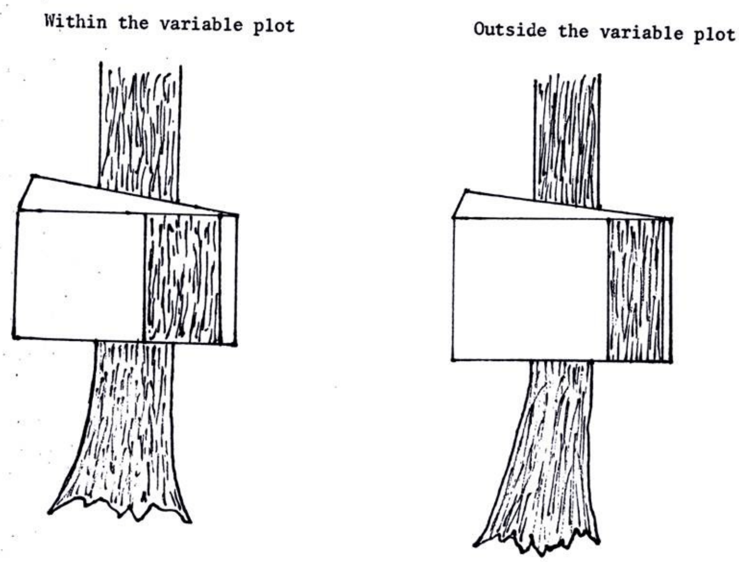


All trees 5.0" dbh and larger were tallied on a variable radius plot (37.5 basal area factor prism).

Variable Radius Plot, Item 18.

All trees 5.0" DBH and larger (except dead trees not qualifying as mortality or salvable-mortality) will be tallied if the tree is within the limiting distance of the 37.5 basal area factor prism. Example 18 illustrates trees that are within the variable plot, outside the variable plot, and those that are questionable. Questionable trees will be checked for their limiting distance. The limiting distance is the horizontal distance from the pin to the center of the tree at DBH. For example, a tree with a DBH of 14.6", is 20.7 feet, using a basal area factor of 37.5. Table 18 shows the limiting distances for the 37.5 basal area factor prism.

EXAMPLE 18



Trees less than 5.0" dbh were tallied on a fixed radius plot (1/300 acre).

Fixed Radius Plot (1/300 Acre), Item 19.

Trees tallied on the fixed radius plot must be live and have the center of their stem at the base within a 6.8' horizontal distance of the point center.

Saplings - Points 1-3. Tally all live saplings (trees ≥ 1.0" DBH, but < 5.0" DBH) within the fixed radius plot.

Points 4-10. If 16.0% stocking is not reached using 5.0" DBH and larger trees record the most dominant saplings to reach 16% stocking on each point.

Seedlings - Points 1-10. If no live trees 5.0" DBH or larger are recorded at a point and if not enough saplings are present to reach 16% stocking, record seedling (trees <1.0" DBH) data until 16% stocking is reached on that point.

Minimum height requirement to be considered a seedling is .5' for softwood and 1.0' for hardwood species. DBH for seedlings is recorded as 000.

Cycle 5: Annual Inventory

Plot Setup

In 1999, FIA began the 5th inventory cycle for Missouri with a new annualized survey design (NCRS 1999). The field plot consists of four subplots approximately 1/24 acre in size with a radius of 24.0 feet. The center subplot is Subplot 1. Subplots 2, 3, and 4 are located 120.0 feet horizontal at azimuths of 360, 120, and 240 degrees, respectively from the center of Subplot 1. Refer to figure 1. Subplots are used to collect data on trees with a diameter (at breast height "DBH") of 5.0 inches or greater.

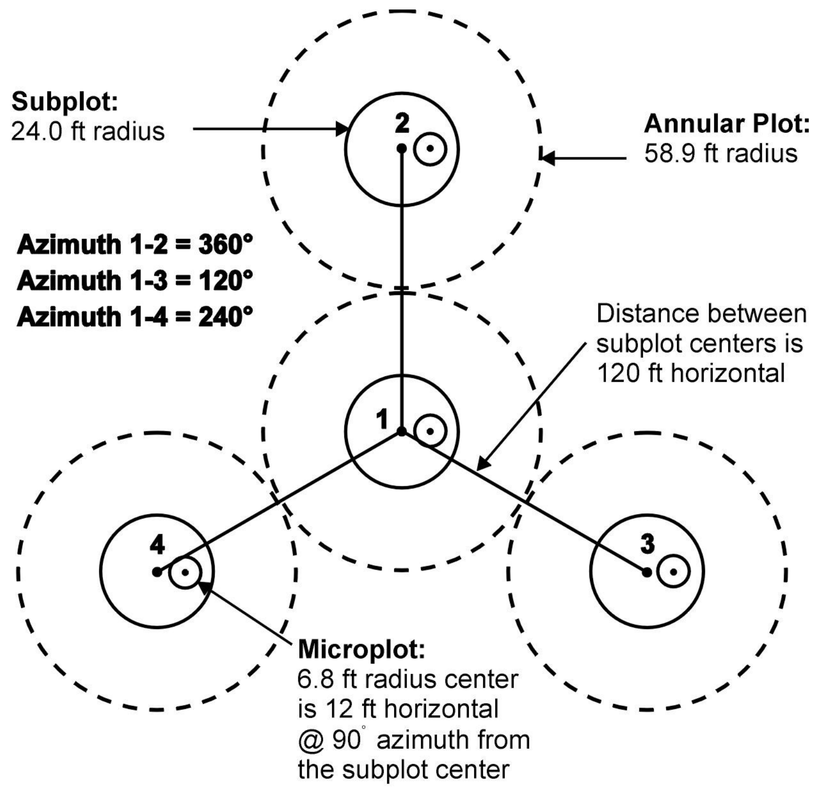


Figure 1. FIA plot diagram.

Each subplot contains a microplot approximately 1/300 acre in size with a radius of 6.8 feet. The center of the microplot is offset 90 degrees and 12.0 feet horizontal from each subplot center. Microplots are numbered in the same way as subplots. Microplots are used to collect data on saplings (DBH of 1.0 inches to 4.9 inches) and seedlings (DBH less than 1.0 inch in diameter and greater than 0.5 foot in height (conifers) or greater than 1.0 foot in height (hardwoods)).

The field plot may also include annular plots of 1/4 acre in size with radius of 58.9 feet with the annular plot center coinciding with each subplot center. Annular plots are numbered in the same way as subplots. Annular plots may be used to collect additional data for regional enhancements such as very large trees.

Tree and Sapling Data

Trees at least 5.0 inches in diameter are sampled within the subplot. 'Tally trees' are defined as all live and standing dead trees in accessible forest land condition classes encountered on the subplot the first time a subplot is established, and all trees that grow into a subplot thereafter. These data yield information on tree growth, mortality, removals; coarse woody debris; wildlife habitats; forest structure and composition; biomass; and carbon sequestration.

Saplings, trees with a diameter at least 1.0 inch but less than 5.0 inches, are sampled within the microplot. 'Tally saplings' are defined as all live saplings in accessible forest land condition classes encountered the first time a microplot is established, and all saplings that grow into each microplot thereafter are included until they grow to 5.0 inches or larger, at which time they are tallied on the 24.0 foot subplot and referenced (new azimuth and distance taken) to the subplot center.

Seedling Data

Stocking and regeneration information are obtained by counting seedlings within the 6.8 foot radius microplot located 90 degrees and 12.0 feet from each subplot center within each of the four subplots. Conifer seedlings must be at least 6.0 inches in length and less than 1.0 inch at DBH in order to qualify for tallying. Hardwood seedlings must be at least 12.0 inches in length and less than 1.0 inch at DBH in order to qualify for tallying. Seedlings are counted in groups by species and condition class, up to 5 individuals per species. Counts beyond 5 are coded as 6. Species are coded in order from most abundant to least abundant when SEEDLING COUNT is coded as 6. Only seedlings that occur in accessible forest land condition classes are counted.

FIA Plot Distribution

We acquired FIA data for cycle 4 and 5 in FVS-ready format through the Internet using the Forest Inventory Mapmaker program (Miles 1992). Cycle 3 data was not readily available. It was obtained directly from the North Central Research Station FIA Unit and required substantial effort to convert to FVS-ready format. Inventory dates by geographic location and measurement cycle are displayed in the following table:

		Measurement Dates		
		Cycle 3	Cycle 4	Cycle 5
Missouri:	All Types	1969-1972 1976-1977	1986-1989	1998-2003
Mark Twain:	All Types	1969-1971 1976-1977	1986-1988	1998-2003
Common:	All Types	1969-1971 1976-1977	1986-1988	1998-2003

We considered the data from each inventory cycle as unique condition class samples. There were 911 '*total*' plots assembled and utilized for various aspects of the study. The data were used to: calibrate the FVS model; determine the maximum bounds expected for stand density and tree size attainment; and, construct regeneration addfiles. The following table displays plot counts by geographic location and measurement cycle:

		FIA Plot Counts		
		Cycle 3	Cycle 4	Cycle 5
Missouri:	All Types	3026	5076	3742
	Oak-Hickory	2467	4010	2933
Mark Twain:	All Types	247	418	406
	Oak-Hickory	213	344	354
Common:	All Types	157	157	157
	Oak-Hickory	150	145	141

--> 557 FIA Plots used for FVS Calibration

\+ --> 911 FIA Plots used for FVS Tree and Stand Maximums

\+ --> 911 FIA Plots used for FVS Regeneration Imputation

North Central FIA also provided a plot number "crosswalk" which enabled us to match the center point of the sample plots among the 3rd, 4th, and 5th FIA inventory cycles. We restricted our data scope to oak forests of the Mark Twain National Forest residing within the Ozark Plateau in south-central Missouri. This corresponds to forestlands in the Northwest Ozark, Southwest Ozark, and Eastern Ozark FIA Survey Units. Through this screening process, we were able to identify 154 '*common*' plots on the MTNF that were remeasured in FIA cycles 3 (1976-1977), 4 (1986-1987), and 5 (1999-2003). After filtering to exclude disturbed plots, non-oak forest types, small diameter stands, and other anomalous plots (such as cycle 3 plots that were measured during 1969-1971), there were 100 '*base'* plots available for our oak decline analysis. For each of these plots, we had field measurements from the same plot center for each of the three inventory cycles spanning a 25 year period.

Common	Unit 5	Disturbed	Non-Oak	Early Cyc3	Small Size	Filtered	Available
157	3	29	4	17	4	57	100

--> FIA Survey Unit 5: Riverborder

3. FVS Model Adjustments

An essential step in properly using the Forest Vegetation Simulator is applying adjustments to the model. The FVS geographic variants are comprised of numerous mathematical relationships. In the biological sciences, regression equations at best achieve r-squared correlation values of 70 relative to the fitted data. If the results of one regression function provide the input to another, then the resultant error is compounded. Thus, it behooves the user to validate the virtual world estimates generated by FVS against real world values obtained from the inventory sample.

FVS Self Calibration

One of the end targets for calibrating the FVS model is the creation of the ReadCorD (Readjust Correction for Diameter) keyword. Input of this keyword alters the baseline estimate for the large-tree diameter growth submodel. For a particular species, the original baseline estimate is multiplied by the value of this keyword, and the result becomes the new baseline estimate. These adjustments are done prior to the model's self calibrating routines. Calculated scale factors derived from FVS self calibrating attenuate toward a value midway between the calculated scale factor and the new baseline estimate at 25 year intervals. The following values were computed for model calibration.

FVS Scale Factors used for Mark Twain Oak Decline

CALIBRATION STATISTICS
GENERATED BY RUNSTREAM: Calib_34
DATE: 06-09-2006 TIME: 10:51:05 VARIANT: CS 6.21

LARGE TREE DIAMETER GROWTH CALIBRATION SUMMARY

			SCALE FACTOR SUMMARY				TOTAL	MEAN
	MODEL					STD	TREE	READCORD
SPECIES	TYPE*	N	MIN	MEAN	MAX	DEV.	RECORDS	MULTIPLIER
3 SP	LD	48	0.194	0.520	1.076	0.224	417	0.511
18 PH	LD	3	0.514	0.855	1.244	0.367	18	0.851
23 BI	LD	2	0.434	0.691	0.948	0.363	10	0.669
39 RL	LD	2	0.536	0.578	0.620	0.059	10	0.566
47 WO	LD	94	0.186	0.527	1.192	0.263	803	0.512
48 RO	LD	5	0.147	0.350	0.758	0.240	42	0.365
50 BO	LD	90	0.128	0.530	1.263	0.243	674	0.503
51 SO	LD	38	0.119	0.457	0.941	0.269	316	0.445
52 BJ	LD	7	0.257	0.595	1.005	0.245	39	0.585
57 PO	LD	30	0.233	0.638	1.199	0.248	222	0.620
85 NC	LD	9	0.199	0.515	1.027	0.352	62	0.499

Refer to Appendix D for the Tree Species Code guide.

Tree Defect

Determining net merchantable volume from gross tree dimensions requires an estimate of tree defect. Values were obtained from personnel at the North Central Forest Experiment Station. This information was retrieved from the FIA database using the Forest Inventory Mapmaker program. Defect data was selected from the Cycle 4 Periodic Inventory.

TABLE 3

Forest Inventory Mapmaker Version 1.0

Geographic area of interest is Missouri 1989 cycle04 (Cycle 4 Periodic inventory).
The attribute of interest is Volume of all live on timberland(cuft).
Filters: National Forest includes (Mark Twain),and .
(t.spcd = 802 or t.spcd = 806 or t.spcd = 812 or t.spcd = 833 or t.spcd = 835 or t.spcd = 837)
Rows are Current dbh 2 inch classes to 40 inches.
Columns are Tree class.
Includes ONLY

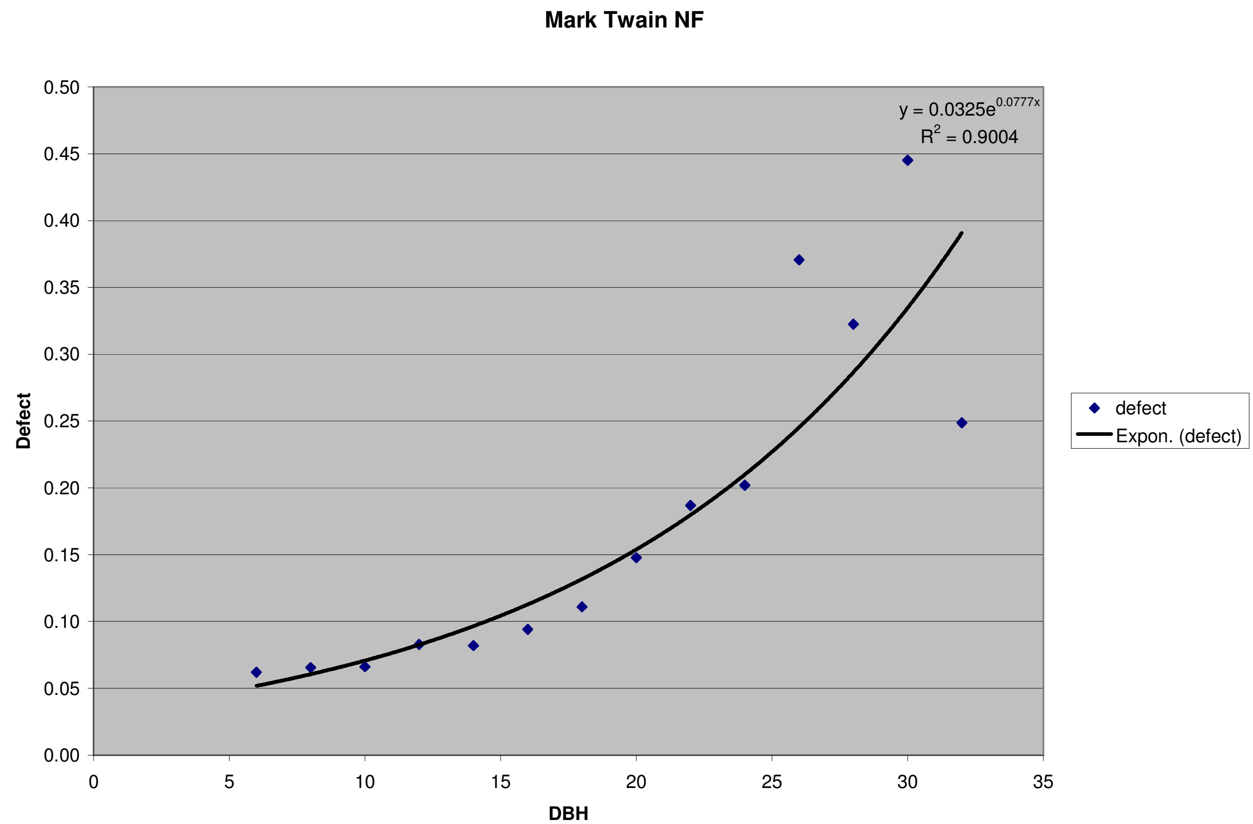
white oak, scarlet oak, S. red oak, N. red oak, post oak and black oak on the MTNF

Two-way table (rows and columns)

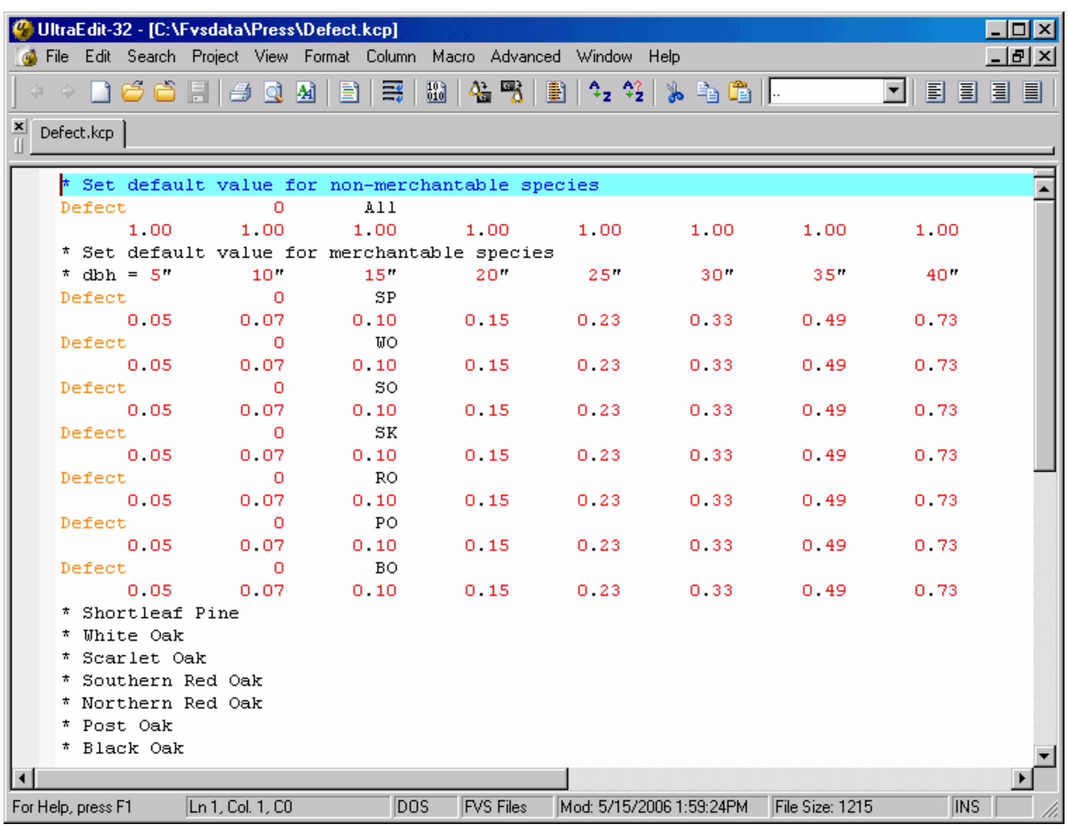
	Dbh class	Total	Growing stock	Rough cull	Rotten cull
3	5.0-6.9	90,759,274	78,364,018	11,257,729	1,137,527
4	7.0-8.9	132,671,714	111,098,496	19,940,516	1,632,703
5	9.0-10.9	154,019,983	129,227,307	22,406,821	2,385,854
6	11.0-12.9	171,080,202	123,750,894	44,169,608	3,159,700
7	13.0-14.9	171,732,025	129,326,022	37,160,850	5,245,153
8	15.0-16.9	129,056,543	87,045,021	37,436,892	4,574,631
9	17.0-18.9	68,324,928	44,421,651	18,022,248	5,881,029
10	19.0-20.9	41,018,123	21,977,832	12,290,249	6,750,042
11	21.0-22.9	16,696,836	7,367,552	4,948,569	4,380,716
12	23.0-24.9	9,918,027	4,144,946	2,732,124	3,040,956
13	25.0-26.9	4,210,371	314,372	692,300	3,203,700
14	27.0-28.9	3,275,212	0	1,498,075	1,777,137
15	29.0-30.9	1,531,150	0	0	1,531,150
16	31.0-32.9	1,334,443	0	977,828	356,615
17	33.0-34.9	92,098	0	0	92,098
18	35.0-36.9	556,060	0	556,060	0
0	Total	996,276,992	737,038,112	214,089,868	45,149,011

5/27/2004 15:03

							observed	predicted
dbh	class	total	growing	rough	rotten		defect	defect
6	5.0-6.9	90,759,274	78,364,018	11,257,729	1,137,527		0.06	0.05
8	7.0-8.9	132,671,714	111,098,496	19,940,516	1,632,703		0.07	0.06
10	9.0-10.9	154,019,983	129,227,307	22,406,821	2,385,854		0.07	0.07
12	11.0-12.9	171,080,202	123,750,894	44,169,608	3,159,700		0.08	0.08
14	13.0-14.9	171,732,025	129,326,022	37,160,850	5,245,153		0.08	0.10
16	15.0-16.9	129,056,543	87,045,021	37,436,892	4,574,631		0.09	0.11
18	17.0-18.9	68,324,928	44,421,651	18,022,248	5,881,029		0.11	0.13
20	19.0-20.9	41,018,123	21,977,832	12,290,249	6,750,042		0.15	0.15
22	21.0-22.9	16,696,836	7,367,552	4,948,569	4,380,716		0.19	0.18
24	23.0-24.9	9,918,027	4,144,946	2,732,124	3,040,956		0.20	0.21
26	25.0-26.9	4,210,371	314,372	692,300	3,203,700		0.37	0.25
28	27.0-28.9	3,275,212	0	1,498,075	1,777,137		0.32	0.29
30	29.0-30.9	1,531,150	0	0	1,531,150		0.45	0.33
32	31.0-32.9	1,334,443	0	977,828	356,615		0.25	0.39
34	33.0-34.9	92,098	0	0	92,098		0.45	0.46
36	35.0-36.9	556,060	0	556,060	0		0.18	0.53
	Total:	996,276,992	737,038,112	214,089,868	45,149,011			
	Defect:		0.040	0.177	0.445			



Associated FVS addfile to input tree defect into projection runs:




```
* Set default value for non-merchantable species
Defect           0           All
      1.00      1.00      1.00      1.00      1.00      1.00      1.00      1.00
* Set default value for merchantable species
* dbh = 5"       10"        15"       20"       25"       30"       35"       40"
Defect           0           SP
      0.05      0.07      0.10      0.15      0.23      0.33      0.49      0.73
Defect           0           WO
      0.05      0.07      0.10      0.15      0.23      0.33      0.49      0.73
Defect           0           SO
      0.05      0.07      0.10      0.15      0.23      0.33      0.49      0.73
Defect           0           SK
      0.05      0.07      0.10      0.15      0.23      0.33      0.49      0.73
Defect           0           RO
      0.05      0.07      0.10      0.15      0.23      0.33      0.49      0.73
Defect           0           PO
      0.05      0.07      0.10      0.15      0.23      0.33      0.49      0.73
Defect           0           BO
      0.05      0.07      0.10      0.15      0.23      0.33      0.49      0.73
* Shortleaf Pine
* White Oak
* Scarlet Oak
* Southern Red Oak
* Northern Red Oak
* Post Oak
* Black Oak
```

Merchantable cubic foot volume specifications were:

Softwood –
- 4.0" minimum dbh {diameter-breast-height}
- 4.0" minimum dib {diameter-inside-bark}

Hardwood –
- 5.0" minimum dbh
- 4.0" minimum dib

Merchantable board foot volume specifications were:

Softwood –
- 9.0" minimum dbh {diameter-breast-height}
- 7.6" minimum dib {diameter-inside-bark}

Hardwood –
- 9.0" minimum dbh
- 9.6" minimum dib

FVS volumes are shown in terms of cubic feet per acre and board feet per acre. The volume equations were those available in the Region 9 cruise program (based on Gevorkiantz and Olsen, 1955). Cordwood volumes can be derived by dividing the cubic foot volume by 79.3 (cubic feet per cord).

Species Abundance

As stated, there were 911 FIA plots from measurement cycles 3 through 5 that comprised the oak-hickory data set for the Mark Twain National Forest. When viewed in aggregate, 59 tree species were present that are recognized by the Central States FVS Variant. For analysis purposes, dealing with approximately 60 separate tree species is cumbersome. Thus, tree species were segregated into "major" and "minor" tree components based on tree occurrence. If a given species comprised at least one tree per acre within the aggregate FIA data set, it was considered to be an important species component to track. If the tree representation on aggregate was less than one tree per acre, then that tree species was assigned as a minor component. There were 31 tree species considered as major and 28 that were considered as minor tree components. Refer to the table on the following page to review individual tree species designation.

Monitoring of the major tree component was used in determining maximum tree size and mortality rates to apply to the data set. Species abundance also came into play when determining regeneration input for various ecological forest strata on the Mark Twain National Forest. Each of these will be discussed in the following text.

Major Tree Component

FIA-Num	Common Name	FVS-Spc
068	Eastern redcedar	RC
110	Shortleaf pine	SP
316	Red maple	RM
318	Sugar maple	SM
391	American hornbeam	AH
402	Bitternut hickory	BH
403	Pignut hickory	PH
407	Shagbark hickory	SH
408	Black hickory	BI
409	Mockernut hickory	MH
471	Eastern redbud	RD
491	Flowering dogwood	DW
521	Persimmon	PS
541	White ash	WA
544	Green ash	GA
693	Black tupelo	BG
701	Eastern hophornbeam	HH
762	Black cherry	BC
802	White oak	WO
806	Scarlet oak	SO
812	Southern red oak	SK
824	Blackjack oak	BJ
826	Chinkapin oak	CK
833	Northern red oak	RO
835	Post oak	PO
837	Black oak	BO
931	Sassafras	SS
971	Winged elm	WE
972	American elm	AE
975	Slippery elm	RL
994	Other hardwoods, non-com	NC

Minor Tree Component

FVS-Alpha	FVS-Num	FIA-Num	Common Name
VP	04	132	Virginia pine
BE	30	313	Boxelder
SV	31	317	Silver maple
OB	70	331	Ohio buckeye
RB	81	373	River birch
SL	16	405	Shellbark hickory
SG	34	461	Sugarberry
HK	35	462	Hackberry
HT	89	500	Hawthorn sp.
AB	24	531	American beech
UA	27	546	Blue ash
HL	73	552	Honeylocust
BN	09	601	Butternut
WN	08	602	Black walnut
SU	82	611	Sweetgum
YP	41	621	Yellow poplar
MB	94	680	Mulberry sp.
TS	11	694	Swamp tupelo
SY	79	731	Sycamore
SW	54	804	Swamp white oak
QI	62	817	Shingle oak
PN	60	830	Pin oak
CO	59	832	Chestnut oak
QS	67	834	Shumard oak
BK	77	901	Black locust
BL	84	922	Black willow
BW	42	951	American basswood
RE	40	977	Rock elm

Tree Mortality

The TreeSzCp keyword sets the morphological limits for maximum diameter and height attainment for a given tree species. The specified diameter acts as a surrogate for age to invoke senescence mortality. Determining the mortality rate is akin to computing the discount interest rate needed to pay off a capital sum. The process entails choosing a large diameter class that contains approximately one tree per acre {dbh/tpa min} (the exact number is dependent on the relative abundance of a particular tree species) and targeting an ending diameter class that contains approximately one-tenth tree per acre {dbh/tpa max}. Subtracting the diameter min from the diameter max and dividing by the diameter growth rate renders the length of time in terms of projection cycles needed to get from the min to the max diameter size. The mortality rate compounds each projection cycle. Iterations of the mortality rate raised to the power of the projection cycle reveals the factor needed to diminish the tree count from one to one-tenth. This factor becomes the proportion of trees to succumb to mortality agents during each projection cycle.

The following table shows the TreeSzCp keyword values for diameter minimum and height maximum per tree species that were used to constrain the upper limit on tree growth. The table was derived using FIA tree measurement data from Oak-Hickory cover types on the Mark Twain National Forest. Adjustments were made based on input from the Forest. The following values were determined:

FIA Code	FVS Code	Species Name	DBH Min	DBH Max	TPA Min	Grow Rate	Mort Rate	Prj Cyc	TPA Max	THt Max
068	RC	Eastern redcedar	7	11	1.00	0.70	0.325	6	0.106	40
110	SP	Shortleaf pine	17	21	1.00	1.00	0.425	4	0.109	75
316	RM	Red maple	7	11	1.00	0.65	0.325	6	0.089	55
318	SM	Sugar maple	9	13	1.00	0.85	0.375	5	0.110	60
391	AH	American hornbeam	3	5	1.00	0.40	0.375	5	0.095	30
402	BH	Bitternut hickory	11	15	1.00	0.85	0.375	5	0.110	70
403	PH	Pignut hickory	13	17	1.00	0.90	0.400	4	0.103	75
407	SH	Shagbark hickory	9	13	1.00	0.90	0.400	4	0.103	75
408	BI	Black hickory	13	17	1.00	0.75	0.350	5	0.101	70
409	MH	Mockernut hickory	13	17	1.00	0.85	0.375	5	0.110	75
471	RD	Eastern redbud	5	7	1.00	0.25	0.250	8	0.100	40
491	DW	Flowering dogwood	5	7	1.00	0.25	0.250	8	0.100	40
521	PS	Persimmon	7	9	1.00	0.40	0.375	5	0.095	45
541	WA	White ash	13	19	1.00	1.00	0.325	6	0.095	70
544	GA	Green ash	11	15	1.00	0.65	0.325	6	0.089	65
693	BG	Black tupelo	15	21	1.00	1.00	0.325	6	0.095	70
701	HH	Eastern hophornbeam	3	5	1.00	0.25	0.250	8	0.100	35
762	BC	Black cherry	9	11	1.00	0.50	0.425	4	0.109	65
802	WO	White oak	25	31	1.00	1.40	0.425	4	0.093	70
806	SO	Scarlet oak	21	27	1.00	1.45	0.425	4	0.101	75
812	SK	Southern red oak	17	23	1.00	1.25	0.375	5	0.105	70
824	BJ	Blackjack oak	11	17	1.00	1.35	0.400	4	0.103	60
826	CK	Chinkapin oak	13	19	1.00	1.00	0.325	6	0.095	65
833	RO	Northern red oak	21	29	1.00	1.50	0.350	5	0.101	75
835	PO	Post oak	21	27	1.00	1.05	0.325	6	0.106	65
837	BO	Black oak	27	33	1.00	1.40	0.425	4	0.093	70
931	SS	Sassafras	5	7	1.00	0.30	0.300	7	0.093	45
971	WE	Winged elm	7	9	1.00	0.30	0.300	7	0.093	45
972	AE	American elm	9	11	1.00	0.30	0.300	7	0.093	45
975	RL	Slippery elm	15	19	1.00	0.90	0.400	4	0.103	65
994	NC	Other hardwoods	9	11	1.00	0.35	0.325	6	0.106	50

Stand Mortality

The theoretical model that controls stand mortality is based on Stand Density Index (SDI). Reineke postulated in 1933 that any pure, fully stocked, even-aged stand of a given average stand diameter contains approximately the same number of trees per acre as any other pure, fully stocked, even-aged stand of the same species of the same average stand diameter. Thus, the most important factor in estimating stand density is the average stand diameter (D_R).

Using SDI, it is possible to compare stands at different stages of development. Regarding FVS implementation, density related mortality begins to occur when a stand reaches 55 percent of maximum SDI. Mortality increases as the stand's SDI increases and once a stand reaches 85 percent of maximum SDI, the stand density stays constant.

Since most forest stands are not pure, fully stocked, or uniformly even-aged, SDI values derived from research tend to overestimate the carrying capacity of general forest sites. The forest at-large is very heterogeneous with regard to stocking and structure. A proxy for the average maximum SDI can be derived from the inventory data sets that are used for the planning effort. The SDI value for each FIA plot was determined. The top 3 percent were then averaged to determine the observed maximum value. To get the average maximum value of measured stands, the maximum value is multiplied by 85 percent. This represents the average upper density achieved by forest stands within southern Missouri. The following values were used to set the maximum SDI and associated maximum BA for the Oak-Hickory cover type on the Mark Twain National Forest.

Forest Type	SDI Average Max	BA Average Max
Oak-Hickory	360	140

Noting the importance of properly setting stand density bounds to limit FVS modeled projections to reflect actual growth capacity stocking charts for oak stands were also examined. The upland central hardwoods stocking chart, introduced by Gingrich (1967), has become one the forest manager's most useful tools. The "A" line on the chart was developed from stands of average maximum density, and the "B" line was developed from open-grown trees. The upper extent of the Gingrich chart defines overly dense conditions at 110 stocking percent. Stocking relates the area occupied by an individual tree to the area occupied by a tree of the same size growing in a fully stocked stand of like trees. Visual inspection of the Gingrich chart indicates an approximate basal area maximum of 140 ft^2/acre for larger average diameter stands. An examination of the FIA plots from MTNF reinforced using this value to set the basal area maximum for the projection runs.

Regeneration Imputation

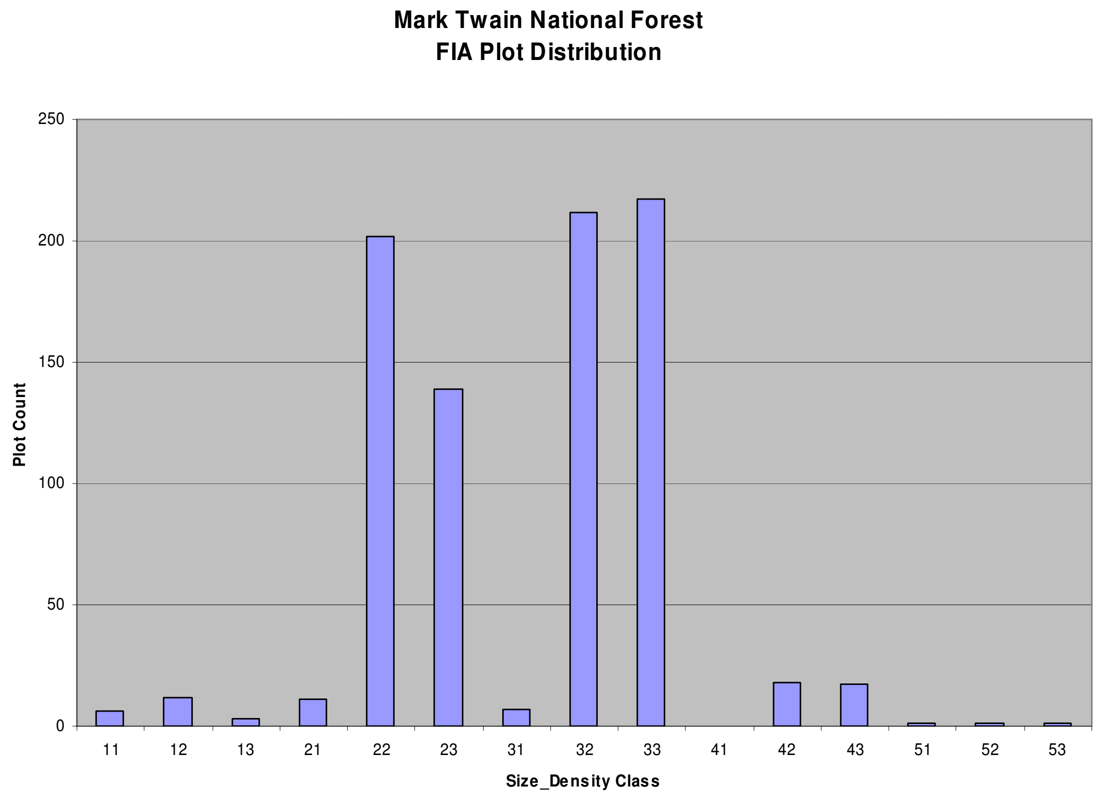
To impute implies the assignment of something to another. With respect to regeneration inferences, imputation procedures examine existing conditions to predict potential conditions of future stands. Basically, the process calls for querying existing data sets for representative *stand types* (stands of similar vegetative characteristics) and tabulating their seedling/sapling component.

Ground Rules

Established seedlings generally have an acceptable minimum girth and height that indicates having a root system firmly entrenched in mineral soil. The threshold used for this analysis examined small trees from 0.2" to 3.0" in diameter to define the large seedling/small sapling understory layer. Reference to these small trees will be as the 2"-sapling component.

A 'Vegetation State' algorithm was developed that classified the Oak-Hickory FIA data set by size and density class. Size class was determined based on the quadratic mean diameter of the largest trees; largest being defined as the largest 20 percent of the trees, with a minimum of 20 trees. Size classes span a five-inch diameter range (i.e. 0"-5", 5"-10", 10"-15", 15"-20", 20"+). Three density classes were computed based on canopy closure. They were: 10%-40%, 40%-70%, and 70%+. Inventory plots rendering canopy cover less than 10% were considered non-stocked.

The FIA plot count distribution by size and density class is presented on the following page. It is apparent from the graphic that the predominant stand size classes are in the range from 5" to 15" quadratic mean diameter. Also, that generally stand densities exceed 40 percent canopy cover. This is an important aspect relative to further discussion concerning regeneration imputation.



Code Template:					
Size - Canopy Cover/Structure	0-5" QMD	5-10" QMD	10-15" QMD	15-20" QMD	20"+ QMD
10-40% CC - Multi	11	21	31	41	51
40-70% CC - Multi	12	22	32	42	52
70%+ CC - Multi	13	23	33	43	53

In an effort to grasps understory relationships within the Oak-Hickory forest community on the Mark Twain National Forest, designation of "Species Groups" based on shade tolerance and height attainment was pursued.

'Shade Tolerance' ratings were used as a guide for determining the mix of individual tree species that would likely reside within a size/density regime. A forest tree that can survive and prosper under a forest canopy is referred to be *tolerant* whereas one that can thrive only in the main canopy or in the open is termed *intolerant*. From the 'Forest Ecology' textbook, Spurr and Barnes state:

> "The problem of survival in the understory is basic to an understanding of forest succession, since those forest trees capable both of surviving as understory plants and responding to release to reach overstory size will inevitably form a major portion of the evolving forest community."

A logical assumption relative to shade tolerance is that intolerant forest trees would be more prevalent in the smaller, less dense size classes. Tolerant forest trees would be more abundant in the larger, denser understory environments. Five classes of shade tolerance were recognized as referenced in "Silvics of North America, USDA Forest Service, Agriculture Handbook 654, Summary of Tree Characteristics, pg. 646-649". The 'Very Intolerant' class was combined with the 'Intolerant' class. Likewise, the 'Very Tolerant' class was merged with the 'Tolerant' class. Thus, three shade tolerance classes were recognized for this analysis.

Height class grouping were also defined for the major tree species. The main purpose for doing so was to differentiate understory tolerant trees (i.e. redcedar, dogwood, hophornbeam) from those that comprise the overstory canopy. Three average maximum height attainment classes were recognized: < 45', 45' – 60', 60' – 75'. Furthermore, the 60' – 70' class was subdivided into Non-Merchantable trees, Shortleaf pine, and Merchantable oaks. Nine combinations of shade tolerance and height attainment were recognized as displayed in the following table:

Oak Decline: Mark Twain NF -- Shade Tolerance/Height Group

FIA-Num	Common Name	FVS-Spc	Shd_Tol	Hgt_max	Hgt-Grp	Code
068	Eastern redcedar	RC	2	40	2	22
931	Sassafras	SS	2	45	2	22
994	Other hardwoods, non-com	NC	2	50	2	22
402	Bitternut hickory	BH	2	70	3	23
409	Mockernut hickory	MH	2	75	3	23
541	White ash	WA	2	70	3	23
762	Black cherry	BC	2	65	3	23
826	Chinkapin oak	CK	2	65	3	23
110	Shortleaf pine	SP	2	75	4	24
806	Scarlet oak	SO	2	75	5	25
835	Post oak	PO	2	65	5	25
403	Pignut hickory	PH	3	75	3	33
407	Shagbark hickory	SH	3	75	3	33
408	Black hickory	BI	3	70	3	33
824	Blackjack oak	BJ	3	60	3	33
972	American elm	AE	3	45	3	33
802	White oak	WO	3	70	5	35
812	Southern red oak	SK	3	70	5	35
833	Northern red oak	RO	3	75	5	35
837	Black oak	BO	3	70	5	35
391	American hornbeam	AH	4	30	1	41
471	Eastern redbud	RD	4	40	1	41
491	Flowering dogwood	DW	4	40	1	41
701	Eastern hophornbeam	HH	4	35	1	41
316	Red maple	RM	4	55	2	42
521	Persimmon	PS	4	45	2	42
971	Winged elm	WE	4	45	2	42
318	Sugar maple	SM	4	60	3	43
544	Green ash	GA	4	65	3	43
693	Black tupelo	BG	4	70	3	43
975	Slippery elm	RL	4	65	3	43

The 2”-sapling component {trees 1.0” to 3.0” diameter} was summarized for the Oak-Hickory data set based on Northerly and Southerly aspects and high and low site index.

```
* Strata Definition:
*   Aspect: Northerly {0-112,293-360 degrees}
*           Southerly {113-292 degrees}
*   Site Index: Low Productivity {SI<=70}
*               High Productivity {SI>=71}
```

	Stand Class	Shade Tolerance/Height Class										
	Size/Density	SAPS00	SAPS22	SAPS23	SAPS24	SAPS25	SAPS33	SAPS35	SAPS41	SAPS42	SAPS43	SAPS99
North Aspect/	22 Average	474	27	42	10	44	71	113	96	26	37	8
Low Site	23 Average	597	46	39	12	41	78	103	160	57	57	5
	32 Average	258	14	19	7	14	27	64	74	12	24	4
Plot Count:	33 Average	298	24	12	0	11	33	48	102	23	42	3
447	Grand Average	339	24	26	6	24	43	67	88	24	35	4
	Percent	100	7	8	2	7	13	20	26	7	10	1
						Total Percent:		49				

	Stand Class	Shade Tolerance/Height Class										
	Size/Density	SAPS00	SAPS22	SAPS23	SAPS24	SAPS25	SAPS33	SAPS35	SAPS41	SAPS42	SAPS43	SAPS99
North Aspect/	22 Average	441	10	19	0	15	60	105	184	7	39	2
High Site	23 Average	575	62	20	2	5	22	37	232	87	97	12
	32 Average	218	20	20	0	5	28	37	55	23	28	3
Plot Count:	33 Average	349	14	20	1	1	45	25	174	22	43	5
102	Grand Average	406	34	23	2	6	46	44	158	35	55	5
	Percent	100	8	6	0	1	11	11	39	9	13	1
						Total Percent:		29				

	Stand Class	Shade Tolerance/Height Class										
	Size/Density	SAPS00	SAPS22	SAPS23	SAPS24	SAPS25	SAPS33	SAPS35	SAPS41	SAPS42	SAPS43	SAPS99
South Aspect/	22 Average	495	31	30	18	82	80	127	58	28	39	2
Low Site	23 Average	571	53	45	9	52	108	97	104	45	46	14
	32 Average	254	13	16	11	28	33	64	43	19	24	3
Plot Count:	33 Average	301	23	38	2	8	47	47	72	34	26	4
317	Grand Average	399	28	32	11	45	62	89	64	30	33	4
	Percent	100	7	8	3	11	16	22	16	8	8	1
						Total Percent:		60				

	Stand Class	Shade Tolerance/Height Class										
	Size/Density	SAPS00	SAPS22	SAPS23	SAPS24	SAPS25	SAPS33	SAPS35	SAPS41	SAPS42	SAPS43	SAPS99
South Aspect/	22 Average	187	4	14	2	7	41	42	40	10	22	5
High Site	23 Average	287	12	23	0	7	60	27	61	21	66	12
	32 Average	82	15	0	0	0	15	52	0	0	0	0
Plot Count:	33 Average	75	0	0	0	0	0	75	0	0	0	0
45	Grand Average	342	12	32	7	25	52	53	80	26	46	9
	Percent	100	3	9	2	7	15	16	23	8	13	3
						Total Percent:		49				

Code Template:					
Size - Canopy Cover/Structure	0-5" QMD	5-10" QMD	10-15" QMD	15-20" QMD	20"+ QMD
10-40% CC - Multi	11	21	31	41	51
40-70% CC - Multi	12	22	32	42	52
70%+ CC - Multi	13	23	33	43	53

```
* Shade Tolerance/Height Class
*   Shd=20: Intolerant
*   Shd=30: Intermediate
*   Shd=40: Tolerant
*   Hgt=01: Understory Trees < 45'
*   Hgt=02: Mid-story Trees  45' - 60'
*   Hgt=03: Overstory Trees  60' - 75', Non-Merchantable
*   Hgt=04: Overstory Trees  60' - 75', Shortleaf Pine
*   Hgt=05: Overstory Trees  60' - 75', WO,SO,SK,NO,PO,BO
*   Xxx=99: Minor Tree Species
```

Numbers appearing below the Aspect/Site label indicate the FIA plot sample residing within the strata. Based on this analysis, combining the North/Low and South/High ecological strata based on commonality of species composition and relative abundance was deemed acceptable. The North/High and South/Low strata were viewed as significantly different in 2”-sapling component from each other and the combined North/Low – South /High strata.

Pattern Revelation

An interesting pattern was observed when viewing the 2”-sapling tables relative to stand size and density. Using a factor of “½” from the smallest size, most dense class to the largest size, least dense class {or conversely “2” from the largest size, least dense class to the smallest size, most dense class} an overlay matrix could be developed that closely mimics observed trends in 2” sapling occurrence. The “2-factor” matrix does a good job of smoothing inordinate ‘jumps’ between adjacent size/density classes.

	North/High {102 FIA Plots}					
	Size - Canopy Cover/Structure	0-5" QMD	5-10" QMD	10-15" QMD	15-20" QMD	20"+ QMD
	10-40% CC - Multi		180			
Measured	40-70% CC - Multi	1140	441	218	180	
	70%+ CC - Multi	2324	575	349	125	
	Size - Canopy Cover/Structure	0-5" QMD	5-10" QMD	10-15" QMD	15-20" QMD	20"+ QMD
	10-40% CC - Multi	363	181	91	45	23
Prorated	40-70% CC - Multi	725	363	181	91	45
	70%+ CC - Multi	1450	725	363	181	91
	North/Low-South/High {492 FIA Plots}					
	Size - Canopy Cover/Structure	0-5" QMD	5-10" QMD	10-15" QMD	15-20" QMD	20"+ QMD
	10-40% CC - Multi	1289	129	153		
Measured	40-70% CC - Multi	1190	496	248	105	
	70%+ CC - Multi	1649	597	297	130	
	Size - Canopy Cover/Structure	0-5" QMD	5-10" QMD	10-15" QMD	15-20" QMD	20"+ QMD
	10-40% CC - Multi	300	150	75	38	19
Prorated	40-70% CC - Multi	600	300	150	75	38
	70%+ CC - Multi	1200	600	300	150	75
	South/Low {317 FIA Plots}					
	Size - Canopy Cover/Structure	0-5" QMD	5-10" QMD	10-15" QMD	15-20" QMD	20"+ QMD
	10-40% CC - Multi	845	366	60		
Measured	40-70% CC - Multi	1332	495	254	22	
	70%+ CC - Multi		571	301	150	
	Size - Canopy Cover/Structure	0-5" QMD	5-10" QMD	10-15" QMD	15-20" QMD	20"+ QMD
	10-40% CC - Multi	350	175	88	44	22
Prorated	40-70% CC - Multi	700	350	175	88	44
	70%+ CC - Multi	1400	700	350	175	88

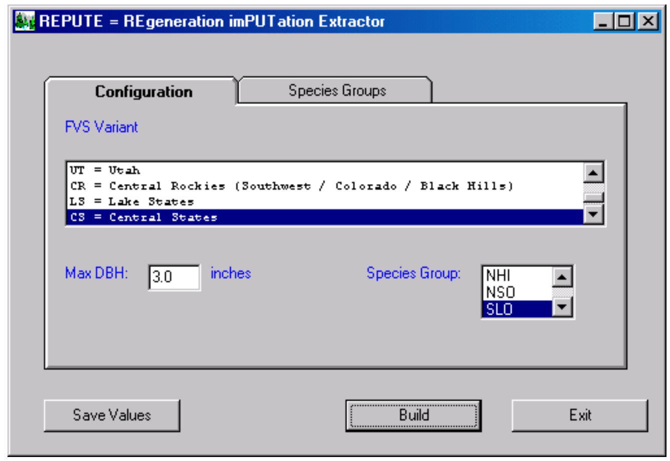
Compare the “Measured” table with the “Prorated” (i.e. apportioned by ½ factor) by tables for each ecological stratum. Notice the 2”-sapling component pattern between the various size and density classes. Trial factors were developed that best fit the measured trends. Use of the prorated tables guided expected sapling counts at various stages of stand development.

FVS keyword files were developed that, as each FIA plot was processed, identified the ecological strata, classified its size/density class, and determined expected 2”-sapling component frequency.

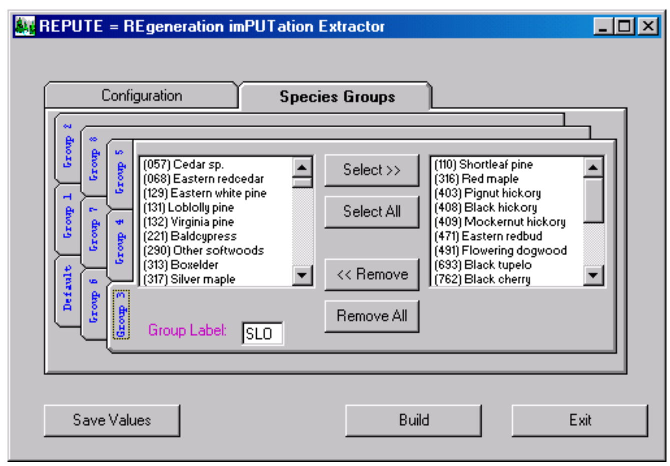
REPUTE the Program

Repute, a *post* post-processing program, has been written that embodies the concept of Regeneration Imputation. This program reads the ‘Stand Table’ output files from the Fvsstand Alone post processing program to develop regeneration keyword component files.

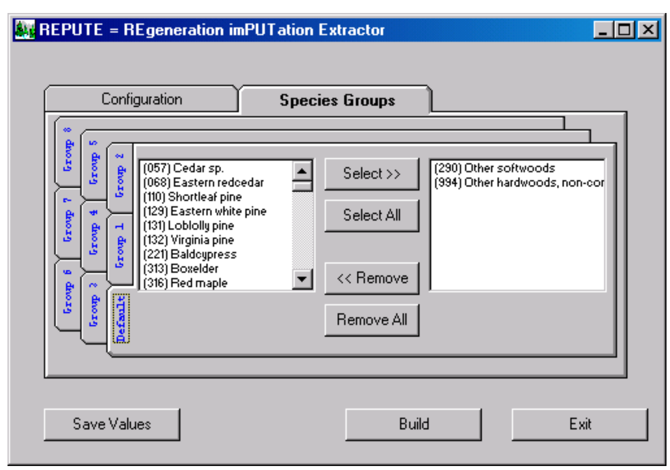
Repute will cycle through the Fvsstand Alone stand tables and pick the diameter classes less than the maximum diameter specified on the initial Repute screen.



To accommodate the major tree species option within the Repute program, the “Species Groups” tab was developed. Individual tree species are chosen to comprise the forest type. A group label is also specified to associate individuals within the collection.



For those minor tree species that occur within a cover type but are not assigned as select tree species, their representative seedling count is capture in the default classes for softwood and hardwood.



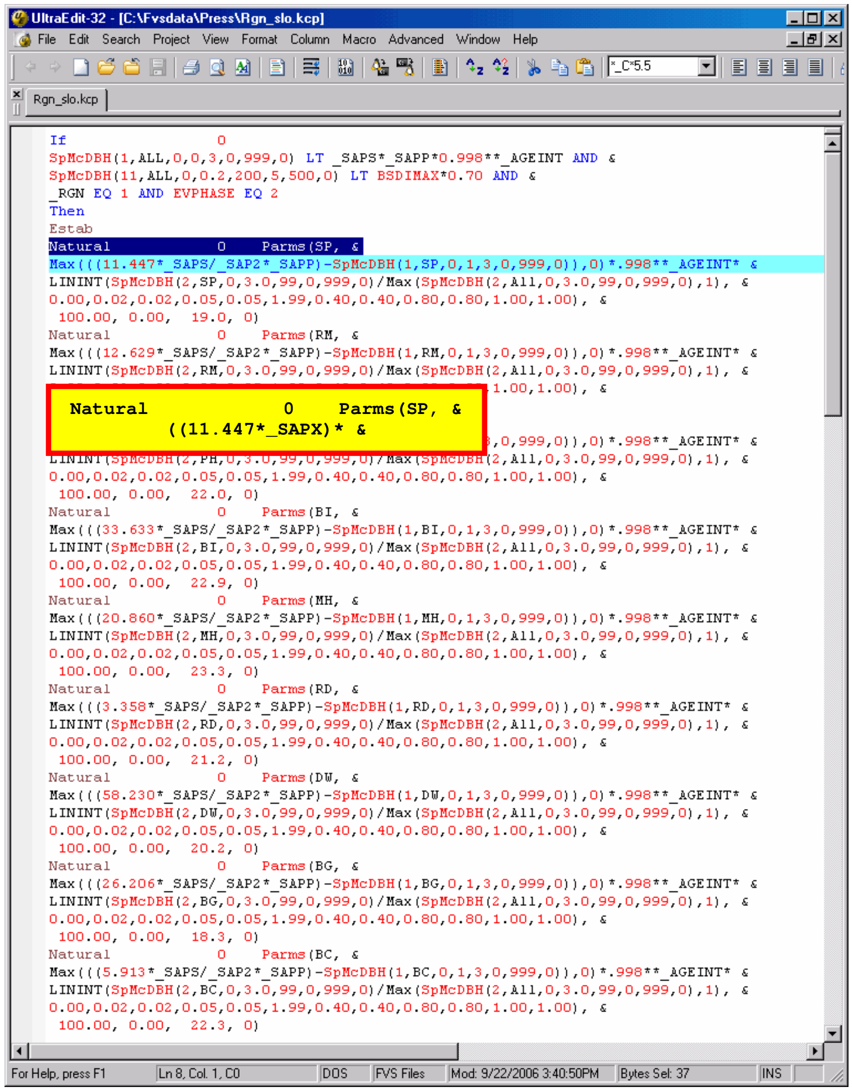
Separate lines in the regeneration addfile (a.k.a. keyword component files) are created per species, per diameter, given that there are trees per acre values listed in the Fvsstand Alone stand tables (refer to following page).

Keyword statements account for minimum stocking targets and for pre-existing tree species occurrence.

Lastly, a test is performed to inquire if mature trees of a given species were present that would ensure an adequate seed source.

The final step for the Repute program includes naming the newly created regeneration addfile.

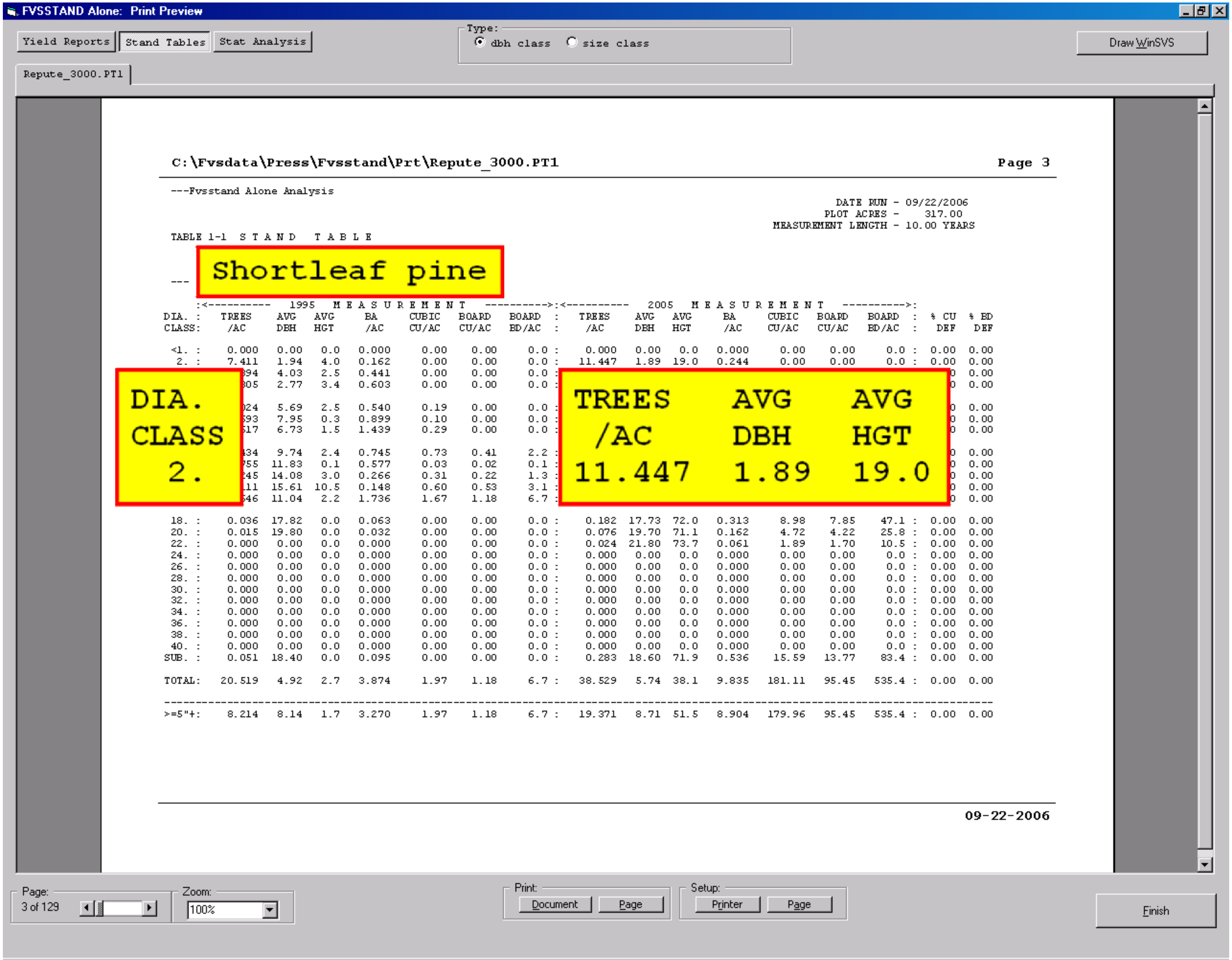
Repute regeneration addfiles were constructed from each of the primary ecological strata.



Elate to Prorate

Running the Repute program using the Oak-Hickory inventory data set per ecological strata produces an *average* representation of the strata. This average condition on the whole depicts size class 2, density class 3 given that this combination contains the largest plot set. Proportioning the 2”-sapling count for each size/density class versus the *average* size class 3, density class 2 rendered the multiplicative factors that can be used in conjunction with 2” sapling values generated through the Repute program.

Regeneration imputation can provide an empirical estimation method on which to base seedling recruitment inferences. The procedures presented in this section describe the process of imputing 2” saplings to model natural growth stand development. This method may be suited for certain silvicultural treatment prescriptions but might need to be augmented with professional judgment of regeneration response.



C:\Fvsdata\Press\Fvsstand\Prt\Repute_3000.PT1 Page 3

---Fvsstand Alone Analysis

DATE RUN - 09/22/2006
PLOT ACRES - 317.00
MEASUREMENT LENGTH - 10.00 YEARS

TABLE 1-1 S T A N D T A B L E

--- Shortleaf pine

DIA. CLASS	1995 MEASUREMENT TREES /AC	AVG DBH	AVG HGT	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC	2005 MEASUREMENT TREES /AC	AVG DBH	AVG HGT	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC	% CU DEF	% BD DEF
<1.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.00	0.00
2.	7.411	1.94	4.0	0.162	0.00	0.00	0.0	11.447	1.89	19.0	0.244	0.00	0.00	0.0	0.00	0.00
[illegible]	[illegible]	4.03	2.5	0.441	0.00	0.00	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00
[illegible]	[illegible]	2.77	3.4	0.603	0.00	0.00	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00
[illegible]	[illegible]	5.69	2.5	0.540	0.19	0.00	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00
[illegible]	[illegible]	7.95	0.3	0.899	0.10	0.00	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00
[illegible]	[illegible]	6.73	1.5	1.439	0.29	0.00	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00
[illegible]	[illegible]	9.74	2.4	0.745	0.73	0.41	2.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00
[illegible]	[illegible]	11.83	0.1	0.577	0.03	0.02	0.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00
[illegible]	[illegible]	14.08	3.0	0.266	0.31	0.22	1.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00
[illegible]	[illegible]	15.61	10.5	0.148	0.60	0.53	3.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00
[illegible]	[illegible]	11.04	2.2	1.736	1.67	1.18	6.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00
18.	0.036	17.82	0.0	0.063	0.00	0.00	0.0	0.182	17.73	72.0	0.313	8.98	7.85	47.1	0.00	0.00
20.	0.015	19.80	0.0	0.032	0.00	0.00	0.0	0.076	19.70	71.1	0.162	4.72	4.22	25.8	0.00	0.00
22.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.024	21.80	73.7	0.061	1.89	1.70	10.5	0.00	0.00
24.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.00	0.00
26.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.00	0.00
28.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.00	0.00
30.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.00	0.00
32.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.00	0.00
34.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.00	0.00
36.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.00	0.00
38.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.00	0.00
40.	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.000	0.00	0.0	0.000	0.00	0.00	0.0	0.00	0.00
SUB.	0.051	18.40	0.0	0.095	0.00	0.00	0.0	0.283	18.60	71.9	0.536	15.59	13.77	83.4	0.00	0.00
TOTAL:	20.519	4.92	2.7	3.874	1.97	1.18	6.7	38.529	5.74	38.1	9.835	181.11	95.45	535.4	0.00	0.00
>=5"+:	8.214	8.14	1.7	3.270	1.97	1.18	6.7	19.371	8.71	51.5	8.904	179.96	95.45	535.4	0.00	0.00

09-22-2006

4. Assigning Plots to Ecological Strata

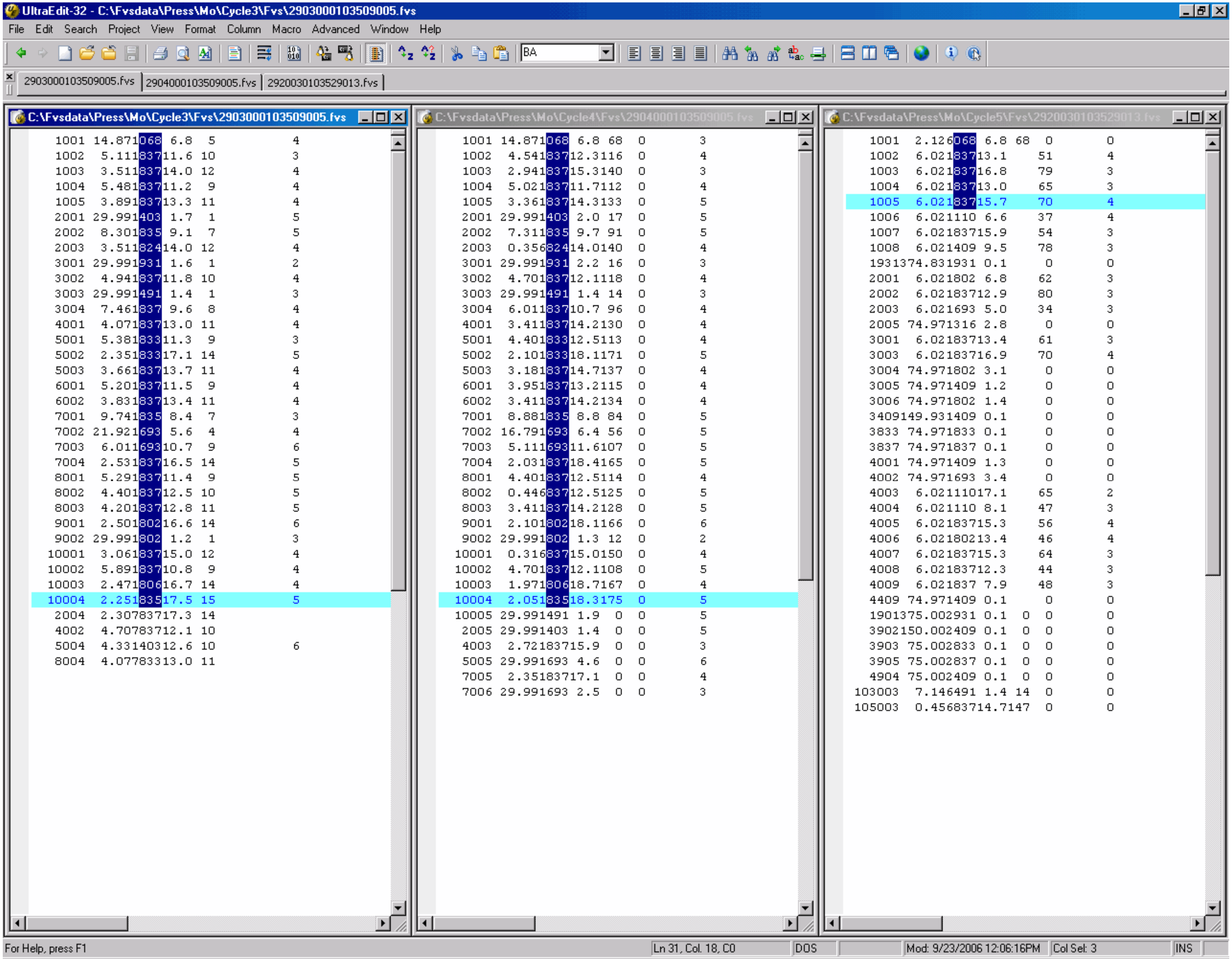
Early on, it became readily apparent that in order to make meaningful comparisons, the stands needed to be assigned to distinct strata. Although we had remeasurement data for specific stands, the variable plot design of the periodic inventories prevented valid tree-by-tree or plot-by-plot comparisons over time. Per acre tree expansion factors varied based on changes in tree diameter. Inferences of tree and plot dynamics become obscure as a result. However, given a large enough plot sample size, strata-based conclusions could be drawn. Let's examine each of the comparison methods separately.

Tree-by-Tree Comparison

FIA cycle 3 and cycle 4 measurements were taken using the periodic inventory design. Trees 5.0" dbh and larger were tallied on a variable radius plot using a 37.5 basal area factor prism. Trees less than 5.0" dbh were tallied on a 1/300 acre fixed area plot. For larger trees, their tree expansion factor (that allows for conversion to a per acre estimate) varies by tree diameter. Refer to the figure on the following page. FIA plot (Survey Unit=1, County=35, Plot Number=9005 periodic/29013 annual) is displayed by inventory cycle, by tree record. The FVS input tree format is as follows:

Column	Data Type	Format Description
1-4	integer i4	plot identification
5-7	integer i3	tree identification
8-13	real f6.2	tree count, number of sample trees this record represents
14	integer i1	tree history code
15-17	integer i3	species code
18-21	real f4.1	dbh
22-24	real i3	diameter increment (tenths of inches)
25-27	real f3.0	live height
28-30	real f3.0	height to topkill
31-34	real f4.1	height increment
35	integer i1	crown ratio code
36-39	integer i2,i2	first pair of tree-damage and severity codes
40-43	integer i2,i2	second pair of tree-damage and severity codes
44-47	integer i2,i2	third pair of tree-damage and severity codes
48	integer i1	tree value class code
49	integer i1	cut or leave prescription code

For reference, the tree species code is highlighted in blue. The column to the left of tree species code is the tree history code. Tree history values 0 to 5 indicate live trees; values 6 to 7 represent recent dead trees; and, values 8 and 9 denote past dead trees. The next six columns to the left hold the tree count representation. The four columns to the right of the tree species code store the current dbh followed by the next three columns to the right which are the past dbh. Notice for the periodic inventory, cycles 3 and 4, as the tree diameter increases, the tree count decreases. This is a result of the variable plot design. A given tree, if it grows in diameter, its tree representation on a per acre basis decreases from one cycle to the next. Although each tree is accounted for, the actual estimate of the trees per acre will differ for a given plot. Inferences regarding growth and mortality are skewed as a result.


UltraEdit-32 - C:\Fvsdata\Press\Mo\Cycle3\Fvs\2903000103509005.fvs
File Edit Search Project View Format Column Macro Advanced Window Help
BA
2903000103509005.fvs
2904000103509005.fvs
2920030103529013.fvs
C:\Fvsdata\Press\Mo\Cycle3\Fvs\2903000103509005.fvs
1001 14.871068 6.8 5 4
1002 5.111837 11.6 10 3
1003 3.511837 14.0 12 4
1004 5.481837 11.2 9 4
1005 3.891837 13.3 11 4
2001 29.991403 1.7 1 5
2002 8.301835 9.1 7 5
2003 3.511824 14.0 12 4
3001 29.991931 1.6 1 2
3002 4.941837 11.8 10 4
3003 29.991491 1.4 1 3
3004 7.461837 9.6 8 4
4001 4.071837 13.0 11 4
5001 5.381833 11.3 9 3
5002 2.351833 17.1 14 5
5003 3.661837 13.7 11 4
6001 5.201837 11.5 9 4
6002 3.831837 13.4 11 4
7001 9.741835 8.4 7 3
7002 21.921693 5.6 4 4
7003 6.011693 10.7 9 6
7004 2.531837 16.5 14 5
8001 5.291837 11.4 9 5
8002 4.401837 12.5 10 5
8003 4.201837 12.8 11 5
9001 2.501802 16.6 14 6
9002 29.991802 1.2 1 3
10001 3.061837 15.0 12 4
10002 5.891837 10.8 9 4
10003 2.471806 16.7 14 4
10004 2.251835 17.5 15 5
2004 2.307837 17.3 14
4002 4.707837 12.1 10
5004 4.331403 12.6 10 6
8004 4.077833 13.0 11
C:\Fvsdata\Press\Mo\Cycle4\Fvs\2904000103509005.fvs
1001 14.871068 6.8 68 0 3
1002 4.541837 12.3116 0 4
1003 2.941837 15.3140 0 3
1004 5.021837 11.7112 0 4
1005 3.361837 14.3133 0 5
2001 29.991403 2.0 17 0 5
2002 7.311835 9.7 91 0 5
2003 0.356824 14.0140 0 4
3001 29.991931 2.2 16 0 3
3002 4.701837 12.1118 0 4
3003 29.991491 1.4 14 0 3
3004 6.011837 10.7 96 0 4
4001 3.411837 14.2130 0 4
5001 4.401833 12.5113 0 4
5002 2.101833 18.1171 0 5
5003 3.181837 14.7137 0 4
6001 3.951837 13.2115 0 4
6002 3.411837 14.2134 0 4
7001 8.881835 8.8 84 0 5
7002 16.791693 6.4 56 0 5
7003 5.111693 11.6107 0 5
7004 2.031837 18.4165 0 5
8001 4.401837 12.5114 0 4
8002 0.446837 12.5125 0 5
8003 3.411837 14.2128 0 5
9001 2.101802 18.1166 0 6
9002 29.991802 1.3 12 0 2
10001 0.316837 15.0150 0 4
10002 4.701837 12.1108 0 5
10003 1.971806 18.7167 0 4
10004 2.051835 18.3175 0 5
10005 29.991491 1.9 0 0 5
2005 29.991403 1.4 0 0 5
4003 2.721837 15.9 0 0 3
5005 29.991693 4.6 0 0 6
7005 2.351837 17.1 0 0 4
7006 29.991693 2.5 0 0 3
C:\Fvsdata\Press\Mo\Cycle5\Fvs\2920030103529013.fvs
1001 2.126068 6.8 68 0 0
1002 6.021837 13.1 51 4
1003 6.021837 16.8 79 3
1004 6.021837 13.0 65 3
1005 6.021837 15.7 70 4
1006 6.021110 6.6 37 4
1007 6.021837 15.9 54 3
1008 6.021409 9.5 78 3
1931374.831931 0.1 0 0
2001 6.021802 6.8 62 3
2002 6.021837 12.9 80 3
2003 6.021693 5.0 34 3
2005 74.971316 2.8 0 0
3001 6.021837 13.4 61 3
3003 6.021837 16.9 70 4
3004 74.971802 3.1 0 0
3005 74.971409 1.2 0 0
3006 74.971802 1.4 0 0
3409149.931409 0.1 0 0
3833 74.971833 0.1 0 0
3837 74.971837 0.1 0 0
4001 74.971409 1.3 0 0
4002 74.971693 3.4 0 0
4003 6.021110 17.1 65 2
4004 6.021110 8.1 47 3
4005 6.021837 15.3 56 4
4006 6.021802 13.4 46 4
4007 6.021837 15.3 64 3
4008 6.021837 12.3 44 3
4009 6.021837 7.9 48 3
4409 74.971409 0.1 0 0
1901375.002931 0.1 0 0 0
3902150.002409 0.1 0 0 0
3903 75.002833 0.1 0 0 0
3905 75.002837 0.1 0 0 0
4904 75.002409 0.1 0 0 0
103003 7.146491 1.4 14 0 0
105003 0.456837 14.7147 0 0
For Help, press F1
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Col Sel: 3
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FIA cycle 5 measurement was taken using the annual inventory design Under this sampling scheme, four fixed-area subplots, 1/24 acre in size, are used to measure trees 5" dbh and larger. A fixed-area microplot, 1/300 acre in size, was co-located within the major plot, offset from plot center, to gather information on trees less than 5" dbh. Annual inventory plots share a common plot center. The designation stake for Subplot 1 is common for all inventory cycles. Notice that the first five trees on the annual inventory from cycle 5 were present during the periodic inventories for cycle 3 and 4. However, all other tree records are different. Although the plot center represents the same stand type, the sampling design differs significantly between the visitation cycles. This obscures the ability to observe actual change components.

<u>Plot-by-Plot Comparison</u>

It could be assumed that the increased tree diameter with the associated decrease in tree count representation would offset and that projecting a FIA plot from cycle 3 to cycle 4 would approximate a field measurement of the plot at cycle 4. Unfortunately, due to the variable plot sample design, it doesn't work out that way. Refer to the figure on the following page. Note for the year 1986 for cycles 3 and 4, different values for numbers of trees and basal area per acre are reported for the same plot. There are less trees of smaller size displayed for cycle 4 than for cycle 3 for the same measurement year.

To make matters worse, for comparison sake, changing from the periodic to annual inventory design renders confounding values between the projected data and the measured data in 2001. It appears that the tendency is having fewer trees of larger proportion the further you are from the measured data.

The FIA plot chosen as an example here was truly the *"best case scenario"*. Most trees are still present between cycles 3 and 4. Most FIA plots cannot account for trees that somehow appear or disappear from plot boundaries. The table on the page following displays a listing of tree accountability. Columns M and R reveal the percentage of trees that can be accounted for between cycles 3 and 4, for trees 0" dbh and greater versus trees 5" dbh greater, respectively. Larger trees are mostly re-sampled between cycles but even one tree difference will effect per acre estimates for a given plot. Small trees do not fare as well in their chances of being re-sampled.

Note columns N and O, plus S and T from the plot listing table. These columns are a tally of trees remeasured on Subplot 1 between cycle 4 and 5. It is obvious that not many of the same trees are actually measured between the periodic and annual inventory designs. Consequently, *tree-by-tree* and *plot-by-plot* analysis could not be pursued given the disparities in sampling design. However, strata-based comparisons proved to be a worthwhile endeavor.

Microsoft Excel - Compare.xls

File Edit View Insert Format Tools Data Window Help

A1 Plot Number

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	Plot Number		Survey	Cycle 3	Cycle 4	Cycle 5					Trees - Diameter 0"+					Trees - Diameter 5"+					Mortality - Diameter 5"+			
2	Periodic	Annual	Unit	Inv Year	Inv Year	Inv Year	Aspect	Site	Disturbance	POD	Cycle 3	Cycle 4	Accnt %	Cyc4_Sub1	Cyc5_Sub1	Cycle 3	Cycle 4	Accnt %	Cyc4_Sub1	Cyc5_Sub1	Mortality	Missing	Mort+	Mort+ %
3	***Large Size/Low Mortality {<=2%/yr}***																							
4	221509006	221520013	2	1977	1987	2000	Southerly	SI<=70	Undisturbed	POD=U	37	25	68	2	2	13	13	100	2	2	0	0	0	0
5	215309005	215320094	2	1977	1987	2000	Southerly	SI<=70	Undisturbed	POD=U	56	32	57	5	1	14	14	100	1	0	0	0	0	0
6	209109001	209120184	2	1977	1987	2000	Southerly	SI<=70	Undisturbed	POD=N	17	16	94	2	1	5	5	100	1	1	0	0	0	0
7	122100167	122129021	1	1976	1986	2003	Southerly	SI<=70	Undisturbed	POD=U	49	33	67	3	0	18	18	100	1	0	0	0	0	0
8	120309014	120320092	1	1977	1986	2002	Southerly	SI<=70	Undisturbed	POD=N	23	14	61	1	1	6	6	100	1	1	0	0	0	0
9	118109013	118120128	1	1976	1987	2003	Southerly	SI<=70	Undisturbed	POD=U	28	20	71	2	1	8	8	100	0	1	0	0	0	0
10	117909014	117920062	1	1976	1987	2002	Southerly	SI<=70	Undisturbed	POD=Y	48	38	79	2	0	36	36	100	2	0	1	0	1	3
11	122109011	122120109	1	1976	1986	2000	Southerly	SI<=70	Undisturbed	POD=Y	32	26	81	2	1	20	19	95	1	1	0	1	1	5
12	114909008	114920083	1	1976	1986	2003	Southerly	SI<=70	Undisturbed	POD=U	44	25	57	4	2	18	18	100	4	2	1	0	1	6
13	109309012	109329014	1	1976	1987	2001	Southerly	SI<=70	Undisturbed	POD=Y	28	25	89	2	0	18	18	100	2	0	1	0	1	6
14	102309005	102329007	1	1977	1987	2003	Southerly	SI<=70	Undisturbed	POD=Y	38	21	55	3	1	15	14	93	3	1	0	1	1	7
15	122109008	122120169	1	1976	1986	2002	Southerly	SI<=70	Undisturbed	POD=Y	28	17	61	1	0	14	13	93	1	0	0	1	1	7
16	105509002	105520019	1	1976	1986	2001	Southerly	SI<=70	Undisturbed	POD=U	28	23	82	1	0	14	13	93	1	0	0	1	1	7
17	209109004	209120157	2	1977	1987	2003	Southerly	SI<=70	Undisturbed	POD=Y	38	25	66	2	2	19	17	89	2	2	0	2	2	11
18	221309007	221329011	2	1977	1987	2002	Southerly	SI<=70	Undisturbed	POD=U	34	23	68	2	0	9	8	89	1	0	0	1	1	11
19	106509009	106520157	1	1976	1987	2002	Southerly	SI<=70	Undisturbed	POD=U	35	27	77	3	3	9	8	89	1	2	0	1	1	11
20	222909001	222920230	2	1976	1987	2003	Southerly	SI<=70	Undisturbed	POD=U	38	27	71	5	2	17	15	88	1	0	0	2	2	12
21	106509001	106520154	1	1976	1987	2001	Southerly	SI<=70	Undisturbed	POD=U	36	30	83	1	1	8	8	100	1	1	1	0	1	13
22	105509008	105520101	1	1976	1986	2001	Southerly	SI<=70	Undisturbed	POD=U	28	23	82	3	2	15	13	87	2	2	0	2	2	13
23	118109004	118120086	1	1976	1987	2002	Southerly	SI<=70	Undisturbed	POD=Y	31	23	74	3	2	14	14	100	2	2	2	0	2	14
24	117909017	117920144	1	1976	1987	2002	Southerly	SI<=70	Undisturbed	POD=Y	28	26	93	4	0	21	20	95	4	0	2	1	3	14
25	109309005	109320091	1	1976	1987	2002	Southerly	SI<=70	Undisturbed	POD=Y	46	38	83	3	2	21	20	95	2	2	2	1	3	14
26	106509004	106520082	1	1976	1986	2000	Southerly	SI<=70	Undisturbed	POD=Y	45	37	82	5	3	21	20	95	4	3	2	1	3	14
27	103509005	103529013	1	1977	1987	2001	Southerly	SI<=70	Undisturbed	POD=N	32	31	97	5	5	28	27	96	5	5	3	1	4	14
28	102309009	102320112	1	1977	1987	2001	Southerly	SI<=70	Undisturbed	POD=Y	33	29	88	1	0	20	19	95	0	0	2	1	3	15
29	117909007	117929003	1	1976	1987	2001	Southerly	SI<=70	Undisturbed	POD=Y	26	24	92	3	2	17	16	94	3	2	2	1	3	18
30																								
31	***Large Size/High Mortality {>2%/yr}***																							
32	122309011	122320136	1	1977	1987	2001	Southerly	SI<=70	Undisturbed	POD=Y	37	27	73	0	0	24	20	83	0	0	1	4	5	21
33	102309004	102320071	1	1977	1987	2003	Southerly	SI<=70	Undisturbed	POD=Y	34	30	88	4	0	31	28	90	3	0	4	3	7	23
34	114909015	114929030	1	1977	1986	2001	Southerly	SI<=70	Undisturbed	POD=U	44	33	75	2	0	8	6	75	0	0	0	2	2	25
35	103509004	103520080	1	1976	1987	2002	Southerly	SI<=70	Undisturbed	POD=U	35	28	80	3	2	13	13	100	2	2	4	0	4	31
36	118109009	118120003	1	1976	1987	2002	Southerly	SI<=70	Undisturbed	POD=U	30	24	80	3	1	16	13	81	1	1	2	3	5	31
37	118109008	118120020	1	1976	1987	2001	Southerly	SI<=70	Undisturbed	POD=Y	35	27	77	1	1	32	26	81	1	1	4	6	10	31
38	215309006	215320112	2	1977	1987	2001	Southerly	SI<=70	Undisturbed	POD=Y	32	24	75	5	3	15	10	67	1	1	0	5	5	33
39	122109003	122120087	1	1976	1986	2000	Southerly	SI<=70	Undisturbed	POD=U	32	20	63	3	2	14	9	64	2	2	0	5	5	36
40	316109005	316120063	3	1976	1987	2003	Southerly	SI<=70	Undisturbed	POD=Y	42	26	62	2	0	15	10	67	0	0	2	5	7	47
41	206709002	206720040	2	1977	1987	2002	Southerly	SI<=70	Undisturbed	POD=U	29	7	24	0	0	8	3	38	0	0	0	5	5	63
42																								
43	***Small Size***																							
44	209109007	209120015	2	1977	2000	1987	Southerly	SI<=70	Undisturbed	POD=N	22	15	68	4	3	1	1	100	0	2	0	0	0	0
45	122309008	122320017	1	1977	2003	1987	Southerly	SI<=70	Undisturbed	POD=U	27	11	41	6	3	3	2	67	1	2	0	1	1	33
46																								
47	***Early Cycle 3 Plots***																							
48	106500053	106520166	1	1969	2003	1987	Southerly	SI<=70	Undisturbed	POD=Y	35	18	51	3	0	16	16	100	3	0	1	0	1	6
49	117900050	117929017	1	1971	1999	1987	Southerly	SI<=70	Undisturbed	POD=Y	35	17	49	3	0	16	15	94	3	0	1	1	2	13
50	122100018	122120099	1	1971	2002	1987	Southerly	SI<=70	Undisturbed	POD=Y	36	15	42	3	0	11	9	82	2	0	0	2	2	18
51	102300108	102320030	1	1969	2000	1987	Southerly	SI<=70	Undisturbed	POD=N	27	16	59	2	0	15	14	93	1	0	2	1	3	20
52	204309013	204320172	2	1970	2002	1987	Southerly	SI<=70	Undisturbed	POD=Y	23	8	35	1	0	13	7	54	0	0	0	6	6	46
53	221500174	221520036	2	1970	2002	1987	Southerly	SI<=70	Undisturbed	POD=Y	28	0	0	0	0	27	0	0	0	0	0	27	27	100
54																								
55	***Non-Oak Forest Type***																							
56	200909009	200920045	2	1977	2001	1987	Southerly	SI<=70	Undisturbed	POD=U	51	15	29	4	0	16	10	63	1	0	0	6	6	38
57	103509011	103529001	1	1977	2002	1987	Southerly	SI<=70	Undisturbed	POD=U	63	44	70	5	3	12	12	100	2	2	0	0	0	0
58																								
59	***Disturbed Plot - Cutting***																							
60	316109006	316120094	3	1976	2000	1987	Southerly	SI<=70	Disturbed	POD=U	38	3	8	0	0	14	2	14	0	0	1	12	13	93
61	221509005	221520060	2	1976	2002	1987	Southerly	SI<=70	Disturbed	POD=U	33	14	42	0	0	13	10	77	0	0	0	3	3	23

Sheet0 / Sheet1 / Sheet2 / Sheet3 / NHI / NSO / SLO / NHI (2) / NSO (2) / **SLO (2)**

Ready NUM

Strata-Based Comparisons

In brief, the 100 *base* plots were assigned to strata according to slope exposure (aspect) and productivity capacity (site index). Aspect was defined as southerly (113-292 degrees) or northerly (0-112 or 293-360 degrees) and had proven to be important in determining regeneration response. High site quality was classified as site index values greater than 70; low was 70 or below. This productivity threshold is cited as important in detecting/assessing oak decline impacts. Since black oak was not always the tree species measured for site index. Hence, each plot was adjusted to a relative black oak site index as averaged over the three inventory cycles. To simplify tracking the results, sites with northerly aspect and high site quality were designated as "good sites"; sites with southerly aspect with low site quality were designated as "poor sites". Sites with northerly aspect and low site quality responded similarly to sites with southerly aspect and high site quality so they were combined into one stratum designated as "moderate sites". Refer to the following table for the FIA plot distribution by productivity class.

Productivity Class	**Available Number of Plots**
Good	15
Moderate	49
Poor	36
Total:	100

5. Establish Baseline Mortality

Tree status coding (i.e. removal tree) could be used to determine past treatment history for a FIA plot. Although there are tree status codes (i.e. mortality tree, dead tree) that indicate loss of life, direct coding to Oak Decline agents was vague at-best. Another method had to be used to assess *endemic* versus *epidemic* levels of mortality for a given plot.

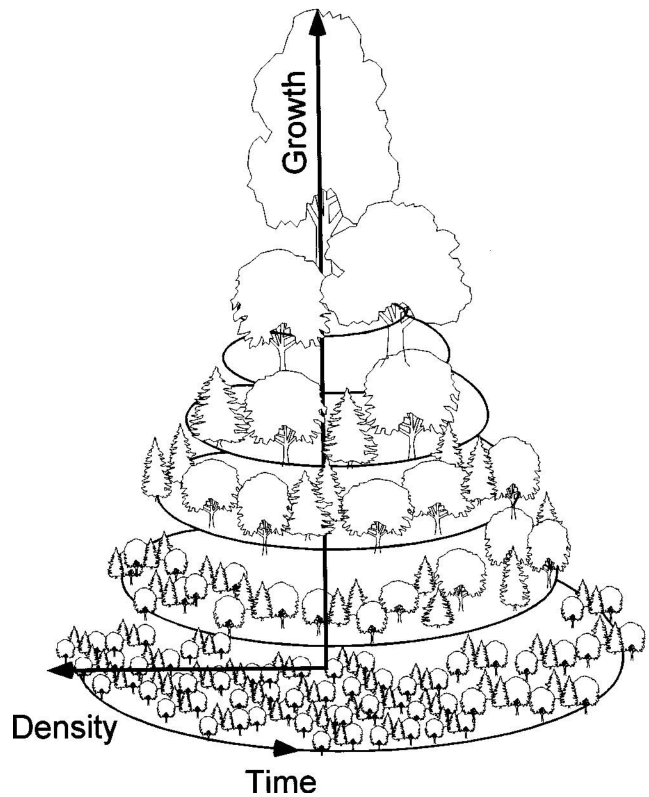
Manion Method

Endemic implies being constantly present in a particular region and generally considered under control. In contrast, epidemic refers to out of control situations where the vector is spreading rapidly among many individuals. To that end, a process of evaluation presented by Manion and Griffin (2001) that distinguishes between endemic and epidemic conditions was pursued.

Paul D. Manion, Professor, and his colleague, David H. Griffin, Professor Emeritus, from State University of New York, College of Environmental Science and Forestry, in their paper entitled: *"Large Landscape Scale Analysis of Tree Death in the Adirondack Park, New York"*, postulated the following:

> "We propose that healthy forests depend on quantitatively predictable tree death as a continuous process linked to forest structure and growth. Quantifying a baseline mortality value by forest structure analysis using the Law of de Liocourt allows estimation of forest health by comparing the observed mortality to a baseline value. This method is applicable to large landscape samples, but not generally to individual forest stands. Observed relative mortality per dbh class from a random sample of the Adirondack Park (New York, USA) forest was slightly, but significantly, less than the baseline relative mortality per dbh class required for maintaining size-distribution stability of the forest. This result suggests a changing structure involving increased forest density, or future mortality increase to maintain the current structure. Differences in structure-mortality relationships among the more abundant species indicate changing composition of the forest. This reflects unhealthy conditions in some species (American beech, yellow birch, balsam fir, and red spruce) that are compensated by enhanced development of others (red maple, sugar maple, and eastern hemlock). For. Sci. 47(4):542–549."
>
> Further: "Observed relative mortality per dbh class is expressed as the percentage of dead trees to total trees, living plus dead, in each dbh class. This method of estimating mortality per dbh class involves the assumption that dead trees remain identifiable to species for about the same time that it takes living trees to grow 2.54 cm. The baseline mortality per dbh class can be used with reliable estimates of dbh growth rates to estimate a baseline annual mortality rate for comparison with observed annual mortality rates from remeasured plot data."

The following depiction, referred to as the *phoenix helix,* conceptualizes the interrelationships of tree growth and tree mortality in a forest ecosystem:



In quantitative terms, the baseline mortality per dbh class can be used with estimates of dbh growth rates to determine an annual mortality rate needed for stand equilibrium. A given number of trees must die within a dbh class to allow space for the survivors to progress to the next dbh class. This number can be transformed into a rate or percentage for all dbh classes.

Inventory Inference

In application of the Manion and Griffin method, 125 FIA '*mortality*' plots were used that were resident from cycle 3 through cycle 5 (i.e. 154 common plots, minus 29 that had experienced disturbance, mainly cutting treatments). Note that for this part of the analysis we were able to use an additional 25 common plots that were of smaller size class or were slightly "off-cycle" from the cycle 3 measurement period. Mortality inferences were based upon the cycle 3 measurements. This period pre-dates the drought years that triggered intensification of oak decline. "Past diameter" and "mortality tree" data is included in each FIA remeasurement dataset. As such, we were able to extrapolate cycle 2 trees per acre values from the cycle 3 data set. The resulting stand table is presented as follow:

Stand table displaying trees per acre in each 2" dbh size class from FIA cycle 2 to cycle 3 with associated diameter growth, baseline mortality estimates, and observed mortality percent.

DBH Size Class (inches)	Trees/Ac Cycle 2	DBH Growth/Yr (inches)	Annual Baseline Mort %[a]	Annual Observed Mort %[b]	Trees/Ac Cycle 3
2	381.953	0.011	0.391	2.286	384.592
4	130.578	0.024	0.851	1.102	118.281
6	59.799	0.040	1.414	0.542	61.196
8	36.070	0.058	2.044	0.355	32.860
10	20.369	0.082	2.877	0.524	22.284
12	12.631	0.097	3.394	0.576	14.359
14	5.900	0.112	3.909	0.802	8.117
16	2.456	0.129	4.489	1.156	3.470
18	1.092	0.143	4.963	1.392	1.485
20	0.551	0.163	5.638	2.595	0.700
22	0.213	0.176	6.073	2.676	0.311
24	0.086	0.203	6.972	4.419	0.124
26	0.058	0.213	7.302	1.552	0.048
28	0.056	0.226	7.730	2.500	0.049
30	0.016	0.243	8.287	1.250	0.037
32	0.006	0.263	8.938	10.000	0.022
Total:	658.552	0.062	2.183	1.582	647.935

[a] Annual Baseline Mortality % = A predictable level of relative mortality caused by biotic and abiotic factors interacting with stocking competition essential for maintenance of a balanced healthy forest. Baseline mortality is linked to forest structure (Law of de Liocourt, Manion and Griffin, 2001) and growth (measured diameter increment).

[b] Annual Observed Mortality % = Sum of the total number of dead trees per diameter size class observed in the field at any point in time divided by the initial live tree stocking, divided by the growth measurement period. Note that mortality is expressed in terms of diameter class rather than years.

Notice the general trend of approximately twice as many trees per acre from the largest to the next smallest diameter class for cycle 2 data. The computed q-slope across all diameter classes equals a 2.038 factor. Think of this as a survivability factor. Conversely, a mortality factor would equal one minus the inverse of the q-slope. Expressing the baseline relative mortality as a percent equals 50.932 (that is: (1-1/2.038)*100). Thus, approximately one-half of the trees need to die for the survivors to progress to the next diameter size class. Knowing the average annual diameter growth rate of the trees allows calculation of the baseline relative mortality. For oak forests on the MTNF, a baseline relative mortality rate of 2.183 percent was computed. The observed mortality rate derived from the data set was 1.582 percent. According to Manion and Griffin, this value indicates an evolving forest structure that will trend toward the baseline relative mortality rate.

Applying these same methods to cycle 4 and 5 data rendered the following results:

Calculated mortality rates (baseline versus observed)
During the three measurement periods.

Measure Period [a]	Annual Baseline Mortality Percent	Annual Observed Mortality Percent
1966 – 1976	2.183	1.582
1976 – 1986	2.981	3.267
1986 – 2001	2.974	3.324

[a] Appendix E contains stand tables for each of the inventory cycles, including the backdated cycle 2.

Endemic/Epidemic Threshold

The reconstruction of cycle 2 from cycle 3 data represents the 1966 to 1976 growth measurement period. FIA cycle 3 to cycle 4 equates to the 1976 to 1986 growth period. Cycle 4 to cycle 5 spans the 1986 to 2001 measurement interval. Notice that the observed relative mortality exceeds baseline relative mortality during the past two FIA measurement cycles. This correlates well to the observed higher incidence of oak decline.

As a point of comparison, Manion and Griffin reported annual baseline mortality for Adirondack Park, New York, in 1996 at 3.0 percent. Buckman (1985) computed an annual measured mortality rate of 2.7 percent for National Forests in Michigan and Wisconsin. Based on these findings, and specifically on values obtained from the cycle 3 data set, we chose a value of 2.0 percent annual mortality (in terms of trees per acre) from reconstructed cycle 2 to cycle 3 as the threshold to indicate stands of low mortality occurrence (*endemic*) versus those of high mortality incidence *(epidemic)*.

6. Analysis of Common Plots

High/Low Mortality Plots

Recall that three ecological strata were identified for this project based on aspect and site index: *poor*, *moderate*, and *good*. Using the 2.0 percent baseline relative mortality threshold to aid in determining low versus high mortality incidence, the plots represented in the FIA data set were distributed as shown in the following table:

Distribution of the base FIA plots among productivity class and mortality group.

		Number of stands in each mortality group	
Productivity Class	**Available Number of Plots**	**Low mortality (< 2% per year)**	**High mortality (>= 2% per year)**
Good	15	14	1
Moderate	49	34	15
Poor	36	26	10
Total:	100	74	26

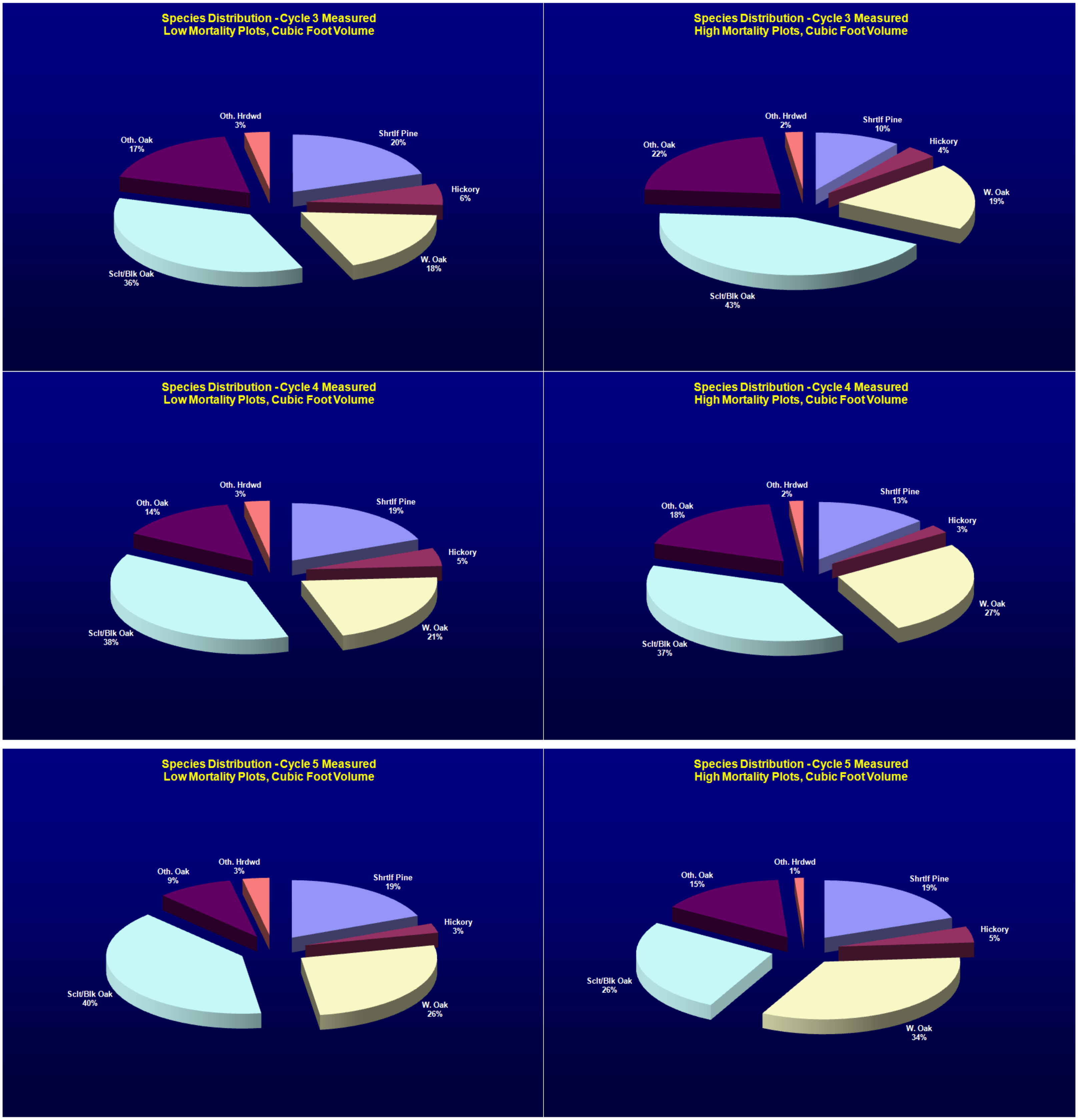
The Forest Vegetation Simulator was used to summarize various growth parameters for the base plot set from the three ecological strata and two mortality groups. The "good site/high mortality" category had only one stand. Strata based inferences could not be drawn for this site-mortality combination, so it was excluded from further consideration.

Measured Trends

For low mortality plots, measured trends indicate that cubic foot volume per acre steadily increased from cycle 3 to 4 to 5. For high mortality stands, cubic foot volume per acre remained mostly constant from cycle 3 to 4 but then rebounded for cycle 5. On these sites, tree mortality made space for associated species to fill in the gaps over the 25-year period. Recall that we used the reconstructed cycle 2 to cycle 3 mortality rate to distinguish stands of observed high mortality versus those of low mortality occurrence. Thus by our definition of mortality groups, the "high mortality" sites were already experiencing increased casualties at the beginning of cycle 3.

In order to observe how the distribution of species changed over time, we calculated the cubic foot volume within six species groups of particular interest. We considered scarlet oak (*Q. coccinea* Muenchh.) and black oak (*Q. velutina* L.) as one unique species group, white oak as another species group, and all other oaks (*Quercus* sp.) as a third group. All hickories were considered in the hickory group. All other hardwoods, such as cherry (*Prunus sp.*), ash (*Fraxinus sp.*), dogwood (*Cornus sp.*), etc., were grouped together. Shortleaf pine was the predominant conifer recorded; however, eastern redcedar was observed in cycle 5. Pine and cedar were combined as a unique species groups. In the figure on the following page, the proportion of total cubic foot volume in each of these species groups is shown for the "low" and "high" mortality sites at each of the three measurement periods.

Cubic Foot Volume Trends in Tree Species Composition over Three FIA Inventory Cycles for Low and High Mortality Sites



On high mortality sites, the proportion of cubic foot volume in scarlet and black oak decreased in successive measurement cycles. Conversely, the proportion of cubic foot volume in white oak increased. This trend is consistent with the silvicultural predictions of tree species response to oak decline (Shifley and other. 2006). On low mortality sites, cubic foot volume in scarlet and black oak increased during each cycle. White oak also increased. The identifiable differences in response pattern between the high and low mortality groups indicate that the criterion we used to distinguish mortality groups was meaningful.

Modeled Forecasts

Projecting Current Conditions

From the 100 base plots measured three times over a 25 year period, we were able to compare the actual measured attributes to projected values when we simulated the stands for 25 years under four different combinations of the FVS model. The combinations we compared were:

- FVS without adjustments
- FVS without adjustments, with the Oak Decline Event Monitor (ODEM) addfile
- FVS with adjustments as described in Section 3 of this paper
- FVS with adjustments as described in Section 3, with the ODEM addfile

From this trial, we concluded that FVS without adjustment consistently underestimated trees per acre and overestimated basal area per acre for all strata, even after a period as short as 25 years. When the ODEM addfile was applied without model adjustments, projected values improved slightly. For best results, applying model adjustments alone for the low mortality plots and including the ODEM addfile for high mortality plots are the proper steps.

Stand tables are presented on the following pages for the six ecological strata/mortality groups that show comparison of measured trends to modeled projections using these methods:

- SLO_L = Poor Sites_Low Mortality: FVS adjustments {26 plots}
- SLO_H = Poor Sites_High Mortality: FVS adjustments + ODEM addfile {10 plots}

- NSO_L = Moderate Sites_Low Mortality: FVS adjustments {34 plots}
- NSO_H = Moderate Sites_High Mortality: FVS adjustments + ODEM addfile {15 plots}

- NHI_L = Good Sites_Low Mortality: FVS adjustments {14 plots}
- NHI_H = Good Sites_High Mortality: FVS adjustments + ODEM addfile {1 plots}

Note the reasonable results in terms of tree per acre and basal area per acre, especially for trees 5” dbh and larger. Of particular interest is the portrayal of measured benchmarks against modeled projections for a 25 year time period. For monitoring purposes, the effects of an epidemic outbreak of oak decline were captured. Future inferences based on this knowledge could be applied.

1976 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	399.10	1.84	18.80	7.96	0.00	0.00	0.00
4	138.42	3.74	33.10	10.80	0.00	0.00	0.00
6	60.27	5.90	45.90	11.54	88.17	0.00	0.00
8	37.12	7.94	53.00	12.84	160.67	0.00	0.00
10	25.09	9.89	57.00	13.42	218.00	41.76	220.90
12	11.03	11.78	60.10	8.36	156.51	65.02	334.10
14	6.83	13.76	62.20	7.07	135.21	79.14	430.20
16	2.79	15.69	63.40	3.75	82.62	57.14	323.90
18	0.79	17.40	64.00	1.30	26.76	19.10	111.00
20	0.42	19.39	59.10	0.86	19.10	13.67	80.10
22	0.22	21.74	59.10	0.58	12.21	9.86	58.10
24	0.04	24.50	50.20	0.15	2.72	1.89	11.60
26	0.04	26.40	60.20	0.15	3.05	2.35	14.20
28	0.04	27.00	53.00	0.14	2.53	2.20	13.70
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.03	32.70	60.20	0.14	2.42	2.18	13.40
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	682.21	8.27	52.00	79.05	909.96	294.32	1611.30
>=5"+:	144.70			60.29			

1986 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	336.70	2.13	19.90	8.68	0.00	0.00	0.00
4	201.73	3.64	29.80	14.91	0.89	0.00	0.00
6	66.93	5.86	44.50	12.67	88.24	0.00	0.00
8	38.45	7.90	52.40	13.15	162.91	0.00	0.00
10	27.87	9.88	56.70	14.89	242.41	54.16	286.00
12	14.99	11.79	60.60	11.39	210.59	90.59	467.90
14	7.65	13.83	60.90	7.99	152.88	89.96	491.00
16	4.23	15.78	64.00	5.75	129.17	88.72	503.00
18	1.13	17.83	65.40	1.97	44.56	31.86	184.50
20	0.49	19.73	59.40	1.05	23.05	16.98	99.60
22	0.15	21.95	60.90	0.40	8.59	6.84	40.30
24	0.08	23.63	55.60	0.24	4.74	4.15	25.00
26	0.04	26.70	60.60	0.15	3.07	2.37	14.30
28	0.02	27.20	53.50	0.10	1.73	1.51	9.40
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.01	33.00	60.60	0.08	1.39	1.25	7.70
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	700.47	8.38	51.50	93.42	1074.23	388.40	2128.80
>=5"+:	162.05			69.83			

2001 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	223.87	2.35	20.60	6.96	0.00	0.00	0.00
4	285.70	3.67	27.70	21.50	0.00	0.00	0.00
6	80.35	5.83	41.30	15.05	76.92	0.00	0.00
8	44.49	7.83	50.50	14.97	171.35	0.00	0.00
10	30.98	9.98	56.80	16.89	261.38	54.97	291.80
12	18.44	11.88	59.70	14.24	283.75	132.33	690.20
14	9.61	13.93	61.80	10.19	183.06	109.55	603.00
16	6.22	15.87	63.80	8.56	188.79	131.55	747.90
18	2.06	17.89	64.80	3.61	82.81	61.07	355.70
20	0.85	19.68	63.50	1.80	41.52	31.47	183.50
22	0.21	21.76	63.90	0.55	12.85	10.27	60.70
24	0.10	23.41	59.30	0.31	7.02	5.43	32.20
26	0.02	25.20	52.00	0.07	1.29	1.12	6.90
28	0.04	27.39	58.30	0.16	3.01	2.67	16.40
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.01	33.50	61.20	0.05	0.81	0.73	4.50
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	702.97	8.48	49.80	114.89	1314.54	541.15	2992.80
>=5"+:	193.39			86.43			

1986 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	366.80	1.77	19.80	6.97	0.00	0.00	0.00
4	117.65	3.82	35.50	9.59	0.92	0.00	0.00
6	53.94	5.87	47.80	10.24	69.31	0.00	0.00
8	41.21	7.91	54.40	14.14	190.36	0.00	0.00
10	27.86	9.97	58.90	15.15	263.17	51.61	273.10
12	17.88	11.90	61.80	13.85	275.99	128.27	669.20
14	9.53	13.93	63.00	10.10	194.61	117.55	644.30
16	4.70	15.92	65.00	6.50	143.50	98.48	556.20
18	1.82	17.85	65.50	3.17	72.85	53.92	314.10
20	0.62	19.65	64.00	1.30	29.52	24.14	143.40
22	0.28	21.88	64.20	0.72	16.63	13.75	81.50
24	0.04	24.50	62.50	0.15	3.10	2.37	14.50
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.04	27.00	61.00	0.14	3.04	2.74	16.60
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.02	34.70	61.00	0.14	2.18	1.96	12.10
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	642.39	8.83	54.80	92.15	1265.19	494.79	2725.10
>=5"+:	157.93			75.59			

2001 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	297.18	2.02	19.70	6.96	0.00	0.00	0.00
4	184.48	3.62	30.70	13.51	0.00	0.00	0.00
6	64.24	5.87	45.20	12.22	77.95	0.00	0.00
8	41.10	8.02	54.10	14.50	177.14	0.00	0.00
10	27.03	9.89	58.40	14.47	244.70	48.51	258.50
12	22.18	11.90	61.50	17.16	344.41	160.50	833.60
14	10.82	13.76	63.40	11.20	230.08	136.78	754.90
16	7.07	15.69	64.40	9.50	205.27	140.43	792.10
18	3.31	17.79	65.70	5.73	137.21	100.26	582.90
20	1.17	19.77	64.40	2.50	58.28	46.20	270.40
22	0.20	21.60	64.10	0.50	11.08	9.22	55.00
24	0.13	23.79	63.60	0.40	9.06	7.73	46.30
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.02	27.50	61.50	0.09	1.78	1.61	9.80
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.01	35.00	61.50	0.08	1.25	1.13	7.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	658.93	8.96	53.70	108.81	1498.21	652.35	3610.40
>=5"+:	177.28			88.34			

2001 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	291.24	1.79	19.80	5.63	0.00	0.00	0.00
4	124.00	3.82	35.30	10.03	0.00	0.00	0.00
6	46.54	5.86	41.50	8.80	53.53	0.00	0.00
8	36.82	7.83	52.50	12.38	146.04	0.00	0.00
10	24.55	9.93	62.70	13.25	240.75	45.84	243.50
12	17.60	12.03	66.20	13.92	302.39	155.03	815.20
14	13.89	13.81	69.60	14.46	338.12	201.90	1108.80
16	10.88	15.89	73.30	15.02	379.73	256.94	1442.70
18	2.78	17.80	71.80	4.81	110.41	82.82	474.40
20	0.70	19.67	64.70	1.47	33.23	28.27	175.70
22	0.46	21.70	63.00	1.19	27.72	21.45	126.20
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	569.46	9.43	55.80	100.96	1631.91	792.26	4386.40
>=5"+:	154.22			85.30			

1976 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	374.88	1.73	17.60	6.77	0.00	0.00	0.00
4	104.97	4.00	35.80	9.30	0.00	0.00	0.00
6	75.27	5.79	45.60	13.88	93.03	0.00	0.00
8	30.36	7.66	53.70	9.75	111.57	0.00	0.00
10	25.90	9.76	57.60	13.50	211.87	6.59	35.80
12	20.12	11.82	60.40	15.37	315.41	130.90	670.00
14	7.51	13.86	62.20	7.88	169.96	101.72	563.00
16	2.12	16.12	61.80	3.00	61.69	40.63	230.60
18	0.44	17.76	66.20	0.75	9.44	7.37	44.10
20	0.34	19.99	57.30	0.75	16.87	12.60	77.60
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.11	24.60	52.90	0.38	7.36	6.45	38.60
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.15	29.80	62.30	0.75	14.37	12.92	88.30
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	642.16	8.13	51.90	82.08	1011.57	319.17	1748.00
>=5"+:	162.32			66.01			

1986 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	347.58	2.02	18.90	8.15	0.00	0.00	0.00
4	160.06	3.72	30.50	12.49	0.00	0.00	0.00
6	83.80	5.89	44.60	15.99	106.61	0.00	0.00
8	37.21	7.74	53.20	12.23	145.81	0.00	0.00
10	26.32	10.01	57.40	14.44	226.28	10.59	55.40
12	17.02	11.98	60.60	13.35	277.31	122.42	630.80
14	10.12	13.62	62.30	10.25	222.61	129.87	712.60
16	4.38	15.63	64.50	5.85	138.19	91.57	526.60
18	1.07	17.39	63.90	1.76	29.98	22.87	131.00
20	0.38	19.59	64.50	0.81	19.73	15.35	95.80
22	0.16	21.50	53.30	0.39	8.02	5.70	33.40
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.11	25.10	53.30	0.38	7.34	6.42	38.50
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.10	30.40	62.90	0.50	9.56	8.59	58.80
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	688.30	8.25	51.40	96.58	1191.43	413.40	2282.70
>=5"+:	180.67			75.94			

2001 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	278.44	2.28	19.50	8.17	0.00	0.00	0.00
4	260.13	3.51	26.30	17.92	2.26	0.00	0.00
6	93.92	5.94	43.00	18.23	119.47	0.00	0.00
8	53.56	7.81	51.60	17.92	210.02	0.00	0.00
10	18.09	10.08	57.30	10.06	155.80	12.22	62.90
12	19.47	11.75	59.60	14.70	278.23	108.71	556.40
14	15.26	13.70	62.20	15.66	347.89	200.39	1090.10
16	5.47	15.81	64.80	7.46	176.08	119.32	686.60
18	1.87	17.87	66.20	3.25	70.53	52.58	308.20
20	0.64	19.78	68.60	1.36	32.63	25.34	156.30
22	0.27	21.67	57.80	0.69	14.76	10.91	67.50
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.10	25.70	53.80	0.37	7.13	6.24	37.50
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.07	31.30	63.90	0.35	6.28	5.65	38.70
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	747.27	8.33	50.30	116.14	1421.09	541.37	3004.20
>=5"+:	208.70			90.04			

1986 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	428.86	1.68	18.70	7.16	0.00	0.00	0.00
4	125.96	3.73	34.40	9.81	0.00	0.00	0.00
6	59.74	5.85	46.20	11.25	83.69	0.00	0.00
8	32.58	7.80	55.30	10.88	146.21	0.00	0.00
10	19.93	9.98	59.40	10.87	184.44	19.76	101.50
12	12.12	11.90	60.40	9.38	195.52	98.25	511.90
14	10.56	13.97	62.90	11.25	254.68	149.99	825.40
16	4.73	15.72	64.10	6.38	147.51	103.77	593.40
18	1.30	17.84	60.00	2.25	35.62	24.40	138.80
20	0.33	20.37	70.90	0.75	20.47	15.67	95.40
22	0.29	21.70	63.60	0.75	17.71	13.78	82.30
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	696.39	8.51	53.40	80.72	1085.84	425.62	2348.70
>=5"+:	141.58			63.76			

2001 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	344.62	2.15	20.90	9.06	0.00	0.00	0.00
4	196.59	3.72	30.70	15.18	1.99	0.00	0.00
6	72.31	5.88	45.10	13.79	89.23	0.00	0.00
8	38.87	7.89	52.20	13.28	155.77	0.00	0.00
10	23.18	10.08	59.40	12.88	224.16	13.06	66.70
12	15.64	11.95	61.90	12.22	252.14	115.14	598.70
14	9.28	14.04	63.10	10.00	228.60	146.48	805.80
16	7.72	15.82	64.00	10.54	249.92	169.02	961.10
18	4.79	17.67	66.10	8.16	194.81	141.11	827.20
20	0.79	19.59	65.70	1.66	35.68	26.78	157.00
22	0.33	22.57	67.70	0.91	22.19	18.79	113.60
24	0.09	23.10	72.20	0.26	6.87	5.65	35.10
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	714.20	8.76	52.70	107.95	1461.34	636.03	3565.20
>=5"+:	172.99			83.70			

2001 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	314.87	1.72	18.90	5.75	0.00	0.00	0.00
4	89.96	3.62	34.20	6.59	0.00	0.00	0.00
6	51.77	5.80	40.30	9.61	63.75	0.00	0.00
8	26.49	7.92	50.50	9.10	110.29	0.00	0.00
10	16.86	10.04	59.20	9.29	167.60	20.11	104.40
12	14.45	12.00	61.10	11.38	218.59	117.27	617.70
14	15.05	13.77	66.80	15.58	372.16	227.26	1243.00
16	10.84	15.73	69.30	14.64	329.53	229.84	1297.80
18	5.42	18.06	80.10	9.65	208.05	161.76	951.20
20	0.60	19.70	75.00	1.27	35.28	29.08	176.60
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	546.31	9.47	53.30	92.85	1505.24	785.31	4390.60
>=5"+:	141.47			80.51			

NSO_L

1976 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	430.45	1.81	20.10	8.38	0.00	0.00	0.00
4	139.37	3.80	35.80	11.22	0.00	0.00	0.00
6	63.68	5.83	47.40	11.91	75.57	0.00	0.00
8	37.40	7.93	53.60	12.91	157.87	0.00	0.00
10	20.07	9.87	58.30	10.70	172.57	36.09	189.50
12	11.13	11.82	61.20	8.49	159.87	68.49	351.20
14	6.77	13.82	63.10	7.06	135.34	79.13	431.00
16	3.07	15.62	63.00	4.08	80.67	54.83	310.70
18	1.14	17.90	64.30	1.99	41.67	30.02	174.10
20	0.31	19.71	65.60	0.66	10.82	8.43	49.00
22	0.16	22.30	66.80	0.44	10.49	8.57	54.80
24	0.07	24.23	64.40	0.22	4.93	4.13	25.90
26	0.09	26.11	68.80	0.33	7.69	6.49	40.50
28	0.03	28.40	67.60	0.11	2.45	1.99	13.50
30	0.05	29.60	73.00	0.22	4.60	4.22	28.70
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	713.76	8.16	52.90	78.73	864.55	302.38	1668.70
>=5"+:	143.95			59.13			

1986 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	369.44	2.10	21.00	9.28	0.00	0.00	0.00
4	204.24	3.62	31.60	14.92	0.00	0.00	0.00
6	73.71	5.83	45.90	13.82	82.23	0.00	0.00
8	41.46	7.86	53.00	14.04	158.84	0.00	0.00
10	24.72	9.82	58.40	13.04	192.24	35.98	191.50
12	13.95	11.91	60.90	10.81	211.98	95.06	489.70
14	7.26	13.86	63.70	7.62	145.55	84.41	460.60
16	4.76	15.83	63.60	6.51	144.10	99.29	563.70
18	1.21	17.94	64.30	2.12	40.22	30.01	173.70
20	0.39	19.56	66.70	0.82	16.96	13.19	76.60
22	0.15	22.06	67.40	0.39	5.38	4.47	29.60
24	0.06	23.64	67.70	0.19	4.69	3.99	24.70
26	0.06	26.11	69.40	0.21	4.87	4.11	25.70
28	0.02	27.50	64.90	0.07	1.41	1.27	7.70
30	0.02	29.10	68.30	0.08	1.64	1.34	9.10
32	0.03	31.30	73.10	0.15	2.98	2.73	18.60
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	742.31	8.21	52.20	94.05	1013.11	375.86	2071.20
>=5"+:	167.77			69.85			

2001 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	248.538	2.35	22.00	7.75	0.00	0.00	0.00
4	293.79	3.70	29.00	22.35	0.00	0.00	0.00
6	80.19	5.83	43.00	14.98	73.65	0.00	0.00
8	48.72	7.90	52.00	16.69	174.04	0.00	0.00
10	28.56	9.89	57.60	15.27	231.70	37.37	197.70
12	17.11	11.86	60.70	13.17	218.33	109.35	568.20
14	10.21	13.73	63.10	10.51	209.82	123.77	679.00
16	6.00	15.88	64.70	8.26	174.87	118.26	672.40
18	2.56	17.64	65.30	4.34	93.13	68.62	393.40
20	0.92	19.81	66.70	1.98	35.71	27.74	162.70
22	0.09	22.12	68.60	0.25	3.46	2.84	16.60
24	0.09	24.02	69.10	0.29	7.04	5.70	36.10
26	0.03	25.78	66.60	0.09	2.05	1.85	11.80
28	0.03	27.89	70.80	0.14	3.06	2.70	17.20
30	0.01	29.90	69.20	0.05	1.10	0.89	6.10
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.02	33.75	73.20	0.11	1.90	1.73	11.90
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	738.04	8.45	51.10	116.23	1229.85	500.83	2773.10
>=5"+:	194.54			86.13			

1986 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	402.22	1.73	20.10	7.26	0.00	0.00	0.00
4	127.90	3.74	36.40	9.98	0.00	0.00	0.00
6	59.93	5.89	48.60	11.47	66.22	0.00	0.00
8	40.17	7.85	55.90	13.57	168.32	0.00	0.00
10	25.65	9.91	60.40	13.79	221.64	35.27	188.00
12	15.82	11.84	62.80	12.13	227.03	105.71	546.90
14	10.38	13.88	64.90	10.92	227.94	133.45	731.70
16	4.64	15.90	64.90	6.40	137.43	94.68	537.60
18	1.78	17.82	65.20	3.09	65.24	50.39	293.50
20	0.72	19.77	66.90	1.54	31.96	24.91	145.10
22	0.21	21.79	70.30	0.55	8.84	7.28	44.90
24	0.15	23.52	68.80	0.44	10.65	8.82	56.10
26	0.06	25.58	66.30	0.22	4.83	4.35	27.60
28	0.05	27.86	70.70	0.22	5.09	4.43	28.60
30	0.07	30.13	72.00	0.33	6.88	6.06	41.30
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	689.75	8.69	55.6	91.91	1182.05	475.34	2641.40
>=5"+:	159.63			74.67			

2001 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	276.71	2.17	21.20	7.33	0.00	0.00	0.00
4	181.89	3.71	32.10	13.95	0.00	0.00	0.00
6	63.47	5.90	45.90	12.17	60.06	0.00	0.00
8	43.46	7.91	54.60	14.90	165.87	0.00	0.00
10	29.46	9.89	59.80	15.78	248.74	32.82	172.90
12	20.23	11.91	63.20	15.70	289.00	136.30	709.80
14	10.67	13.84	64.50	11.16	232.30	136.77	748.10
16	9.23	15.71	66.60	12.43	281.26	189.00	1076.50
18	3.47	17.94	66.10	6.11	133.73	97.78	561.80
20	1.04	19.57	66.80	2.17	45.09	35.59	209.40
22	0.52	21.79	67.70	1.34	28.44	22.42	132.00
24	0.13	24.21	70.20	0.41	10.16	8.46	52.80
26	0.04	25.58	71.10	0.16	3.74	3.05	20.50
28	0.04	27.56	71.20	0.14	3.35	2.92	18.80
30	0.01	30.80	67.60	0.07	1.54	1.26	7.60
32	0.04	31.96	72.40	0.24	4.48	4.11	28.20
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	640.74	9.04	54.90	114.05	1507.76	670.48	3738.40
>=5"+:	181.81			92.77			

2001 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	304.29	1.81	20.30	5.96	0.00	0.00	0.00
4	116.87	3.83	36.90	9.58	1.54	0.00	0.00
6	52.76	5.89	44.60	10.06	60.20	0.00	0.00
8	38.07	7.96	55.00	13.22	159.48	0.00	0.00
10	24.43	9.95	62.90	13.25	210.82	39.40	207.90
12	17.53	11.81	67.90	13.36	268.79	126.12	658.30
14	11.33	13.90	71.60	11.97	256.29	158.95	874.30
16	5.84	15.81	70.80	7.97	158.11	116.91	672.90
18	1.77	17.82	67.00	3.07	67.96	50.23	292.30
20	1.77	20.05	75.50	3.89	83.09	65.03	389.60
22	0.53	21.40	81.30	1.33	36.21	30.44	183.10
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	575.20	9.04	56.40	93.67	1302.50	587.07	3278.40
>=5"+:	154.04			78.12			

1976 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	439.85	1.73	18.90	7.94	0.00	0.00	0.00
4	143.95	3.72	33.40	11.11	4.80	0.00	0.00
6	55.17	5.88	44.50	10.50	67.25	0.00	0.00
8	25.89	7.96	52.20	9.00	84.33	0.00	0.00
10	14.85	9.77	56.10	7.75	90.19	4.82	25.00
12	10.03	12.08	59.10	8.00	142.91	62.74	324.10
14	8.41	13.80	62.40	8.75	161.51	89.84	496.80
16	2.49	16.06	64.00	3.50	63.61	41.89	239.10
18	3.02	17.86	63.30	5.25	122.15	90.97	529.30
20	1.05	19.82	59.50	2.25	44.89	34.29	207.90
22	0.30	21.36	58.60	0.75	16.92	12.80	74.50
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.07	25.40	64.00	0.25	5.28	4.74	29.40
28	0.18	27.52	67.10	0.75	16.84	14.18	89.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	705.27	8.57	51.10	75.82	820.67	356.28	2015.10
>=5"+:	121.46			56.77			

1986 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	382.00	2.03	20.10	8.95	0.00	0.00	0.00
4	209.96	3.70	30.80	16.01	1.55	0.00	0.00
6	56.53	5.86	43.90	10.68	69.91	0.00	0.00
8	29.39	7.77	50.40	9.73	91.08	0.00	0.00
10	19.17	9.73	55.60	9.93	98.41	9.60	51.50
12	9.95	11.74	60.20	7.50	128.05	48.42	248.00
14	10.13	13.88	61.80	10.66	213.31	119.35	660.30
16	3.23	15.76	62.80	4.38	92.04	61.20	347.20
18	2.51	17.97	64.90	4.43	95.27	71.40	414.10
20	1.90	19.61	62.00	3.98	90.80	70.10	422.80
22	0.64	21.48	60.20	1.61	30.04	23.88	139.20
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.05	26.00	64.50	0.18	3.69	3.32	20.60
28	0.11	28.05	68.00	0.47	10.40	9.16	58.10
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	726.49	8.64	50.80	88.50	924.56	416.44	2361.80
>=5"+:	133.62			63.54			

2001 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	273.59	2.34	21.80	8.41	0.00	0.00	0.00
4	282.28	3.73	28.40	21.90	1.44	0.00	0.00
6	81.24	5.75	41.00	14.79	75.69	0.00	0.00
8	36.17	7.84	48.70	12.17	124.43	0.00	0.00
10	22.39	9.95	56.30	12.12	108.47	6.96	37.10
12	11.05	11.91	60.40	8.57	135.44	55.23	286.80
14	8.72	13.98	61.90	9.31	195.02	113.66	627.70
16	6.91	15.78	62.60	9.40	201.55	132.66	762.00
18	1.62	18.13	64.80	2.91	61.65	46.60	268.50
20	2.76	19.88	64.60	5.95	136.00	105.66	630.00
22	0.86	21.62	63.20	2.20	51.49	39.88	239.10
24	0.21	23.43	55.60	0.63	5.70	4.99	29.60
26	0.03	26.70	65.00	0.13	2.59	2.33	14.50
28	0.05	28.49	72.60	0.21	4.67	4.08	26.60
30	0.02	29.70	60.60	0.09	1.84	1.66	10.10
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	729.16	8.41	48.50	108.78	1105.97	513.71	2931.90
>=5"+:	172.03			78.47			

1986 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	383.87	1.66	18.10	6.33	0.00	0.00	0.00
4	121.96	3.92	34.80	10.46	3.20	0.00	0.00
6	40.56	5.89	46.20	7.74	58.33	0.00	0.00
8	31.40	7.89	52.60	10.73	125.72	0.00	0.00
10	16.93	9.86	56.70	9.00	105.77	11.79	63.20
12	9.06	11.88	59.60	7.00	120.90	52.58	275.00
14	7.08	13.93	62.50	7.50	153.42	84.00	460.70
16	4.39	15.82	62.80	6.00	118.25	81.61	465.80
18	2.56	17.90	64.90	4.48	99.11	74.09	432.40
20	1.63	19.80	63.80	3.49	75.00	58.46	352.50
22	0.49	21.50	62.90	1.25	28.50	22.67	135.10
24	0.16	23.78	58.30	0.50	10.37	8.47	51.10
26	0.14	25.20	60.40	0.50	10.76	8.97	54.50
28	0.12	27.20	68.70	0.50	11.61	9.47	60.50
30	0.05	29.20	64.40	0.25	5.07	4.57	27.70
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	620.42	8.99	53.00	75.73	926.00	416.69	2378.40
>=5"+:	114.58			58.94			

2001 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	305.21	2.20	21.20	8.35	0.00	0.00	0.00
4	149.68	3.59	29.30	10.78	1.51	0.00	0.00
6	81.11	5.61	42.40	14.06	66.17	0.00	0.00
8	32.50	7.90	50.80	11.13	140.77	0.00	0.00
10	24.82	9.91	57.50	13.34	174.85	18.45	97.40
12	10.24	11.89	58.60	7.92	118.83	56.67	295.40
14	7.31	13.80	62.80	7.61	157.39	88.53	490.70
16	6.16	15.82	63.30	8.42	185.67	120.94	691.50
18	3.38	17.72	64.70	5.80	120.63	86.75	505.70
20	2.29	19.93	64.50	4.97	115.19	92.19	548.20
22	0.59	21.96	66.50	1.54	37.09	29.21	178.50
24	0.42	23.31	61.30	1.25	21.46	16.80	102.60
26	0.17	25.64	59.80	0.59	11.91	10.17	61.60
28	0.08	28.20	69.90	0.33	7.54	6.57	42.60
30	0.03	30.00	65.40	0.15	2.99	2.69	16.40
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	624.58	8.36	49.70	96.24	1162.01	528.96	3030.60
>=5"+:	169.10			77.11			

2001 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	359.86	1.69	20.80	6.25	0.00	0.00	0.00
4	139.94	3.79	34.70	11.15	0.00	0.00	0.00
6	56.19	5.82	40.60	10.48	57.11	0.00	0.00
8	30.50	7.94	49.60	10.56	104.23	0.00	0.00
10	26.09	9.84	55.90	13.82	201.87	35.24	186.30
12	12.44	11.83	62.10	9.51	191.72	98.17	510.70
14	10.03	13.95	66.10	10.66	209.38	129.23	710.40
16	3.61	15.90	65.00	4.99	114.86	79.46	452.90
18	2.01	17.68	67.00	3.42	80.75	60.00	341.50
20	0.80	20.60	79.50	1.86	51.45	40.37	244.90
22	1.20	21.77	76.30	3.12	83.40	66.50	390.50
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	642.68	8.74	50.50	85.82	1094.76	508.97	2837.00
>=5"+:	142.88			68.42			

NHI_H -- 1 stand only

1976 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	239.92	1.98	27.20	5.69	0.00	0.00	0.00
4	59.98	4.30	42.50	6.13	0.00	0.00	0.00
6	36.03	6.15	54.90	7.50	95.22	0.00	0.00
8	19.98	8.28	62.50	7.50	123.94	0.00	0.00
10	40.74	10.05	63.90	22.51	474.12	66.35	355.20
12	24.77	11.77	67.80	18.75	426.92	154.32	800.50
14	14.45	13.79	68.80	15.01	389.15	233.45	1308.60
16	5.84	15.35	69.20	7.50	190.62	121.44	703.50
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	441.71	9.71	62.80	90.59	1699.97	575.56	3167.80
>=5"+:	141.81			78.76			

1986 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	141.58	1.88	24.20	2.80	0.00	0.00	0.00
4	115.22	3.44	38.70	7.63	0.00	0.00	0.00
6	49.44	5.68	49.80	8.76	76.62	0.00	0.00
8	25.73	7.78	60.00	8.53	140.69	0.00	0.00
10	36.70	10.21	64.70	20.92	434.70	85.49	441.60
12	32.13	11.97	67.30	25.19	582.52	280.56	1513.10
14	11.96	13.90	69.40	12.63	327.02	191.56	1073.70
16	12.63	15.58	69.90	16.75	425.05	270.52	1569.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	425.39	9.51	60.80	103.20	1986.59	828.13	4597.40
>=5"+:	168.59			92.78			

2001 MODELED

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	142.59	2.27	23.60	4.11	0.00	0.00	0.00
4	169.37	3.31	31.20	10.20	0.00	0.00	0.00
6	46.86	5.68	44.80	8.25	51.73	0.00	0.00
8	34.86	7.50	57.00	10.75	176.40	0.00	0.00
10	26.72	9.83	62.80	14.14	275.30	55.74	298.70
12	30.92	11.89	67.80	23.85	538.95	213.87	1098.60
14	23.98	13.63	69.80	24.33	625.93	339.18	1891.10
16	14.13	15.92	70.80	19.55	498.48	335.95	1960.70
18	5.73	17.40	71.00	9.47	239.31	187.43	1110.20
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	499.89	9.88	59.70	124.65	2406.10	1132.19	6359.30
>=5"+:	183.19			110.33			

1986 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	209.93	1.77	22.50	3.95	0.00	0.00	0.00
4	89.97	3.83	41.10	7.44	0.00	0.00	0.00
6	15.32	6.70	54.60	3.75	55.15	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	24.59	11.80	67.30	18.75	443.75	186.62	996.30
14	7.13	13.88	71.10	7.50	193.28	107.78	603.10
16	8.31	15.75	71.60	11.25	285.69	181.71	1057.40
18	6.77	17.44	74.50	11.24	190.29	149.20	882.10
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	362.02	11.93	66.00	63.88	1168.18	625.31	3539.00
>=5"+:	62.12			52.49			

2001 MODELED

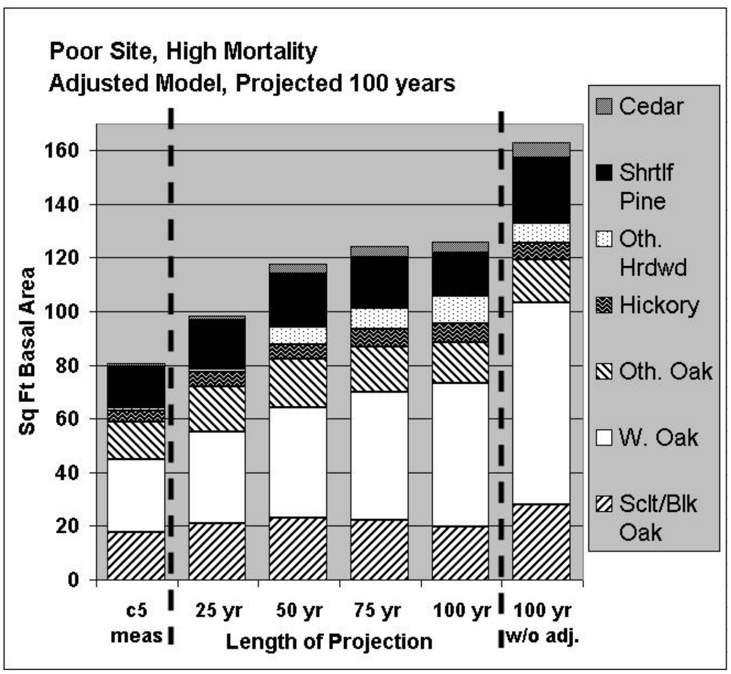
DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	114.68	2.02	23.20	2.58	0.00	0.00	0.00
4	145.60	3.57	37.00	10.26	0.00	0.00	0.00
6	22.49	6.10	45.40	4.57	0.00	0.00	0.00
8	15.24	7.80	56.80	5.06	74.66	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	10.99	12.20	65.10	8.92	198.93	123.54	663.80
14	13.40	14.31	72.40	14.98	387.29	249.14	1401.90
16	7.07	15.92	73.00	9.79	249.41	177.22	1035.90
18	8.24	17.82	73.30	14.29	396.65	280.54	1670.50
20	5.90	19.18	75.00	11.83	255.21	180.34	1085.30
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	343.61	11.46	61.60	82.28	1562.15	1010.77	5857.40
>=5"+:	83.33			69.43			

2001 MEASUREMENT

DIA. CLASS	TREES /AC	AVG DBH_5	AVG HGT_5	BA /AC	CUBIC CU/AC	BOARD CU/AC	BOARD BD/AC
2	974.61	1.68	16.80	16.78	0.00	0.00	0.00
4	74.97	4.50	37.80	8.28	0.00	0.00	0.00
6	216.72	5.76	28.60	39.57	238.99	0.00	0.00
8	66.22	7.47	29.90	20.22	186.62	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	6.02	11.10	41.00	4.05	59.60	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:	1338.54	6.26	29.10	88.89	485.21	0.00	0.00
>=5"+:	288.96			63.83			

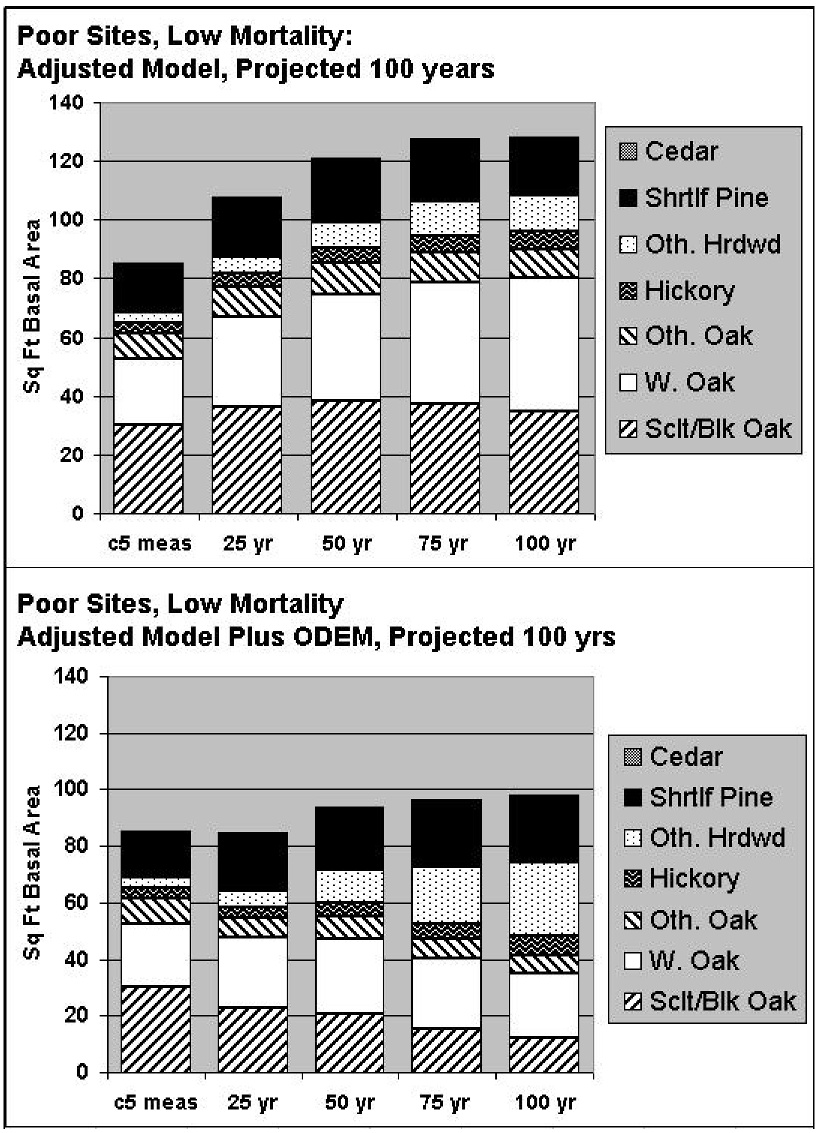
Predicting Future Conditions

After determining that the FVS model with adjustments provided realistic estimates of stand growth, we simulated the development of the poor sites, with both high and low mortality levels, for 100 years into the future. Refer to the figure below. The poor sites with high mortality were projected from cycle 5 for 100 years using the FVS model with adjustments. The Oak Decline Event Monitor addfile was not applied in this case under the assumption that these are "aftermath" stands that have already lost their vulnerable scarlet and black oak component. The adjusted FVS model predicts that these stands would increase in basal area to a maximum slightly above 120 sq. ft. It predicts that the white oak and other hardwoods would occupy an increasingly large proportion of the basal area. Projecting data beyond 50 years is suspect, but if pressed to do so, it is encouraging to see that the adjusted model predicts a basal area level and species composition that are similar to measured trends. Note that we also produced an iteration of the FVS model without adjustments to determine what the predicted basal area would be after 100 years of growth. This simulation produced an unrealistically high prediction of basal area.



Projected basal area and species composition of poor sites with high mortality from Cycle 5 for 100 years into the future using the adjusted FVS model. For comparison, projected 100-year values using FVS without adjustment are also shown.

Poor sites, low mortality, were also projected from cycle 5 for 100 years. For this trial, we ran the model with and without the ODEM addfile in order to observe the effect of the ODEM addfile on the projection. When the FVS model with adjustments was used, the predicted pattern of stand development was very similar to the pattern predicted for the high mortality stands. Refer to the figure below. This was not surprising since the average basal area of the stands within these two groups was actually quite similar for cycle 5. The interesting result here is the effect of including the ODEM addfile in the projection. Over a 100-year period, adding the ODEM addfile causes a fairly significant shift in species composition. It predicts a much lower proportion of the stand to be composed of either the “scarlet/black oak” or “white oak” species group and a much larger proportion of the stand in “other hardwoods”. It also holds the basal area below 100 ft^2/acre throughout the projection. Based on these findings, we recommend that the species related mortality impacts within the ODEM addfile be modified to apply a lower level to the “white oak” and a higher level to the “other hardwoods” species group



Projected basal area and species composition of poor sites with low mortality from Cycle 5 for 100 years into the future using the FVS model with adjustments and the FVS model with adjustments with the ODEM addfile.

Conclusions

The purpose of this paper has been to provide further detail of the process used to compare oak decline on the Mark Twain National Forest to actual growth and mortality data as measured over three FIA inventory cycles. It should be readily apparent that this study required extensive effort and intensive resolve to bring to fruition. It is the intention of the authors to have provided enough documentation to provide a good template for studies of a similar nature. Formal conclusions and recommendations should be gleaned from the Third FVS Conference proceedings paper.

Appendix A – Original Request from Mark Twain National Forest

Data Assessment needs from FIA data for the Mark Twain National Forest

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In FY 2002, The Mark Twain National Forest requested that FIA revisit the Mark Twain FIA plots that were measured in 1999 (possible some in 1998), 2000 and some 2001. This request was made in order for the Forest to gain some understanding of the Oak Decline and/or Red Oak Borer problems currently afflicting Missouri and Arkansas. The following questions are asked:

Compare original 1999-2000 data to re-measured 2002

What are the changes – tree by tree and plot by plot on the plots that were measured in 1999 and 2000 and then revisited (re-measured) in 2002? Are there indications of Oak Decline on the original measurements? Re-measurements? What species, age class, crown closure, crown position is most effected? Can the location of these plots tell us anything? Effects lumped in one or 2 counties or scattered everywhere?

Can these changes be summarized to a total mortality per acre basis? Total mortality by Species per acre? Expand to a Forest or Countywide figure? Can a "percent of the Forest will die (or has died)" figure be calculated? By species?

Compare previous FIA data with succeeding re-measurements; Trend Analysis

How can we use mortality figures over time so that we can "estimate" the effects that have happened since the early 1980s and how might this effect be looked at over the next planning horizon – 2002-2052? Can the data tell us that xxx, xxx CCF has died in the last 2 years? 5years? 10years? 20 years? Are the summary plot data – Forest Type, Size class, Age class, changing with each re-measure?

Major drought conditions occurred in 1980 and in 1998-2001. These droughts are considered the primary trigger of Oak Decline in Missouri.

Missouri FIA Data has been collected in 1972, 1989 and 1999 (new 5 year cycle).
The Mark Twain has FIA Data collected for 1972, 1977, 1989 and the 1999 cycle. The 1977 data was reprocessed using the 1989 procedures for Resource Bulletin NC-129.

Can the data for the Mark Twain FIA Plots be compared tree by tree and then summarized by plot for:
1977 vs 1989?
1989 vs. 1999 (re-measure of the 1989 before new plot design)?
1999-2000 vs. re-measure 2002?

What are the species/age classes being effected over the years? As the MT's Forest grows older – is there likely to be another occurrence of Oak Decline in say 15 years? Which area or county most likely to be effected?

If possible, can a comparison of the 1989 and 1999 plot data for southern Missouri be done for all ownerships? Or maybe just for the Eastern and South Western Ozarks survey units. Plotting the plot location with a high-med-low occurrence of mortality would be very useful.

Appendix B – Additional Oak Decline Citations Relative to the Ozark Plateau

Kromroy, Kathryn W.; Juzwik, Jennifer; Castillo, Paul; Hansen, Mark H. 2008. Using Forest Service forest inventory and analysis data to estimate regional oak decline and oak mortality. Northern Journal of Applied Forestry. 25(1): 17-24.

Moser, W. Keith; Hansen, Mark H.; Treiman, Thomas B.; Leatherberry, Earl C.; Jepsen, Ed; Olson, Cassandra L.; Perry, Charles H.; Piva, Ronald J.; Woodall, Christopher W.; Brand, Gary J. 2007. Missouri's forests 1999-2003 (Part A). Resour. Bull. NRS-10. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 79 p.

Moser, W. Keith; Hansen, Mark H.; Hatfield, Mark A.; Nigh, Timothy A. 2006. Evaluating sustainability: a method for assessing vegetation change in southern Missouri, U.S.A.: 1820-2003. In: Lafortezza, R.; Sanesi, G., eds. Patterns and processes in forest landscapes. Consequences of human management. Proceedings of the 4th meeting of IUFRO working party 8.01.03; 2006, September 26-29; Locorotondo, Bari, Italy. Accademia Italiana di Scienze Forestali. 399-408.

Moser, W. Keith; Hansen, Mark; McWilliams, Will; Sheffield, Ray. 2006. Oak composition and structure in the eastern United States. In: Dickinson, Matthew B., ed. 2006. Fire in eastern oak forests: delivering science to land managers, proceedings of a conference; 2005 November 15-17; Columbus, OH. Gen. Tech. Rep. NRS-P-1. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 49-61.

Moser, W. Keith; Liknes, Greg; Hansen, Mark; Nimerfro, Kevin. 2005. Incorporation of Precipitation Data into FIA Analyses: A Case Study of Factors Influencing Susceptibility to Oak Decline in Southern Missouri, U.S.A. p. 33-41 In: Proceedings of the fifth annual forest inventory and analysis symposium; 2003 November 18-20; New Orleans, LA. Gen. Tech. Rep. WO-69. Washington, DC: U.S. Department of Agriculture Forest Service. 222p.

Woodall, Chris W.; Morin, Randall S.; Steinman, Jim R.; Perry, Charles H. 2008. Status of oak seedlings and saplings in the northern United States: implications for sustainability of oak forests. In: Jacobs, Douglass F.; Michler, Charles H., eds. 2008. Proceedings, 16th Central Hardwood Forest Conference; 2008 April 8-9; West Lafayette, IN. Gen. Tech. Rep. NRS-P-24. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 535-542.

Woodall, C.W.; Grambsch, P.L.; Thomas, W.; Moser, W.K. 2005. Survival analysis for a large scale forest health issue: Missouri oak decline. Environmental Monitoring and Assessment (2005) 108: 295-307

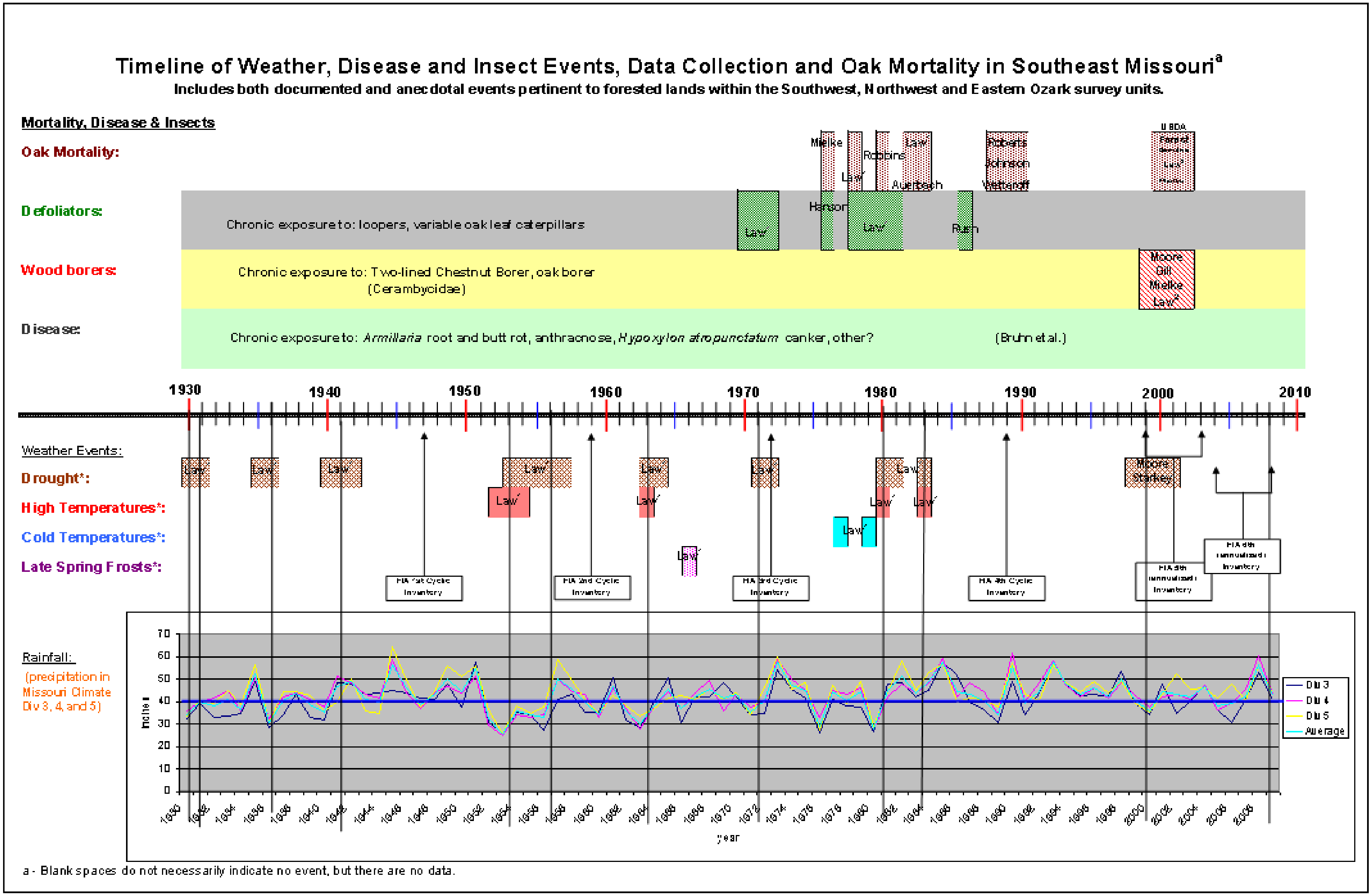
Also, FIA annual reports commonly include some discussion of oak decline:

Moser WK, Hansen MH, Crocker SJ, Treiman TB. 2008. Missouri’s forest resources in 2007. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station Res. Note NRS-y. 4 p. In press.

Moser W..K., Hansen M..H., Treiman T. B. 2007. Missouri’s forest resources in 2006. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station Res. Note NRS-4. 4 p.

Moser WK, Hansen MH, Brand GJ, Treiman TB. 2007. Missouri's forest resources in 2005. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. Resour. Bull. NRS-15. 25 p.
Moser WK, Hansen MH, Treiman T, Moltzan B, Lawrence R, Brand GJ. 2006. Missouri's forest resources in 2004. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. Resour. Bull. NC-257. 37 p.
Moser WK, Treiman T, Moltzan B, Lawrence R, Brand GJ. 2005. Missouri's forest resources in 2003. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. Resour. Bull. NC-243. 44 p.
Moser WK, Brand GJ, Treiman T, Moltzan B, Lawrence R. 2004. Missouri's forest resources in 2002. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. Resour. Bull. NC-233. 42 p.
Moser WK, Treiman T, Moltzan B, Lawrence R, Brand GJ. 2003. Missouri's Forest Resources in 2001. St. Paul, MN: USDA, Forest Service North Central Research Station Resour Bull NC-226. 26 p.

Appendix C – Timeline of Events in Southeast Missouri



Appendix D – Tree Species Code Guide

Oak Decline Assessment: Mark Twain NF -- Tree Species Codes

FVS-Alpha	FVS-Grp	FVS-Num	FIA-Grp	FIA-Num	Common Name
SP	02	03	02	110	Shortleaf pine
VP	03	04	03	132	Virginia pine
RC	01	01	09	068	Eastern redcedar
WO	19	47	25	802	White oak
SW	24	54	25	804	Swamp white oak
CK	24	53	25	826	Chinkapin oak
RO	20	48	26	833	Northern red oak
QS	27	67	26	834	Shumard oak
PO	25	57	27	835	Post oak
CO	26	59	27	832	Chestnut oak
SK	20	49	28	812	Southern red oak
BO	21	50	28	837	Black oak
SO	22	51	28	806	Scarlet oak
BJ	23	52	28	824	Blackjack oak
QI	27	62	28	817	Shingle oak
PN	27	60	28	830	Pin oak
SL	07	16	29	405	Shellbark hickory
SH	07	15	29	407	Shagbark hickory
MH	07	17	29	409	Mockernut hickory
BH	08	21	29	402	Bitternut hickory
PH	08	18	29	403	Pignut hickory
BI	08	23	29	408	Black hickory
SM	17	43	31	318	Sugar maple
RM	12	29	32	316	Red maple
SV	12	31	32	317	Silver maple
AB	09	24	33	531	American beech
SU	29	82	34	611	Sweetgum
BG	06	13	35	693	Black tupelo
TS	06	11	35	694	Swamp tupelo
UA	10	27	36	546	Blue ash
WA	18	45	36	541	White ash
GA	18	46	36	544	Green ash
BW	16	42	38	951	American basswood
YP	15	41	39	621	Yellow poplar
WN	05	08	40	602	Black walnut
BN	05	09	41	601	Butternut
BE	12	30	41	313	Boxelder
BC	13	32	41	762	Black cherry
SG	14	34	41	461	Sugarberry
HK	14	35	41	462	Hackberry
WE	14	36	41	971	Winged elm
AE	14	33	41	972	American elm
RL	14	39	41	975	Slippery elm
OB	28	70	41	331	Ohio buckeye
SS	28	69	41	931	Sassafras
RB	29	81	41	373	River birch
SY	29	79	41	731	Sycamore
BL	29	84	41	922	Black willow
RE	14	40	42	977	Rock elm
PS	28	72	42	521	Persimmon
HL	28	73	42	552	Honeylocust
BK	28	77	42	901	Black locust
DW	30	88	42	491	Flowering dogwood
MB	30	94	42	680	Mulberry sp.
AH	30	86	43	391	American hornbeam
RD	30	87	43	471	Eastern redbud
HT	30	89	43	500	Hawthorn sp.
HH	30	95	43	701	Eastern hophornbeam
NC	30	85	43	994	Other hardwoods, non-com

Appendix E – Application of Manion Method by Inventory Cycle

Mark Twain National Forest - Undisturbed Oak-Hickory Common Plots {125 FIA Plots}

dbh	tpa_2	mort_2	surv_2	dgrow_2	ingrow_3	tpa_3	ln(tpa_2)	calc_tpa2	q-slope	calc_mort	rel_mort%	an_ormrt%	ormrt%
2	381.953	87.331	294.622	0.011	105.320	384.592	5.945	327.864	2.038	50.934	0.391	2.286	0.000
4	130.578	14.395	116.183	0.024	0.000	118.281	4.872	160.871	2.038	50.934	0.851	1.102	91.867
6	59.799	3.243	56.556	0.040	0.000	61.196	4.091	78.933	2.038	50.934	1.414	0.542	27.116
8	36.070	1.281	34.789	0.058	0.000	32.860	3.585	38.729	2.038	50.934	2.044	0.355	12.246
10	20.369	1.068	19.301	0.082	0.000	22.284	3.014	19.003	2.038	50.934	2.877	0.524	12.788
12	12.631	0.728	11.903	0.097	0.000	14.359	2.536	9.324	2.038	50.934	3.394	0.576	11.884
14	5.900	0.473	5.427	0.112	0.000	8.117	1.775	4.575	2.038	50.934	3.909	0.802	14.316
16	2.456	0.284	2.172	0.129	0.000	3.470	0.899	2.245	2.038	50.934	4.489	1.156	17.928
18	1.092	0.152	0.940	0.143	0.000	1.485	0.088	1.101	2.038	50.934	4.963	1.392	19.468
20	0.551	0.143	0.408	0.163	0.000	0.700	-0.596	0.540	2.038	50.934	5.638	2.595	31.844
22	0.213	0.057	0.156	0.176	0.000	0.311	-1.546	0.265	2.038	50.934	6.073	2.676	30.410
24	0.086	0.038	0.048	0.203	0.000	0.124	-2.453	0.130	2.038	50.934	6.972	4.419	43.533
26	0.058	0.009	0.049	0.213	0.000	0.048	-2.847	0.064	2.038	50.934	7.302	1.552	14.570
28	0.056	0.014	0.042	0.226	0.000	0.049	-2.882	0.031	2.038	50.934	7.730	2.500	22.124
30	0.016	0.002	0.014	0.243	0.000	0.037	-4.135	0.015	2.038	50.934	8.287	1.250	10.288
32	0.006	0.006	0.000	0.263	0.000	0.022	-5.116	0.008	2.038	0.000	8.938	10.000	0.000
34	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	2.038	0.000	0.000	0.000	0.000
36	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	2.038	0.000	0.000	0.000	0.000
38	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	2.038	0.000	0.000	0.000	0.000
40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.038	0.000	0.000	0.000	0.000
Total:	658.552	115.940	542.612	0.062	105.320	647.935		643.706					
								inverse q	0.491	50.934	2.183	1.582	
								m% =	50.932				

dbh	tpa_3	mort_3	surv_3	dgrow_3	ingrow_4	tpa_4	ln(tpa_3)	calc_tpa3	q-slope	calc_mort	rel_mort%	obs_mort%	ormrt%
2	384.592	147.518	237.074	0.045	138.434	334.929	5.952	292.920	1.945	48.583	1.486	3.836	0.000
4	118.281	39.926	78.355	0.060	2.639	102.926	4.773	150.611	1.945	48.583	1.976	3.376	100.000
6	61.196	23.529	37.667	0.076	9.771	51.340	4.114	77.440	1.945	48.583	2.496	3.845	91.181
8	32.861	11.096	21.765	0.089	8.735	34.601	3.492	39.817	1.945	48.583	2.917	3.377	75.880
10	22.284	7.235	15.049	0.104	5.979	23.488	3.104	20.473	1.945	48.583	3.400	3.247	62.437
12	14.359	4.290	10.069	0.112	3.471	15.628	2.664	10.527	1.945	48.583	3.657	2.988	53.351
14	8.117	2.279	5.838	0.118	2.351	10.871	2.094	5.412	1.945	48.583	3.849	2.808	47.588
16	3.470	0.797	2.673	0.109	1.082	5.827	1.244	2.783	1.945	48.583	3.560	2.297	42.144
18	1.484	0.389	1.095	0.114	0.326	2.127	0.395	1.431	1.945	48.583	3.721	2.621	45.988
20	0.700	0.159	0.541	0.097	0.222	1.153	-0.357	0.736	1.945	48.583	3.175	2.271	46.834
22	0.311	0.073	0.238	0.112	0.115	0.463	-1.168	0.378	1.945	48.583	3.657	2.347	41.915
24	0.124	0.017	0.107	0.078	0.020	0.214	-2.087	0.195	1.945	48.583	2.561	1.371	35.153
26	0.048	0.019	0.029	0.124	0.015	0.074	-3.037	0.100	1.945	48.583	4.040	3.958	63.844
28	0.049	0.023	0.026	0.098	0.000	0.035	-3.016	0.051	1.945	48.583	3.207	4.694	95.793
30	0.037	0.014	0.023	0.089	0.000	0.025	-3.297	0.026	1.945	48.583	2.917	3.784	85.029
32	0.022	0.012	0.010	0.143	0.000	0.016	-3.817	0.014	1.945	48.583	4.645	5.455	0.000
34	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.007	1.945	0.000	0.000	0.000	0.000
36	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	1.945	0.000	0.000	0.000	0.000
38	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	1.945	0.000	0.000	0.000	0.000
40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	1.945	0.000	0.000	0.000	0.000
Total:	647.935	237.376	410.559	0.091	173.161	583.721		602.927					
								inverse q	0.514	48.583	2.981	3.267	
								m% =	48.583				

dbh	tpa_3	mort_3	surv_3	dgrow_3	ingrow_4	tpa_4	ln(tpa_4)	calc_tpa4	q-slope	calc_mort	rel_mort%	obs_mort%	ormrt%
2	384.592	147.518	237.074	0.045	138.434	334.929	5.814	322.306	1.942	48.501	1.482	3.836	0.000
4	118.281	39.926	78.355	0.060	2.639	102.926	4.634	165.985	1.942	48.501	1.971	3.376	112.517
6	61.196	23.529	37.667	0.076	9.771	51.340	3.938	85.482	1.942	48.501	2.490	3.845	101.181
8	32.861	11.096	21.765	0.089	8.735	34.601	3.544	44.022	1.942	48.501	2.910	3.377	75.880
10	22.284	7.235	15.049	0.104	5.979	23.488	3.156	22.671	1.942	48.501	3.392	3.247	62.437
12	14.359	4.290	10.069	0.112	3.471	15.628	2.749	11.676	1.942	48.501	3.648	2.988	53.351
14	8.117	2.279	5.838	0.118	2.351	10.871	2.386	6.013	1.942	48.501	3.840	2.808	47.588
16	3.470	0.797	2.673	0.109	1.082	5.827	1.763	3.097	1.942	48.501	3.552	2.297	42.144
18	1.484	0.389	1.095	0.114	0.326	2.127	0.755	1.595	1.942	48.501	3.712	2.621	45.988
20	0.700	0.159	0.541	0.097	0.222	1.153	0.142	0.821	1.942	48.501	3.167	2.271	46.834
22	0.311	0.073	0.238	0.112	0.115	0.463	-0.770	0.423	1.942	48.501	3.648	2.347	41.915
24	0.124	0.017	0.107	0.078	0.020	0.214	-1.542	0.218	1.942	48.501	2.555	1.371	35.153
26	0.048	0.019	0.029	0.124	0.015	0.074	-2.604	0.112	1.942	48.501	4.031	3.958	63.844
28	0.049	0.023	0.026	0.098	0.000	0.035	-3.352	0.058	1.942	48.501	3.199	4.694	95.793
30	0.037	0.014	0.023	0.089	0.000	0.025	-3.689	0.030	1.942	48.501	2.910	3.784	85.029
32	0.022	0.012	0.010	0.143	0.000	0.016	-4.135	0.015	1.942	48.501	4.634	5.455	0.000
34	0.000	0.000	0.000	0.000	0.000	0.005	-5.298	0.008	1.942	0.000	0.000	0.000	0.000
36	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	1.942	0.000	0.000	0.000	0.000
38	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	1.942	0.000	0.000	0.000	0.000
40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	1.942	0.000	0.000	0.000	0.000
Total:	647.935	237.376	410.559	0.091	173.161	583.721		664.538					
								inverse q	0.515	48.583	2.974	3.267	
								m% =	48.501				

dbh	tpa_4	mort_3	surv_3	dgrow_3	ingrow_4	tpa_5	ln(tpa_5)	calc_tpa5	q-slope	calc_mort	rel_mort%	obs_mort%	ormrt%
2	334.929	147.518	237.074	0.045	138.434	332.517	5.807	255.035	1.807	44.656	1.322	4.404	0.000
4	102.926	39.926	63.000	0.060	2.639	106.725	4.670	141.147	1.807	44.656	1.759	3.879	129.303
6	51.340	23.529	27.811	0.076	9.771	43.982	3.784	78.116	1.807	44.656	2.223	4.583	120.605
8	34.601	11.096	23.505	0.089	8.735	29.889	3.397	43.233	1.807	44.656	2.598	3.207	72.064
10	23.488	7.235	16.253	0.104	5.979	21.814	3.083	23.927	1.807	44.656	3.029	3.080	59.236
12	15.628	4.290	11.338	0.112	3.471	16.432	2.799	13.242	1.807	44.656	3.259	2.745	49.019
14	10.871	2.279	8.592	0.118	2.351	11.686	2.458	7.329	1.807	44.656	3.430	2.096	35.532
16	5.827	0.797	5.030	0.109	1.082	8.003	2.080	4.056	1.807	44.656	3.173	1.368	25.097
18	2.127	0.389	1.738	0.114	0.326	4.037	1.396	2.245	1.807	44.656	3.316	1.829	32.085
20	1.153	0.159	0.994	0.097	0.222	1.204	0.186	1.242	1.807	44.656	2.828	1.379	28.433
22	0.463	0.073	0.390	0.112	0.115	0.638	-0.449	0.688	1.807	44.656	3.259	1.577	28.155
24	0.214	0.017	0.197	0.078	0.020	0.212	-1.551	0.381	1.807	44.656	2.281	0.794	20.369
26	0.074	0.019	0.055	0.124	0.015	0.283	-1.262	0.211	1.807	44.656	3.601	2.568	41.412
28	0.035	0.023	0.012	0.098	0.000	0.071	-2.645	0.117	1.807	44.656	2.857	6.571	134.111
30	0.025	0.014	0.011	0.089	0.000	0.000	0.000	0.065	1.807	44.656	2.598	5.600	125.843
32	0.016	0.012	0.004	0.143	0.000	0.000	0.000	0.036	1.807	44.656	4.142	7.500	0.000
34	0.005	0.000	0.005	0.000	0.000	0.000	0.000	0.020	1.807	0.000	0.000	0.000	0.000
36	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011	1.807	0.000	0.000	0.000	0.000
38	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	1.807	0.000	0.000	0.000	0.000
40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	1.807	0.000	0.000	0.000	0.000
Total:	583.721	237.376	346.345	0.091	173.161	577.494		571.107					
								inverse q	0.553	44.656	2.656	3.324	
								m% =	44.656				

Mark Twain National Forest – Ozark Plateau: Oak Decline