CHAPTER FIVE

5. Summary and Recommendations

5.1 Summary

Methods for quantifying tree crown shapes and profiles must continue to improve for a number of reasons. First, productivity modeling is gaining momentum within the forest research community. Physiological process models typically use crown shape when determining foliage distribution, which is used in turn to calculate photosynthetic rates. Second, crown volumes are used to assess wildlife habitat and abundance. Finally, crown volumes are used to assess the competitive status of trees relative to one another as well to calculate other crown descriptors such as fractal dimensions. The ability to describe the shape of tree crowns or profiles is required to calculate crown volumes.

Crown profiles have been represented by geometric shapes in the past, but the current trend is moving away from their use. The need for flexible models with the ability to incorporate tree to tree differences in crown shape or methods whereby such varying shapes can be described is apparent.

Single-regressor, nonparametric regression is just such a method. The modeler does not impose a functional form or shape onto the data. Rather a data-driven, weighting technique is used to determine the overall shape of a curve, with the modeler determining the amount of local curvature to depict. No functional form of such a curve exists. However, numerical techniques can be used to obtain volumes if warranted.

Three forms of nonparametric regression were examined: kernel, local linear, and local quadratic. All three forms are flexible with respect to shape. However, kernel

regression typically possesses boundary problems whereas local linear and local quadratic nonparametric regression do not exhibit this problem.

Modeler subjectivity can possibly enter any application of nonparametric regression modeling. This subjectivity enters during bandwidth selection. The use of PRESS* as the bandwidth selection criteria, however, removes much of this subjectivity.

Nonparametric regression techniques are fully capable of describing the wide variety of loblolly pine crown shapes which typically occur throughout the stages of stand development, provided individual tree data are available. The use of nonparametric regression to describe loblolly pine crown profiles performs admirably when compared to multiple linear regression, especially in those cases when multiple linear regression is clearly innappropriate.

Nonparametric regression also performs well when compared to more traditional models that modify a generic crown shape based upon individual tree attributes. When traditional models work well, nonparametric regression returns a similar crown profile. However, when traditional models fail, nonparametric regression can provide a considerably more realistic representation of crown profile.

This study has shown that nonparametric regression can be used to describe the outer profile of loblolly pine tree crowns, requiring only minimal data. The individualistic nature of tree crowns is maintained. When used to model inner crown profile, however, some problems do arise when compared to traditional (linear) models. The problems can be averted by discontinuing the use of the PRESS* criterion and subjectively improve boundary performance by decreasing bandwidth. However, doing so may lead to an

inflated variance of prediction by concentrating weights at the respective points of prediction. Such consequences should be carefully considered.

Single-regressor nonparametric regression, as used in this study, is a method of expressing the curvilinear relationship (no matter the degree) present between two variables in a given dataset. It does not predict this shape for a dataset. If no data exist, then the techniques described herein cannot be used, and the modeler would be better served by employing a model that actually predicts the shape, as opposed to a method that describes a shape.

It is hoped that the techniques described and the work performed in this study will provide forest modelers with a new tool for curve estimation, especially in situations where more traditional techniques are inadequate. Describing the crown profile of loblolly pine, where functional forms are often difficult to identify, is one such application.

5.2 Recommendations

Whereas attempts were made to study crown profile modeling in loblolly pine crowns, the project was somewhat data limited and should be considered mainly an observational study. Possible avenues of future study include:

(i) Expansion of the modeling efforts to thinned plantations, where considerably different crown dynamics occur. Trees which were subjected to crown competition prior to thinning often have some part of their crowns free of crown competition after thinning.

The dynamics of crown development post-thinning will undoubtedly result in even more varied crown shapes than those present in these data.

(ii) Expansion to general additive models whereby additional stand and or tree attributes can be used in the modeling efforts, especially with regard to bandwidth determination. Crown profiles of older trees and those subject to higher levels of crown competition often possess more local curvature and thus are more individualistic in nature. Smaller bandwidths need to be used within nonparametric regression to account for the presence of local curvature. The methods used in this research were restricted to the single-regressor case. As such, expected differences in shapes based upon stand age and/or levels of crown competition could not be directly included in the modeling process.

(iii) Possible merger with stochastic modeling techniques such ARMA models whereby the ARMA model generates random points along some specified trend, and then nonparametric regression is used to fit a smooth curve to the data while maintaining their nuances in shape.

(iv) In this study, the randomly selected sample branches were assumed to representative of the all the branches occurring at that height above ground. As a result, the radius measured in the given direction of the sample branch was assumed to be the radius of the crown in all directions at that height.

Crowns profiles can vary significantly based upon the level of crown competition in any one given direction. Collection of additional data in multiple directions around the bole, for example radii in each of the four quadrants about the bole, could greatly enhance the ability to describe crown profile. With the additional data, the estimated crown profiles could then vary within and between individual tree crowns, as opposed to just the latter. The cost of data collection would increase, but the additional data collected would undoubtedly lead to better quantification of a given tree's crown shape.

(v) Expansion of nonparametric regression use within forestry wherever a need for smoothing arises.