

CHAPTER ONE

1. *Introduction and objectives*

1.1 *Introduction*

Loblolly pine (*Pinus taeda* L.) is the most important commercial tree species in the Southeastern United States. In recent times, naturally-occurring pine stands occupied about two-thirds of the pine forest area in the South, with plantations comprising the remaining one-third of the area (or about 20 million acres). Projections, however, show a shift in the natural to planted pine forest area ratio, with plantations projected to exceed naturally forested areas in the near future (USDA Forest Service 1988). Alig *et al.* (1986) projected a doubling of planted pine timberland area in the South by 2030.

The reason for the shift is simple: demand for southern pine wood products. Southern pine pulpwood production, as an example, increased about 400% from approximately 16 million cords in 1953 to 66 million cords in 1993 (Johnson 1996). The demand for southern pine wood products continues to increase, and it seems only natural that loblolly pine is the species that will be used to meet that demand. Some have even projected a timber shortage to occur early in the 21st century, claiming there are simply not enough trees presently in the ground to accommodate future demand.

There are basically three ways in which the demand for southern pine timber can be met: (a) increase the area regenerated with southern pine, (b) increase stand productivity of southern pine forests, (c) both (a) and (b). Continual urban expansion and

current trends in the environmental movement which place restrictions on the area available for pine plantations both make scenario (a) highly unlikely. As a result, efforts seem to be concentrated on scenario (b) - increasing stand productivity.

There are a multitude of ways to increase stand productivity. One such method is provided by changing technologies. Manufactured products such as laminated veneer lumber (LVL) and Parallam™ utilize smaller trees to produce products similar to, and often stronger than, solid wood products. Such manufactured lumber can be used in place of solid wood products. Computerized programs can determine the best method to saw a log thereby assuring the most efficient use of each log being sent to the mill. For the most part, improving technologies increases the amount of wood products realized after the tree(s) have been harvested.

Other methods of increasing productivity include those which increase the amount of timber produced in the woods, namely the use of silvicultural treatments such as herbicide and fertilizer applications (intensively managed plantations). Mean annual increment (MAI) in southern pine plantations in the past typically averaged 0.8 - 1.3 cords/acre/year (c/a/y). Currently, industrial plantation managers are trying to raise production levels to a MAI of 2.0 to 3.0 c/a/y. Borders and Bailey (1998) have shown that MAI's of up to 4.5 c/a/y are possible with loblolly pine in the South given a stringent competition control/fertilization program.

The increased timber demand and attention on silvicultural applications has increased focus on productivity. Tree productivity, however, is an end result of photosynthetic activity of tree crowns. The photosynthetic productivity of any terrestrial

plant form is strongly governed by the geometric form of its foliage and/or crown (Jahnke and Lawrence 1965). Grace *et al.* (1987a) reported how crown form and foliage distribution within the crown modify the interception of precipitation and utilization of solar radiant energy. This in turn affects photosynthesis, respiration, transpiration, and other inherent physiological processes that occur within tree crowns. Sampson *et al.* (1998) proposed a loblolly pine stand management regime based upon maintaining a Leaf Area Index (LAI) of about 3.5, considered to be biologically optimal (plantations not intensively managed have LAI of 1.0 to 2.0.)

The forest modeling community has likewise increased its attention to the tree crown, but mainly on the distribution and location of branches (Kurttio and Kellomäki 1990; Maguire *et al.* 1991; Doruska and Burkhart 1994). Much of this work is related to wood quality and location of knots. With respect to crown shape, simple geometric solids were used in the past to approximate tree crowns (Mawson *et al.* 1976), but more recent efforts have begun to incorporate the individualistic nature of tree crowns (Nepal *et al.* 1996, Baldwin and Peterson 1997, Biging and Gill 1997).

Individual-tree, physiologically-based process models such as MAESTRO (Wang and Jarvis 1990a) employ representations of tree crowns and have tended to use geometric solids as proxies for the shapes of tree crowns. As attention is drawn to the individualistic (both inter- and intraspecific) nature and shape of the tree crown, the need for models or modeling techniques which can account for these subtle tree to tree differences is apparent. This study is aimed at examining the current techniques of

modeling crown shape or crown profile and evaluating the use of nonparametric regression to describe the crown profile of loblolly pine.

The organization of this dissertation is as follows. Chapter 2 contains a review of present state of crown shape/profile modeling. Chapter 3 provides the background to nonparametric regression analysis. A description of the data used herein and the results of the analyses and comparisons made in this effort appear in Chapter 4. Chapter 5 summarizes the findings of this study and outlines recommendations for future research.

1.2 Objectives and Approach

The specific objectives of the study include:

- i)* Review and contrast the current state of crown shape/profile modeling.

- ii)* Describe crown profile of loblolly pine via nonparametric regression analysis using
 - kernel regression,
 - local linear regression, and
 - local quadratic regression.

- iii)* Compare the nonparametric representations of crown profile with those presently available in the literature.

This research endeavor addresses the question of whether or not nonparametric regression is capable of providing realistic outer and inner crown profiles for individual loblolly pine trees. A relatively small but adequate dataset consisting of a random sample of 34 loblolly pine trees from unthinned stands in the Piedmont and Atlantic Coastal Plain was utilized to answer this question. Visual inspection of profile representations in combination with statistical analysis was used to compare nonparametric regression fits with others reported in the literature as well as to draw conclusions regarding its potential use for such modeling efforts.

1.3 Variable definitions and notation

The following terminology and notation are used in this study.

<i>DBH</i>	Diameter at breast height (1.37 m above ground) (cm)
<i>HT</i>	Total tree height (m)
<i>HLC</i>	Height to base live crown (m)
<i>HBLF</i>	Height to base live foliage (m)
<i>CL</i>	Crown length ($HT - HLC$) (m)
<i>RCH</i>	Relative crown height $((\text{Branch height} - HLC)/CL)$
<i>RB</i>	Crown radius at base live crown (m)
<i>ker</i>	Kernel regression
W	Weight matrix
<i>h</i>	Bandwidth
<i>LPR</i>	Local polynomial regression
X	X matrix
Ξ	Penalty function
<i>SSE</i>	Sum of squared errors
<i>PRESS</i>	Prediction sum of squares
<i>PRESS*</i>	Penalized <i>PRESS</i>
$s^2_{(NP)}$	Nonparametric estimate of s^2
<i>MAR</i>	Mean absolute residual $(\sum_{i=1}^n y_i - \hat{y}_i /n)$