# Has Virginia Pine Declined? The Use of Forest Health Monitoring and Other Information in the Determination

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Abstract.—This paper examines the current status of Virginia, pine focusing on Forest Health Monitoring (FHM) results and using Forest Inventory and Analysis (FIA) information to determine if Virginia pine is showing a decline. An examination of crown condition data from live trees in the FHM program from 1991 through 1997 showed that Virginia pine had significantly poorer crown conditions for crown dieback and crown density. The crown variable relationships were poorer for trees that died after 1993. In addition, the numbers of Virginia pines on the FHM plots declined during the same time period, even accounting for ingrowth. FIA information across the range of Virginia pine has shown that mortality was 48 percent and removals were 92 percent of net annual growth. Virginia pine is showing a decline based on both FHM crown rating information and FIA data for removals and growth, but this is typical and expected due to the shade intolerance and short-lived nature of Virginia pine.

Virginia pine (*Pinus virginiana* Mill.) is a small to medium tree found from northern Alabama to New Jersey, growing throughout the Piedmont and lower elevations of the Appalachians (Carter and Snow 1990). It can grow in pure stands and is a major species in the Society of American Foresters cover types of Virginia Pine-Oak and Virginia pine (Eyre 1980). It is also an associate of nine other cover types. It grows well on a wide variety of soils and is usually a pioneer species on old fields, burned areas, and other disturbed sites. Being a pioneer species and shade intolerant, it generally is a transitional tree species that is replaced by more shade tolerant trees.

The Forest Health Monitoring (FHM) program began in 1990, with additional activity in the southern and mid-Atlantic areas of the US in 1991. FHM plots were installed in Alabama, Delaware, Georgia, Maryland, New Jersey, and Virginia at this time. FHM is designed to annually collect, analyze, and report on the forest conditions of the US. The basis of this information is various groups of measurements (indicators) that describe aspects of forest conditions. The current indicators that are implemented on FHM plots are tree growth, tree mortality, tree regeneration, crown conditions, damage symptoms, and ozone bioindicator plants. For more information about FHM, see Stolte (1997) or visit the FHM web site at "http://willow.ncfes.umn.edu/fhm/fhm_hp.htm".

Three crown condition variables have been shown to reflect stresses on trees: crown density, crown dieback, and foliage transparency (Cox *et al.* in preparation).

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These crown ratings are collected for each live tree on FHM plots with a dbh of 5.0 inches or greater. All three of these crown variables are recorded in 5 percent increments with the recorded code being the upper range, i.e., 25 is 21 to 25 percent. The value for a given tree is the value agreed to by field crew members. Crown density values for a species are generally normally distributed, while crown dieback and foliage transparency values are usually skewed toward zero. For a complete description of crown rating procedures, see USDA Forest Service (1997).

Crown density is an estimate of the amount of skylight obstructed by branches, foliage, and reproductive structures. Anderson and Belanager (1987) showed that high crown-density values were positively correlated with radial growth in loblolly (*Pinus taeda* L.) and shortleaf pines (*Pinus echinata* Mill.). Crown dieback is branch mortality that starts near the terminal and proceeds toward the trunk or at the top of a tree toward the ground. Crown dieback usually occurs in the upper part of the crown and is a symptom of various stresses on the tree, such as drought (Millers *et al.* 1992). Foliage transparency is the amount of skylight visible through the live, normally foliated portion of the crown. This measurement is an indicator of the foliage in the crown, a surrogate measure of defoliation (Millers *et al.* 1992).

As early as 1993, crown conditions in Virginia pine were identified as deviating from the trend of other pine species in the active FHM southern and mid-Atlantic states (Burkman *et al.* 1998). These authors stated that "... crown ratings and damage data from sample plots do not suggest any widespread decline, except for Virginia pine where crown conditions continue to decline." It is this possible decline in Virginia pine that initiated the work described in this paper to determine if the decline is real and what its potential causes are. The objectives of this paper are to:

1. determine if Virginia pine is experiencing a decline through the detailed analyses of FHM crown condition data, and
2. use the FHM and FIA data to offer possible explanations.

## PROCEDURES

FHM plot data from Alabama, Delaware, Georgia, Maryland, New Jersey, and Virginia for loblolly, shortleaf, Virginia, and slash (*Pinus elliottii* Engelm.) pines from 1991 through 1997 were included in this study. Due to budget constraints, no data were collected in 1996. All FHM plots in these six states were installed in 1991. From 1992 through 1994, all plots were visited and the crown condition and damage symptom data were collected on all live trees. Also, any tree that died on each plot was recorded by year, but no ingrowth trees were added to the data set. In 1995, all plots were revisited and data were collected as in 1992 through 1994, but ingrowth trees were also recorded. In 1996, FHM moved from an "every plot, every year" sampling strategy to a "rotating panel" sampling scheme. In the rotating panel, a subset of the plots, one-third, was visited on a rotating format. So in 1997, only one-third of the plots were visited, but all measurements were collected and both mortality and ingrowth trees were included in the data collection effort. This sampling scheme will be continued in the future for FHM. For a complete description of this rotating panel design, please see Smith *et al.* (in review).

From the FHM data set for these years, two data sets were created:

1. A data set of all loblolly, shortleaf, Virginia, and slash pines alive in 1997 that included crown density, crown dieback, and foliage transparency for the years 1991 through 1995 and 1997, and
2. A data set of all loblolly, shortleaf, Virginia, and slash pines that died from 1993 through 1997 that included crown density, crown dieback, and foliage transparency for the years 1991 through 1995 and 1997.

Using linear regression analysis in SAS (SAS 1989), a line for each crown variable over time was fitted for each tree on each plot. The slopes of each of these lines were then organized into another data set. From this output data set of individual tree slopes, a weighted mean for each crown variable by species by plot was determined. A weighted mean was used because the number of trees per plot ranged from 1 to 58 for loblolly pine, 1 to 25 for shortleaf pine, 1 to 64 for slash pine, and 1 to 44 for Virginia pine. Each of these weighted plot means was then tested for deviation from zero by a using a standard t-test (SAS 1989). This analysis was repeated for the mortality tree data set. This analysis would not test any complex relationship, i.e., curvilinear, but tested only whether the overall trend over time was increasing or decreasing.

The interpretation of the results will vary by the crown rating variable. A positive slope for crown density means that the crown condition of the tree is improving, while a positive slope for crown dieback and foliage transparency means that the crown condition is declining.

## RESULTS AND DISCUSSION

The mean crown density, crown dieback, and foliage transparency data for 1991 through 1997 for Virginia, loblolly, shortleaf, and slash pines are shown in figures 1, 2, and 3, respectively. Generally, Virginia pine had the poorest or one of the poorest plot means for all crown variables from 1991 through 1997. It is especially true for crown dieback (fig. 2) and foliage transparency (fig. 3) for all years and for crown density for most years except 1997 (fig. 2).

The results for the mean slope plot values for the live trees are contained in table 1. Virginia pine had a significant ($P$ = 0.05) annual increase (declining condition) for crown dieback of almost 1 percent and it had a significant ($P$ = 0.05) annual decrease (declining condition) of 1 percent for crown density. The results for shortleaf pine were non-significant ($P$ = 0.05) for all three crown variables. Slash pine had significant ($P$ = 0.05) improving conditions for both crown density and crown dieback. Results for all crown variables for loblolly pine were significantly declining ($P$ = 0.05). This is most likely due to the large numbers of plots and trees in the data set.

The results for the trees that died after 1993 are contained in table 2. Slash pine was not included in the analysis because of the small number of plots (five) and trees (eight) in the data set. Virginia pine had a significant ($P$ = 0.05) annual increase (declining condition) for crown dieback of 2.54 percent. The value for mortality trees was almost three times greater that for trees still alive in 1997. Virginia pine also had a significant ($P$ = 0.05) annual decrease (declining condition) of 1.7 percent for crown density, which was almost two times greater than trees still alive in 1997. The results for shortleaf and loblolly pines were non-significant for all three crown variables.

The results for live loblolly and Virginia pine trees show that a decline is occurring with crown density and crown dieback. In general, the annual change is larger in Virginia pine than in loblolly pine. Another issue that

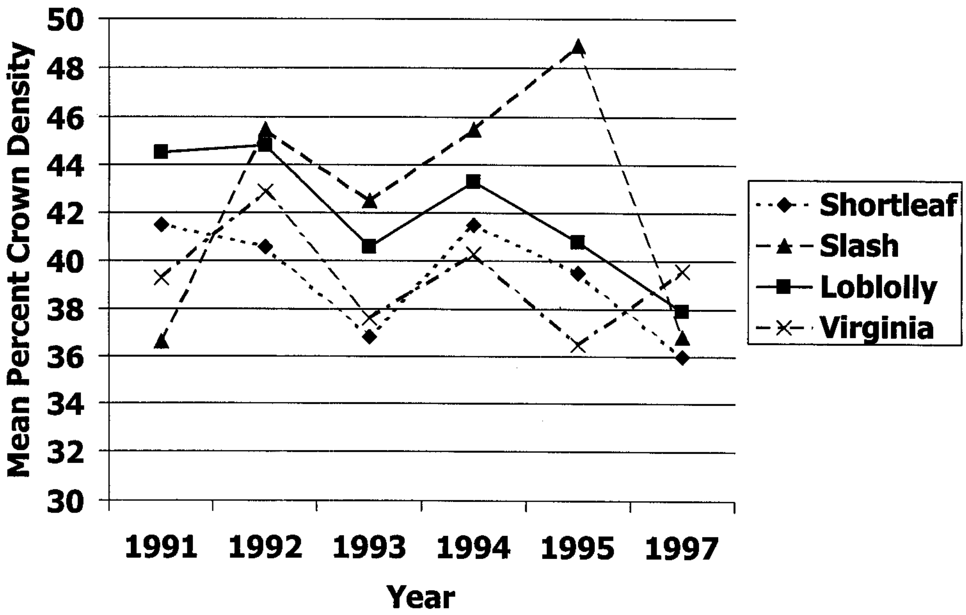


Figure 1.—*Mean crown density for shortleaf, slash, loblolly, and Virginia pines on FHM plots in Alabama, Delaware, Georgia, Maryland, New Jersey, and Virginia, 1991 through 1995 and 1997.*

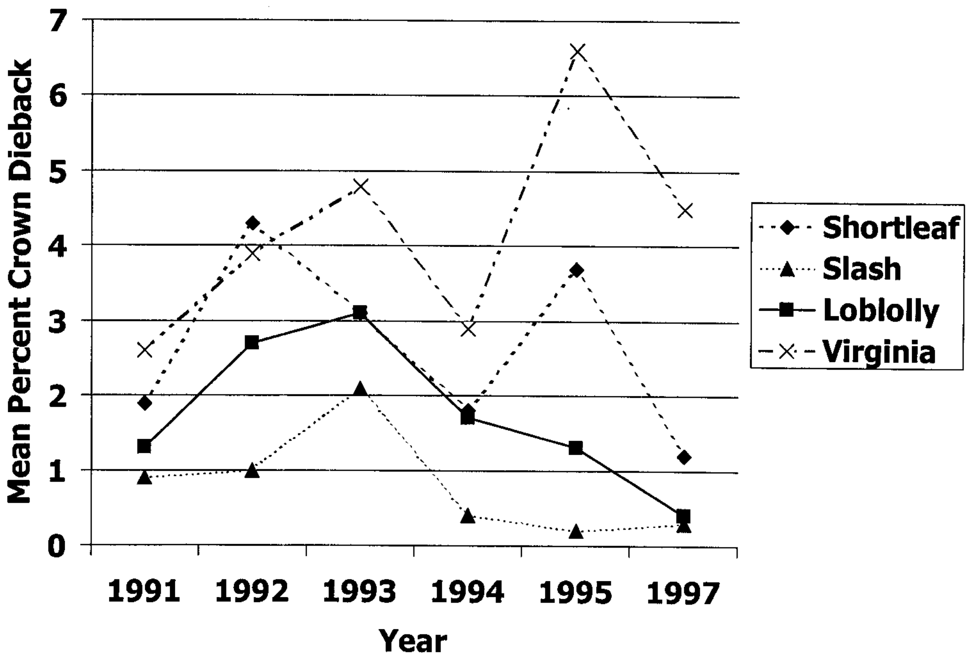


Figure 2.—*Mean crown dieback for shortleaf, slash, loblolly, and Virginia pines on FHM plots in Alabama, Delaware, Georgia, Maryland, New Jersey, and Virginia, 1991 through 1995 and 1997.*

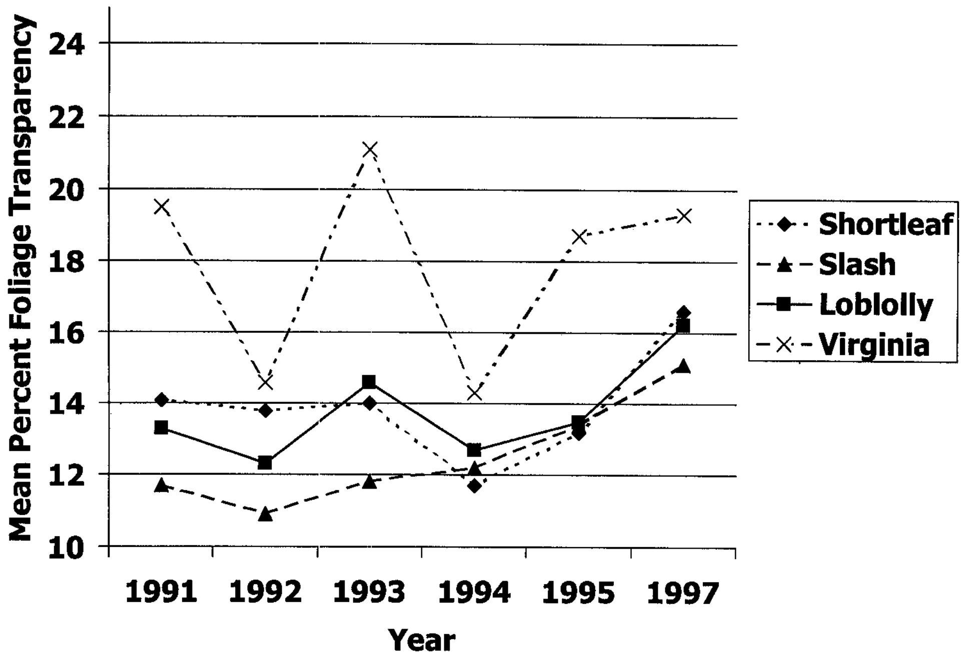


Figure 3.—*Mean foliage transparency for shortleaf, slash, loblolly, and Virginia pines on FHM plots in Alabama, Delaware, Georgia, Maryland, New Jersey, and Virginia, 1991 through 1995 and 1997.*

Table 1.—*Mean slope, probabilities, number of plots, and number of trees by pine species (shortleaf, slash, loblolly, and Virginia) and crown variables (crown density, crown dieback, and foliage transparency) for trees alive in 1997*

| Species | Mean slope | Probability | Number of plots | Number of trees |
|---|---|---|---|---|
| Crown Density: | | | | |
| Shortleaf pine | -0.53 | 0.0681 | 60 | 249 |
| Slash pine | 1.35 | 0.0044 | 29 | 263 |
| Loblolly pine | -1.43 | 0.0001 | 152 | 1,625 |
| Virginia pine | -1.00 | 0.0096 | 43 | 424 |
| Crown Dieback: | | | | |
| Shortleaf pine | 0.29 | 0.0904 | 60 | 249 |
| Slash pine | -0.20 | 0.0005 | 29 | 263 |
| Loblolly pine | 0.20 | 0.0013 | 152 | 1,625 |
| Virginia pine | 0.86 | 0.0001 | 43 | 424 |
| Foliage Transparency: | | | | |
| Shortleaf pine | -0.32 | 0.1868 | 60 | 249 |
| Slash pine | 0.55 | 0.0737 | 29 | 263 |
| Loblolly pine | 0.81 | 0.0001 | 152 | 1,625 |
| Virginia pine | 0.38 | 0.3118 | 43 | 424 |

Table 2.—*Mean slope, probabilities, number of plots, and number of trees by pine species (shortleaf, loblolly, and Virginia) and crown variables (crown density, crown dieback, and foliage transparency) for trees that died after 1993*

| Species | Mean slope | Probability | Number of plots | Number of trees |
|---|---|---|---|---|
| Crown Density: | | | | |
| Shortleaf pine | -0.06 | 0.9661 | 12 | 17 |
| Loblolly pine | -1.15 | 0.2784 | 29 | 41 |
| Virginia pine | -1.73 | 0.0041 | 18 | 71 |
| Crown Dieback: | | | | |
| Shortleaf pine | -0.65 | 0.6107 | 12 | 17 |
| Loblolly pine | 1.51 | 0.1404 | 29 | 41 |
| Virginia pine | 2.54 | 0.0001 | 18 | 71 |
| Foliage Transparency: | | | | |
| Shortleaf pine | -0.15 | 0.8503 | 12 | 17 |
| Loblolly pine | 1.72 | 0.0809 | 29 | 41 |
| Virginia pine | 2.58 | 0.0869 | 18 | 71 |

needs to be recognized is that the initial mean values for each crown rating variable were more favorable in loblolly pine than in Virginia pine, so even a smaller change may be more critical for Virginia pine.

On the FHM plots, the relative number of sample trees from 1991 to 1995 is presented in figure 4. For slash pine, when ingrowth is factored into the total number, the relative number of trees in 1995 was 88 percent of 1991 numbers of trees and showed a major increase between 1994 and 1995. For loblolly, the number was 131 percent of the 1991 total. Both these results show that the mortality and cut trees are not being replaced in the sample population. The results for both Virginia and shortleaf pines show a steady decrease over time including the year (1995) when ingrowth was accounted for.

Another way to present these data is to examine the numbers of trees by 2-inch dbh class. Figure 5 shows a constant dbh distribution in loblolly pine for 1991, 1995, and 1997. But in Virginia pine, the distribution curve is shifting to a larger dbh class (fig. 6.). The 6-inch dbh class was most common in 1991 and 1995, but the 8-inch dbh class was the most common in 1997. This result also shows that for Virginia pine, the sample population is not being replaced for mortality and cut trees.

To determine if this decline in Virginia pine needs further attention, the FIA data set was examined. The analysis was conducted using the FIA interactive database retrieval system (located at web site - http://www.srs.fia.usfs.msstate.edu). Across the entire range of Virginia pine, mortality volume is 48 percent of the growth and removal volume is 92 percent of growth, for a net change of 140 percent—further evidence that Virginia pine that dies or is cut is not being replaced.

## CONCLUSIONS

Based on the analysis of FHM crown density and crown dieback data, Virginia pine is showing a decline. In addition, loblolly pine is also showing a decline for these two crown variables and for foliage transparency. The FHM plot results for Virginia pines that died after 1993 identified larger annual changes (declines) than for trees that were still alive in 1997. The results from an examination of the number of sample trees and proportion of trees by dbh class show a sample population that is shifting from smaller trees to larger trees with very little recruitment in the smaller size classes. This relationship is the opposite of that found in loblolly pine. The implication is that the Virginia pine sample population is getting older and more susceptible to various stress-causing agents, especially ice damage and windthrow, which are common in older stands (Carter and Snow 1990).

The FIA data did show that mortality and removal volume was 140 percent of the growth, a net deficit. Because it is a relatively short-lived tree and intolerant of shade, Virginia pine will generally be replaced by more tolerant hardwood species (Carter and Snow 1990). So it appears this species is showing a decline based on both FHM crown rating information and FIA data for removals and growth, but that this is typical and expected due to the shade intolerance and short-lived nature of Virginia pine.

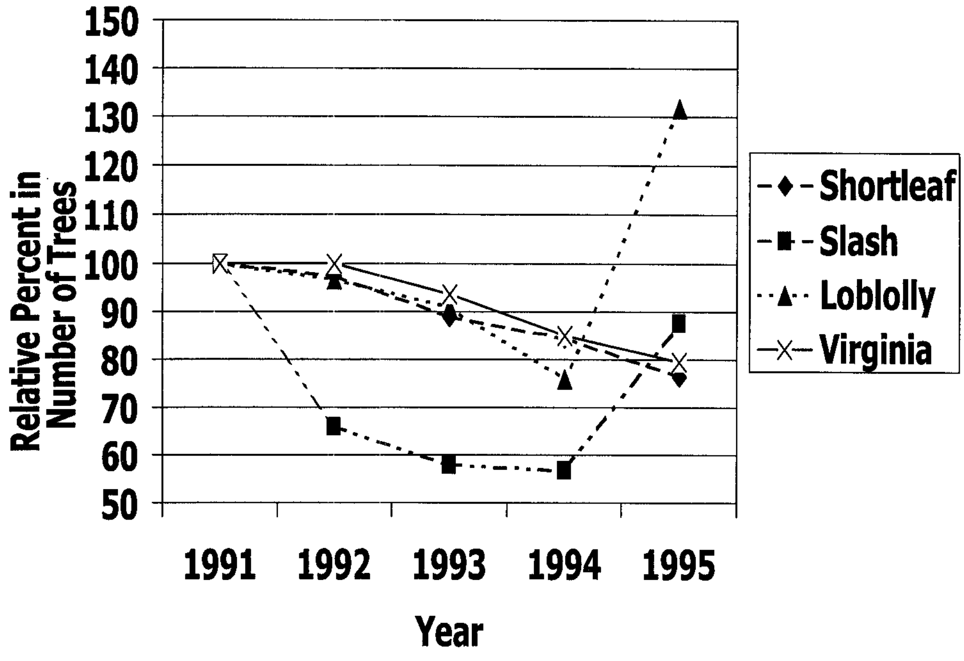


Figure 4.—*Relative change in numbers of live trees for shortleaf, slash, loblolly, and Virginia pines on FHM plots in Alabama, Delaware, Georgia, Maryland, New Jersey, and Virginia, 1991 through 1995.*

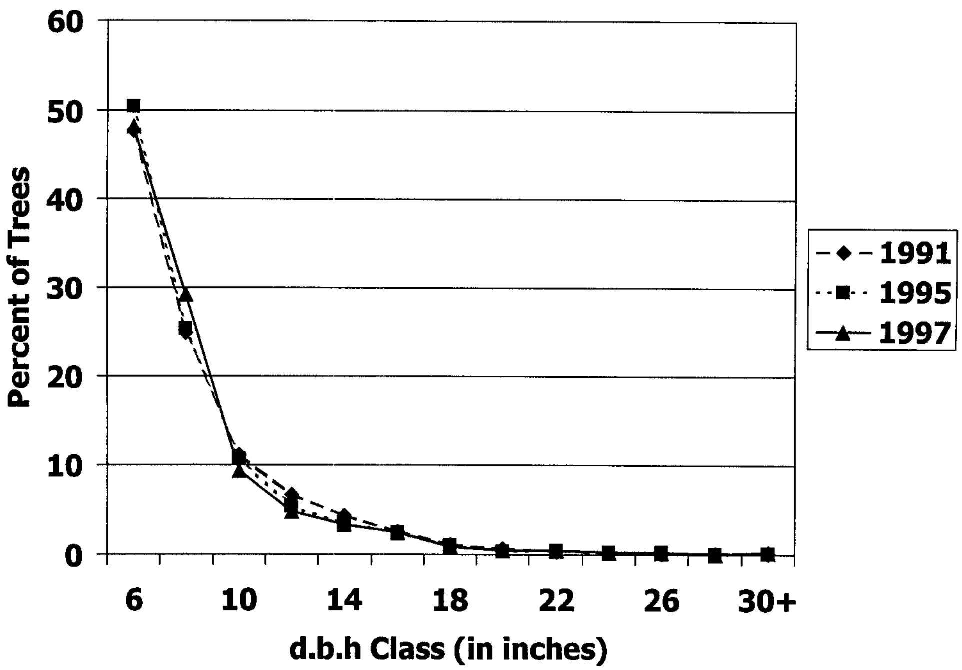


Figure 5.— *Distribution of live trees by 2-inch dbh class for loblolly pine on FHM plots in Alabama, Delaware, Georgia, Maryland, New Jersey, and Virginia, 1991 through 1995 and 1997.*

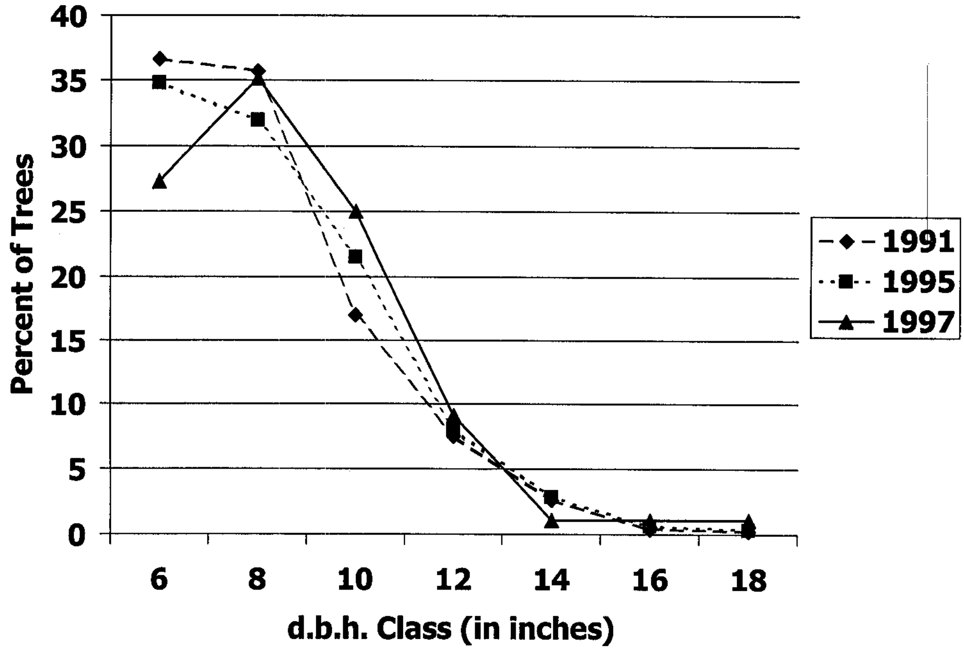


Figure 6.— *Distribution of live trees by 2-inch dbh class for Virginia pine on FHM plots in Alabama, Delaware, Georgia, Maryland, New Jersey, and Virginia, 1991 through 1995 and 1997.*

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