Literature Cited

Aigner, D.J., Lovell, C.A., Knox, C.A., and Schmidt, P. 1977. Formulation and estimation of stochastic frontier production function models. J. Econ. 6:21-37.

Alig, R.L., Knight, H.A., and Birdsey, R.A. 1986. Recent area changes in southern forest ownership and cover types. USDA For. Serv. South. For. Exp. Stat. Res. Pap. SE-260. 10p.

Allen, D. 1974. The relationship between variable selection and data augmentation and a method for prediction. Technometrics 16:125-127.

Altman, N.S. 1990. Kernel smoothing of data with correlated errors. J. Amer. Stat. Assoc. 85:749-759.

Amateis, R.L., and Burkhart, H.E. 1985. Site index curves for loblolly pine plantations on cutover site-prepared lands. South. J. Appl. For. 9:166-169.

Assmann, E. 1970. The principles of forest yield study. Pergamon Press. New York.

Baldwin, V.C. Jr., and Peterson, K.D. 1997. Predicting the crown shape of loblolly pine trees. Can. J. For. Res. 27:102-107.

Baldwin, V.C. Jr., Burkhart, H.E., Dougherty, P.M., and Teskey R.O. 1993. Using a growth and yield model (PTAEDA2) as a driver for a biological process model (MAESTRO). USDA For. Serv. Res. Pap. SO-276. 9p.

Bertram, J.E.A. 1989. Size-dependent differential scaling in branches: the mechanical design of trees revisited. Trees 3:241-253.

Biging, G.S., and Dobbertin, M. 1992. A comparison of distance dependent competition measures for height and basal area growth of individual conifer trees. For. Sci. 38:695-720.

Biging, G.S., and Dobbertin, M. 1995. Evaluation of competition indices in individual-tree growth models. For. Sci. 41:360-377.

Biging, G.S., and Gill, S.J. 1997. Stochastic models for conifer tree crown profiles. For. Sci. 43:25-34.

Biging, G.S., and Wensel, L.C. 1990. Estimation of crown form for six conifer species of northern California. Can. J. For. Res. 20:1137-1142.

Borders, B.E., and Bailey, R.L. 1998. Loblolly pine plantation growth rates - what is possible? *in* Proceedings of the ninth biennial southern silvicultural conference. In press.

Buckley, M.J., Eagleson, G.K., and Silverman, B.W. 1988. The estimation of residual variance in nonparametric regression. Biometrika 75:189-199.

Clark, A., III., and Souter, R.A. 1994. Stem cubic-foot volume for tree species in the South. USDA For. Serv. Res. Pap. SE-290. 241p.

Cleveland, W.S. 1979. Robust locally weighted regression and smoothing scatter plots. J. Amer. Stat. Assoc. 74:829-836.

Chu, C., and Marron, J. 1991. Choosing a kernel regression estimator (with discussion). Stat. Sci. 6:404-436.

Doruska, P.F., and Burkhart, H.E. 1994. Modeling the diameter and locational distribution of branches within the crowns of loblolly pine trees in unthinned plantations. Can. J. For. Res. 24:2362-2376.

Dralle, K., and Rudemo, M. 1996. Stem number estimation by kernel smoothing of aerial photos. Can. J. For. Res. 26:1228-1236.

Droessler, T.D., and Burk, T.E. 1989. A test of nonparametric smoothing of diameter distributions. Scan. J. For. Res. 4:407-415.

Droessler, T.D., and Burk, T.E. 1994. Modeling individual tree growth using temporary plot records: evaluation of a non-parametric diameter distribution based method. For. Ecol. Mgmt. 68:325-338.

Einsporn, R. 1987. HATLINK: a link between least squares regression and nonparametric curve estimation. Ph.D. dissertation, Virginia Poly. Inst. and State University, Blacksburg, VA.

Ellis, R., and Gulick, D. 1986. Calculus with analytic geometry. 3rd edition. Harcourt, Brace, and Jovanovich. San Diego, CA.

Eubank, R.L. 1988. Spline smoothing and nonparametric regression. Dekker, New York.

Eubank, R.L., and Speckman, P.L. 1993. Confidence bands in nonparametric regression. J. Amer. Stat. Assoc. 88:1287-1301.

Figueiredo-Filho, A., Borders, B.E., and Hitch, K.L. 1996. Number of diameters required to represent stem profiles using interpolated cubic splines. Can. J. For. Res. 26:1113-1121.

Goulding, C.J. 1979. Cubic spline curves and calculation of volume of sectionally measured trees. New.Zeal. J. For. Sci. 9:89-99.

Grace, J.C. 1990. Modelling the interception of solar radiation energy and net photosynthesis. *In* Process modeling of forest responses to environmental stresses (Dixon *et al. eds*). Timber Press. Portland OR. pp. 142-158.

Grace, J.C., Jarvis, P.G., and Norman, J.M. 1987a. Modelling the interception of solar radiant energy in intensively managed stands. New Zeal. J. For. Sci. 17:193-209.

Grace, J.C., Cook, D.A., and Lane, P.M. 1987b. Modelling canopy photosynthesis in *Pinus radiata* stands. New Zeal. J. For. Sci. 17:210-228.

Greene, W.H. 1980. Maximum likelihood estimation of econometric frontier functions. J. Econ. 13:27-56.

Hall, P., and Marron, J.S. 1990. On variance estimation in nonparametric regression. Biometrika 77:415-419.

Härdle, W. 1990. Applied nonparametric regression. Econometric Society Monograph No.19. Cambridge University Press, New York. 333 p.

Härdle, W. and Bowman, A.W. 1988. Bootstrapping in nonparametric regression: local adaptive smoothing and confidence bands. J. Amer. Stat. Assoc. 83:102-110.

Hart, J.D., and Yi, S. 1998. One-sided cross-validation. J. Am. Stat. Assoc. 93:620-631.

Hasanauer, H, H.E. Burkhart, and Sterba, H. 1994. Variation in potential volume yield of loblolly pine plantations. For. Sci. 40:1-14.

Hashimoto, R. 1990. Analysis of the morphology and structure of crowns in a young sugi (*Cryptomeria japonica*) stand. Tree Phys. 6:119-134.

Hashimoto, R. 1991. Canopy development in young sugi (*Cryptomeria japonica*) stands in relation to changes with age in crown morphology and structure. Tree Phys. 8:129-143.

Hastie, T., and Loader, C. 1993. Local regression: automatic kernel carpentry (with discussion). Stat. Sci. 8:120-143.

Hastie, T.J., and Tibshirani, H.J. 1990. Generalized additive models. Chapman and Hall, London. 335p.

Hatch, C.R., Gerrard, D.J., and Tappeiner, J.C. II. 1975. Exposed crown surface area: a mathematical index of individual tree growth performance. Can. J. For. Res. 5:224-228.

Honda, H., and Fisher, J.B. 1978. Tree branch angle: maximizing effective leaf area. Science 199:888-889.

Horn, H.S. 1971. The adaptive geometry of trees. Princeton University Press. Princeton, N.J.

Huang, C.J. 1984. Estimation of stochastic frontier production function and technical inefficiency via the EM algorithm. South. Econ. J. 50:847-856.

Inglis, C.S., and Cleland, M.R. 1982. Predicting final branch size in thinned *radiata* pine stands. New Zeal. For. Serv. FRI Bull. No. 3.

Jahnke, L.S., and Lawrence, D.B. 1965. Influence of photosynthentic crown structure on potential productivity of vegetation, based primarily on mathematical models. Ecology 46:319-326.

Johnson, T.G. 1996. Trends in southern pulpwood production, 1953-1993. USDA For. Serv. South. Res. Stat. Res. Bull. SRS-3. 18p.

Kangas, A. 1996. Small-area estimates using model-based methods. Can. J. For. Res. 26**:**758-766.

Kangas, A., and Korhonen, K.T. 1995. Generalizing sample tree information with semiparametric and parametric models. Silv. Fenn. 29:151-158.

Kellomäki, S. 1986. A model for the relationship between branch number and biomass in *Pinus sylvestris* crowns and the effect of crown shape and stand density on branch and stem biomass. Scand. J. For. Res. 1:455-472.

Koop, H. 1989. Forest dynamics SILVI-STAR: a comprehensive monitoring system. Berlin. Springer-Verlag.

Korzukhin, M.D., and Ter-Mikaelian, M.T. 1995. An individual tree-based model of competition for light. Ecol. Model. 79:221-229.

Kranigk, V.J., and Gravenhorst, G. 1995. Ein dreidimensionales modell für fichtenkronen. Allg. Forst-u. J.-Ztg. 164:146-149.

Kurth, V.W., and Lanwert, D. 1995. Biometrische grundlagen für ein dynamisches architekturmodel der fichte (*Picea abies* (L.) Karst.). Allg. Forst-u. J.-Ztg. 166:177-184.

Kurttio, O., and Kellomäki, S. 1990. Structure of young *Pinus sylvestris*: branching and its dependence on tree size. Scand. J. For. Res. 5:169-176.

Maguire, D.A., Moeur, M., and Bennett, W.S. 1990. Simulating branch diameter and branch distribution in young Douglas-fir. p 85-94 *in* Research in forest mensuration, growth and yield. Burkhart, H.E. (ed.) Virginia Polytechnic Institute and State University Publ. FWS-2-90.

Maguire, D.A., Kershaw Jr., J.A., and Hann, D.W. 1991. Predicting the effects of silvicultural regime on branch size and crown wood core in Douglas-fir. For. Sci. 37:1409-1428.

Mandelbrot, B.B. 1983. The fractal geometry of nature. W.H. Freeman. New York.

Mawson, J.C., Thomas, J.W., and DeGraaf, R.M. 1976. Program HTVOL: the determination of tree crown volume by layers. USDA For. Serv. Res. Pap. NE-354. 9p.

Mays, J.E. 1995. Model robust regression: combining parametric, nonparametric, and semiparametric methods. Unpublished Ph.D. dissertation. Virginia Polytechnic Institute and State University. Blacksburg, VA. 200p.

Meeusen, W. and van den Broeck, J. 1977. Efficiency estimation from Cobb-Douglas production functions with composed error. Int. Econ. Rev. 2:435-444.

M'Hirit, O., and Postaire, J.G. 1985. A nonparametric technique for taper function estimation. Can. J. For. Res. 15:862-871.

Mitchell, K.J. 1975. Dynamics and simulated yield of Douglas-fir. For. Sci. Monogr. No. 17.

Mohren, G.M.J. 1987. Simulation of forest growth, applied to Douglas-fir stands in the Netherlands. Unpublished Ph.D. dissertation. Agricultural University of Wagenin. The Netherlands.

Morrison, M.L., Timosse, I.M., and With, K.A. 1987. Development and testing of linear regression models predicting bird-habitat relationships. J. Wildl. Manage. 51:247-253.

Müller, H.-G. 1988. Nonparametric regression analysis of longitudinal data. Springer-Verlag. Berlin. 199 p.

Nadaraya, E.A. 1964. On estimating regression. Theory Prob. Appl. 9:141-142.

Nadaraya, E.A. 1965. On non-parametric estimates of density functions and regression curves. Theory Prob. Appl. 10:186-190.

Nepal, S.K., Somers, G.L., and Caudill, S.B. 1996. A stochastic frontier model for fitting tree crown shape in loblolly pine (*Pinus taeda* L.). J. Agric. Bio. and Env. Stat. 1:336-353.

Oohata, S., and Shinozaki, K. 1979. A statical model of plant form-further analysis of the pipe model theory. Jap. J. Ecol. 29:323-335.

Oker-Blom, P., and Kellomäki, S. 1982. Theoretical computations on the role of crown shape in the absorption of light by forest trees. Math. Biosci. 59:291-311.

Osawa, A. 1995. Inverse relationship of crown fractal dimension to self-thinning exponent of tree populations: a hypothesis. Can. J. For. Res. 25:1608-1617.

Ovington, J.D. and Madgwick, H.A.I. 1959. Distribution of organic matter and plant nutrients in a plantation of Scots pine. For. Sci. 5:344-355.

Priestley, M.B., and Chao, M.T. 1972. Nonparametric function fitting. J. Royal Stat. Soc. Series B. 34:385-392.

Pukkala, T., Karsikko, J. and Kolström, T. 1992. A spatial model for the diameter of the thickest branch of Scots pine. Silv. Fenn. 26:219-230.

Reinsch, C.H. 1967. Smoothing by spline functions. Numer. Math. 10:177-183.

Rudemo, M. 1982. Empirical choice of histograms and kernel density estimators. Scand. J. Statist. 9:65-78.

Sampson, D.A., Vose, J.M., and Allen, H.L. 1998. A conceptual approach to stand management using leaf area index as the integral of site structure, function, and resource supply and use. *in* Proceedings of the ninth biennial southern silvicultural conference. In press.

Shinozaki, K., Yoda, K., Hozumi, K., and Kira, T. 1964a. A quantitative analysis of plant form - the pipe model theory I. Basic analysis. Jap. J. Ecol. 14:97-105.

Shinozaki, K., Yoda, K., Hozumi, K., and Kira, T. 1964b. A quantitative analysis of plant form - the pipe model theory II. Further evidence of the theory and its application in forest ecology. Jap. J. Ecol. 14:133-139.

Silverman, B.W. 1984. A fast and efficient cross-validation method for smoothing parameter choice in spline regression. J. Amer. Stat. Assoc. 79:584-589.

Silverman, B.W. 1985. Some aspects of the spline smoothing approach to nonparametric regression curve fitting (with discussion). J. Royal Stat. Soc. Series B. 47:1-52.

Smith, W.R. 1990. The static geometric modeling of three-dimensional crown competition. *in* Process modeling of forest growth responses to environmental stress, (Dixon, *et al. eds*.) Timber Press, Portland, Oregon. p. 294-302.

Stiell, W.M. 1962. Crown structure in plantation red pine. Can. Dept. For. For. Res. Br. Tech. Note No. 122. 36p.

Suits, D.B., Mason, A., and Chan, L. 1978. Spline functions fitted by standard regression methods. Rev. Econ. and Stat. 6:132-139.

Terjung, W.H., and Louie, S.S.F. 1972. Potential solar radiation on plant shapes. Inter. J. Biometeor. 16:25-43.

Tombleson, J.D., Grace, J.C., and Inglis, C.S. 1990. Response of *radiata* pine branch characteristics to site and stocking. *in* New approaches to spacing and thinning in plantation forestry. (James and Tarlton, eds). New. Zeal. For. Serv. FRI Bull. 151. pp. 229-231.

USDA Forest Service. 1988. The South's fourth forest: alternatives for the future. Forest Resource Report No. 24. Washington D.C. 512p.

Valentine, H.T. 1985. Tree-growth models: derivations employing the pipe-model theory. J. Theor. Bio. 117:579-585.

Wand, M.P., and Jones, M.C. 1995. Kernel Smoothing, 1st edition. Chapman and Hall, London.

Wang, Y.P., and Jarvis, P.G. 1990a. Description and validation of an array model -- MAESTRO. Agric. For. Meteorol. 51:257-280.

Wang, Y.P., and Jarvis, P.G. 1990b. Influence of crown structural properties on PAR absorption, photosynthesis, and transpiration in Sitka spruce: an application of a model (MAESTRO). Tree Phys. 7:297-316.

Watson, G.S. 1964. Smooth regression analysis. Sankhya, Series A. 26:359-372.

Wensel, L.C., Meerschaert, W.J., and Biging, G.S. 1987. Tree height and diameter growth models for northern California conifers. Hilgardia 55:1-20.

Wickramasinghe, A. 1988. Modeling tree growth potential based on effective evapotranspiration. For. Sci. 34:864-881.

Zeide, B. 1990. Fractal geometry and forest measurements. USDA For. Serv. Gen. Tech. Rep. PNW-263. p. 260-266.

Zeide, B. 1997. Fractal analysis of foliage distribution in loblolly pine crowns. Unpublished research report. Arkansas Forest Resource Center. Monticello, Arkansas. 28p.

Zeide, B., and Gresham, C.A. 1991. Fractal dimensions of tree crowns in three loblolly pine plantations of coastal South Carolina. Can. J. For. Res. 21:1208-1212.

Zeide, B., and Pfeiffer, P. 1991. A method for estimation of fractal dimension of tree crowns. For. Sci. 37:1253-1265.

Appendix

Appendix A3.1

Consider the following example applying kernel regression with varying bandwidths to the dataset shown in Table A3.1. Bandwidths of 0.50, 0.25, and 0.10 were used. The corresponding weight matrices obtained via kernel regression are shown in Tables A3.2, A3.3, and A3.4 for bandwidths of 0.50, 0.25, and 0.10, respectively.

Table A3.1. Dataset used to illustrate changing weights with changing bandwidths in kernel regression.

	X value	Y value	$\hat{Y}(h = 0.50)$	$\hat{Y}(h = 0.25)$	$\hat{Y}(h = 0.10)$
x_1	0.000	2.11	1.828	2.065	2.110
x_2	0.245	2.22	1.557	1.910	1.980
x_3	0.285	1.70	1.500	1.854	1.940
x_4	0.588	1.04	0.998	0.864	0.930
x_5	0.711	0.43	0.804	0.577	0.517
x_6	0.857	0.29	0.612	0.341	0.274
x_7	1.000	0.00	0.467	0.191	0.033

Table A3.2. Weight matrix used to obtain a kernel regression fit to the data shown in Table A3.1 using a bandwidth=0.50.

	x_1	x_2	x_3	x_4	x_5	x_6	x_7
x_1	0.33739	0.26524	0.24405	0.08459	0.04456	0.01795	0.00617
x_2	0.18937	0.24089	0.23941	0.15054	0.10101	0.05408	0.02467
x_3	0.16857	0.23161	0.23305	0.16121	0.11245	0.06301	0.03007
x_4	0.05261	0.13113	0.14516	0.20984	0.19745	0.15734	0.10644
x_5	0.02864	0.09094	0.10464	0.20407	0.21687	0.19938	0.15541
x_6	0.01285	0.05425	0.06534	0.18119	0.22216	0.24165	0.22251
x_7	0.00539	0.03017	0.03802	0.14943	0.21111	0.27126	0.29459

Table A3.3. Weight matrix used to obtain a kernel regression fit to the data shown in Table A3.1 using a bandwidth=0.25.

	x_1	x_2	x_3	x_4	x_5	x_6	x_7
x_1	0.60241	0.23010	0.16491	0.00238	0.00018	4.82E-6	6.77E-8
x_2	0.15016	0.39313	0.38354	0.59965	0.01215	0.00099	0.00004
x_3	0.10785	0.38437	0.39398	0.09022	0.02135	0.00210	0.00011
x_4	0.00155	0.59772	0.08973	0.39187	0.30725	0.12387	0.02595
x_5	0.00011	0.01086	0.01904	0.27534	0.35117	0.25087	0.09262
x_6	2.91E-6	0.00092	0.00194	0.11464	0.25909	0.36268	0.26072
x_7	5.49E-8	5.37E-5	0.00014	0.03231	0.12870	0.35080	0.48799

Table A3.4. Weight matrix used to obtain a kernel regression fit to the data shown in Table A3.1 using a bandwidth=0.10.

	x_1	x_2	x_3	x_4	x_5	x_6	x_7
x_1	0.99726	0.00243	0.00030	9.5E-16	1.0E-22	1.4E-32	3.7E-44
x_2	0.00131	0.53781	0.46087	4.23E-6	2.0E-10	3.2E-17	9.8E-26
x_3	0.00016	0.46137	0.53841	0.00005	6.59E-9	3.4E-15	3.2E-23
x_4	7.8E-16	6.45E-6	0.00008	0.82002	0.17927	0.00061	3.50E-8
x_5	7.8E-23	2.6E-10	9.13E-9	0.16301	0.74568	0.09112	0.00018
x_6	1.1E-32	4.8E-17	5.0E-15	0.00060	0.09776	0.79999	0.10166
x_7	3.3E-44	1.6E-25	5.2E-23	3.79E-8	0.00021	0.11272	0.88706

As the bandwidth decreases in magnitude, the weights are concentrated at the respective points of prediction. Weights decrease in magnitude as one moves away from the respective points of prediction. This effect can be seen in the rows of weight matrices.

Consider prediction at x_4 . The weights used to obtain the fitted value can be found in the fourth rows of Tables A3.2, A3.3, and A3.4. With the bandwidth set to 0.50 (Table A3.2), the weight assigned to x_4 was 0.20984. The corresponding weights assigned to x_1 and x_7 were 0.05261 and 0.10644, respectively.

In comparison, examine the weights when a considerably smaller bandwidth was used. With the bandwidth set to 0.10 (Table A3.4), the weight assigned to x_4 was 0.82002. The corresponding weights assigned to x_1 and x_7 were 7.8E-16 and 3.50E-8, respectively. As one moves from a bandwidth of 0.50 to a bandwidth of 0.10, the distribution of weights across the data clearly becomes concentrated at the respective points of prediction. The weight matrix approaches the identity matrix as the bandwidth approaches 0. The weights obtained using a bandwidth=0.25 (Table A3.3) fall in between those obtained at bandwidths of 0.50 and 0.10.

Vita

Paul F. Doruska was born on February 3, 1968 in Chicago, Illinois. In 1986, he graduated from Fenwick High School, Oak Park, Illinois and enrolled at Michigan Technological University, Houghton, Michigan. He graduated Summa Cum Laude in May, 1990 with a Bachelor of Science degree in Forestry. In August, 1990, he entered the Forestry graduate program at Virginia Polytechnic Institute and State University (VPI&SU). He received a Master of Science degree in Forestry in May, 1993. After interning with Westvaco Corporation, Summerville, South Carolina, he continued his graduate studies at VPI&SU beginning a Ph.D. program in Forestry in August, 1993, and completed work for the Ph.D. degree in Forestry in June, 1998. During this time period, he left the program for two years to work as a Forest Analyst with Boise Cascade Corporation, DeRidder, LA. Upon completion of his Ph.D., he was employed as an Assistant Professor in Forestry by the School of Forest Resources at the University of Arkansas-Monticello.