To the Graduate Council:

I am submitting herewith a dissertation written by Elizabeth Ransom Smith entitled "Temporal and Spatial Variability in Tree Growth Response to Climate." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Ecology.

John C. Rennie, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Vice Provost
and Dean of The Graduate School

TEMPORAL AND SPATIAL VARIABILITY IN TREE GROWTH RESPONSE TO CLIMATE

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Elizabeth Ransom Smith

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ABSTRACT

A study was conducted using tree-ring data collected by the Tennessee Valley Authority from a system of permanent forest inventory plots. The purpose of the study was to characterize temporal and spatial variability in the growth response of four major hardwood species to climatic fluctuations, and to evaluate the role of environmental factors associated with differences in response among individuals.

Standardized series of annual radial increment for individual trees were grouped using cluster analysis. The relationship between average monthly temperature and total monthly precipitation values for the current growing season and values lagged one year was modelled using a time-variant response function. Resulting models were evaluated using graphical analysis and estimated confidence intervals for parameter values. Environmental variables associated with each core tree were determined using the permanent plot remeasurements, detailed site descriptions, and site-specific soils descriptions. Discriminant analysis and canonical discriminant analysis were used to reclassify cluster groupings of core trees using the environmental variables, and to assess which variables were most strongly correlated with important in producing differences in growth response.

Results of the dendroclimatic modelling indicated that there is a great deal of temporal variability in the climate/growth relationship for the species and sites included in this study. Only three groups out of 54 showed no variation over time in parameter coefficients. Trends in growth generally showed a decrease in

sensitivity to climate occurring in the tree-ring series. Statistical tests indicate that these trends are significantly different from random. However, a majority of the groups also showed a slight increase in sensitivity to climate in recent years. Changes in tree sensitivity do not appear to coincide with changes in climate.

Environmental factors were effective in explaining groupings of tree core series as long as interactions between variables were considered. Overall, the most important variables appeared to be relative frequency and importance value of a species, and the relative frequency and importance value of competing species. Other important environmental variables included soil depths and textures. These factors indicate that differences in growth response to climate may be a function of changes in stand structure, competitive interactions and soil moisture holding capacity.

TABLE OF CONTENTS

SECTION	PAGE
I. INTRODUCTION	1
II. LITERATURE REVIEW	3
Introduction	3
Factors Influencing Spatial Variability	4
Factors Influencing Temporal Variability	6
Analysis Techniques	10
Data Collection	12
Crossdating	13
Standardization	14
Response Function Analysis	18
Past Analyses on "Complacent" Species	24
III. METHODS	30
Selection and Description of Study Sites	30
Data Collection	37
Increment Cores and Tree Data	37
Supplementary Environmental Data	38
Increment Core Preparation and Measurement	41
Analysis	43
Standardization	46
Clustering	46
Selection of Climate Variables	48
Dendroclimatic Modelling	50
Discriminant Analysis	54
IV. RESULTS	57
Evaluation of Climate Data	57
Clustering of Tree-ring Data	57
Selection of Climate Variables	67
Tests of Model Misspecification	73
Dendroclimatic Modelling	76
Discriminant Analysis	89
V. DISCUSSION AND CONCLUSIONS	95
LITERATURE CITED	107
APPENDICES	116

SECTION PAGE

APPENDIX A -- Results of Dendroclimatic Modelling 117

APPENDIX B -- Results of Discriminant Analysis 337

APPENDIX C -- Miscellaneous 359

VITA 363

LIST OF TABLES

TABLE PAGE

1. Percent of plots disturbed by various agents at each site 33

2. Number of plots and remeasurement years for study sites 37

3. Acquisition years for aerial photography available for determining site history 40

4. Number of trees and range of ages by site and species 44

5. Common measurement period used for clustering tree-ring data 47

6. Ranking of soil textures -- fine to coarse 56

7. Cluster statistics for each species at the three study sites 62

8. Percent of plots in which all trees of one species clustered into the same group 64

9. Correlation matrix for white oak clusters, all sites 65

10. Correlation matrix for chestnut oak clusters, all sites 66

11. Correlation matrix for northern red oak clusters, all sites 67

12. Correlation matrix for yellow-poplar clusters, all sites 68

13. Rank of climate variables selected using stepwise regression, white oak clusters 69

14. Rank of climate variables selected using stepwise regression, chestnut oak clusters 70

15. Rank of climate variables selected using stepwise regression, northern red oak clusters 71

16. Rank of climate variables selected using stepwise regression, yellow-poplar clusters 72

TABLE PAGE

17. Results of model misspecification tests: modified Von Neumann ratio (MVNR), cumulative sum of prediction errors statistic (C^*), and minimum tolerance value for independent variables 74

18. Clusters which show recent increases in sensitivity to climate variables and date of apparent change in sensitivity 88

19. Error count estimates (percent) for linear discriminant functions on non-transformed data 90

A1. Climate parameter estimates for Emory River white oak, cluster 1 119

A2. Climate parameter estimates for Emory River white oak, cluster 2 123

A3. Climate parameter estimates for Emory River white oak, cluster 3 127

A4. Climate parameter estimates for Emory River white oak, cluster 4 131

A5. Climate parameter estimates for Emory River white oak, cluster 5 135

A6. Climate parameter estimates for Emory River white oak, cluster 6 139

A7. Climate parameter estimates for Emory River white oak, cluster 7 143

A8. Climate parameter estimates for Emory River white oak, cluster 8 147

A9. Climate parameter estimates for Emory River white oak, cluster 9 151

A10. Climate parameter estimates for LBL white oak, cluster 1 155

A11. Climate parameter estimates for LBL white oak, cluster 2 159

TABLE PAGE

A12. Climate parameter estimates for LBL white oak, cluster 3 163

A13. Climate parameter estimates for LBL white oak, cluster 4 167

A14. Climate parameter estimates for LBL white oak, cluster 5 171

A15. Climate parameter estimates for LBL white oak, cluster 6 175

A16. Climate parameter estimates for LBL white oak, cluster 7 179

A17. Climate parameter estimates for LBL white oak, cluster 8 184

A18. Climate parameter estimates for LBL white oak, cluster 9 188

A19. Climate parameter estimates for Wayne County white oak, cluster 1 192

A20. Climate parameter estimates for Wayne County white oak, cluster 2 196

A21. Climate parameter estimates for Wayne County white oak, cluster 3 201

A22. Climate parameter estimates for Wayne County white oak, cluster 4 205

A23. Climate parameter estimates for Wayne County white oak, cluster 5 209

A24. Climate parameter estimates for Wayne County white oak, cluster 6 213

A25. Climate parameter estimates for Emory River chestnut oak, cluster 1 217

A26. Climate parameter estimates for Emory River chestnut oak, cluster 2 221

A27. Climate parameter estimates for Emory River chestnut oak, cluster 3 225

TABLE PAGE

A28. Climate parameter estimates for Emory River chestnut oak, cluster 4 229

A29. Climate parameter estimates for Emory River chestnut oak, cluster 5 233

A30. Climate parameter estimates for Emory River chestnut oak, cluster 6 237

A31. Climate parameter estimates for Emory River chestnut oak, cluster 7 241

A32. Climate parameter estimates for LBL chestnut oak, cluster 1 245

A33. Climate parameter estimates for LBL chestnut oak, cluster 2 249

A34. Climate parameter estimates for LBL chestnut oak, cluster 3 253

A35. Climate parameter estimates for LBL chestnut oak, cluster 4 257

A36. Climate parameter estimates for Wayne County chestnut oak, cluster 1 261

A37. Climate parameter estimates for Wayne County chestnut oak, cluster 2 266

A38. Climate parameter estimates for Wayne County chestnut oak, cluster 3 270

A39. Climate parameter estimates for Emory River northern red oak, cluster 1 275

A40. Climate parameter estimates for Emory River northern red oak, cluster 2 279

A41. Climate parameter estimates for LBL northern red oak, cluster 1 283

TABLE PAGE

A42. Climate parameter estimates for LBL northern red oak, cluster 2 287

A43. Climate parameter estimates for Wayne County northern red oak, cluster 1 292

A44. Climate parameter estimates for Wayne County northern red oak, cluster 2 296

A45. Climate parameter estimates for Wayne County northern red oak, cluster 3 300

A46. Climate parameter estimates for Emory River yellow-poplar, cluster 1 304

A47. Climate parameter estimates for Emory River yellow-poplar, cluster 2 308

A48. Climate parameter estimates for Emory River yellow-poplar, cluster 3 312

A49. Climate parameter estimates for Emory River yellow-poplar, cluster 4 316

A50. Climate parameter estimates for LBL yellow-poplar, cluster 1 320

A51. Climate parameter estimates for Wayne County yellow-poplar, cluster 1 324

A52. Climate parameter estimates for Wayne County yellow-poplar, cluster 2 327

A53. Climate parameter estimates for Wayne County yellow-poplar, cluster 3 331

A54. Climate parameter estimates for Wayne County yellow-poplar, cluster 4 335

B1. Results of one-way analyses of variance, variable F values and significance levels, Emory River white oaks 338

TABLE PAGE

B2. Results of canonical discriminant analysis -- standardized canonical coefficients, Emory River white oaks 339

B3. Results of one-way analyses of variance, variable F values and significance levels, Land Between the Lakes white oaks 340

B4. Results of canonical discriminant analysis -- standardized canonical coefficients, Land Between the Lakes white oaks 341

B5. Results of one-way analyses of variance, variable F values and significance levels, Wayne County white oaks 342

B6. Results of canonical discriminant analysis -- standardized canonical coefficients, Wayne County white oaks 343

B7. Results of one-way analyses of variance, variable F values and significance levels, Emory River chestnut oaks 344

B8. Results of canonical discriminant analysis -- standardized canonical coefficients, Emory River chestnut oaks 345

B9. Results of one-way analyses of variance, variable F values and significance levels, Land Between the Lakes chestnut oaks 346

B10. Results of canonical discriminant analysis -- standardized canonical coefficients, Land Between the Lakes chestnut oaks 347

B11. Results of one-way analyses of variance, variable F values and significance levels, Wayne County chestnut oaks 348

B12. Results of canonical discriminant analysis -- standardized canonical coefficients, Wayne County chestnut oaks 349

B13. Results of one-way analyses of variance, variable F values and significance levels, Emory River northern red oaks 350

B14. Results of canonical discriminant analysis -- standardized canonical coefficients, Emory River northern red oaks 351

TABLE PAGE

B15. Results of one-way analyses of variance, variable F values and significance levels, Land Between the Lakes northern red oaks 352

B16. Results of canonical discriminant analysis -- standardized canonical coefficients, Land Between the Lakes northern red oaks 353

B17. Results of one-way analyses of variance, variable F values and significance levels, Wayne County northern red oaks 354

B18. Results of canonical discriminant analysis -- standardized canonical coefficients, Wayne County northern red oaks 355

B19. Results of one-way analyses of variance, variable F values and significance levels, Emory River yellow-poplar 356

B20. Results of canonical discriminant analysis -- standardized canonical coefficients, Emory River yellow-poplar 357

B21. Results of one-way analyses of variance, variable F values and significance levels, Wayne County yellow-poplar 358

B22. Results of canonical discriminant analysis -- standardized canonical coefficients, Wayne County yellow-poplar 359

C1. Species groups and scientific nomenclature for tree species in the Tennessee Valley region 361

LIST OF FIGURES

FIGURE PAGE

1. Map showing location of study sites 31
2. Percent of total basal area by species group for Emory River, 1987 32
3. Percent of total basal area by species group for Land Between the Lakes, 1986 34
4. Percent of total basal area by species group for Wayne County, 1987 35
5. Schematic of TVA's Continuous Forest Inventory System plot layout 36
6. Map showing National Weather Service Climatic Divisions for the state of Tennessee 42
7. Flowchart showing steps of analysis 45
8. Graphs of average monthly temperature by year, Tennessee Climatic Division 2, 1895-1986 58
9. Graphs of total monthly precipitation by year, Tennessee Climatic Division 2, 1895-1986 59
10. Graphs of average monthly temperature by year, Tennessee Climatic Division 3, 1895-1986 60
11. Graphs of total monthly precipitation by year, Tennessee Climatic Division 3, 1895-1986 61
12. Percent of Emory River clusters with June temperature coefficients that are significantly different than zero by year 81
13. Percent of Emory River clusters with past August rain coefficients that are significantly different than zero by year 81
14. Percent of Land Between the Lakes clusters with June temperature coefficients that are significantly different than zero by year 82

FIGURE PAGE

15. Percent of Land Between the Lakes clusters with past August rain coefficients that are significantly different than zero by year 82

16. Percent of Wayne County clusters with June temperature coefficients that are significantly different than zero by year 83

17. Percent of Wayne County clusters with past August rain coefficients that are significantly different than zero by year 83

18. Runs in the time sequence of deviations from the mean for June temperature coefficients by year 85

19. Runs in the time sequence of deviations from the mean for past August rain coefficients by year 87

A1. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 1 117

A2. Graph of predicted and actual standardized growth, Emory River white oak, cluster 1 117

A3. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 1 118

A4. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 2 121

A5. Graph of predicted and actual standardized growth, Emory River white oak, cluster 2 121

A6. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 2 122

A7. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 3 125

A8. Graph of predicted and actual standardized growth, Emory River white oak, cluster 3 125

A9. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 3 126

FIGURE PAGE

A10. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 4 129

A11. Graph of predicted and actual standardized growth, Emory River white oak, cluster 4 129

A12. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 4 130

A13. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 5 133

A14. Graph of predicted and actual standardized growth, Emory River white oak, cluster 5 133

A15. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 5 134

A16. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 6 137

A17. Graph of predicted and actual standardized growth, Emory River white oak, cluster 6 137

A18. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 6 138

A19. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 7 141

A20. Graph of predicted and actual standardized growth, Emory River white oak, cluster 7 141

A21. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 7 142

A22. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 8 145

A23. Graph of predicted and actual standardized growth, Emory River white oak, cluster 8 145

FIGURE PAGE

A24. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 8 146

A25. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 9 149

A26. Graph of predicted and actual standardized growth, Emory River white oak, cluster 9 149

A27. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 9 150

A28. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 1 153

A29. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 1 153

A30. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 1 154

A31. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 2 157

A32. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 2 157

A33. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 2 158

A34. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 3 161

A35. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 3 161

A36. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 3 162

A37. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 4 165

FIGURE PAGE

A38. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 4 165

A39. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 4 166

A40. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 5 169

A41. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 5 169

A42. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 5 170

A43. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 6 173

A44. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 6 173

A45. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 6 174

A46. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 7 177

A47. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 7 177

A48. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 7 178

A49. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 8 182

A50. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 8 182

A51. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 8 183

FIGURE PAGE

A52. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 9 186

A53. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 9 186

A54. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 9 187

A55. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 1 190

A56. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 1 190

A57. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 1 191

A58. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 2 194

A59. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 2 194

A60. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 2 195

A61. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 3 199

A62. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 3 199

A63. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 3 200

A64. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 4 203

A65. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 4 203

FIGURE PAGE

A66. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 4 204

A67. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 5 207

A68. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 5 207

A69. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 5 208

A70. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 6 211

A71. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 6 211

A72. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 6 212

A73. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 1 215

A74. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 1 215

A75. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 1 216

A76. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 2 219

A77. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 2 219

A78. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 2 220

A79. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 3 223

FIGURE PAGE

A80. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 3 223

A81. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 3 224

A82. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 4 227

A83. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 4 227

A84. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 4 228

A85. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 5 231

A86. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 5 231

A87. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 5 232

A88. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 6 235

A89. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 6 235

A90. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 6 236

A91. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 7 239

A92. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 7 239

A93. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 7 240

FIGURE PAGE

A94. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes chestnut oak, cluster 1 243

A95. Graph of predicted and actual standardized growth, Land Between the Lakes chestnut oak, cluster 1 243

A96. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes chestnut oak, cluster 1 244

A97. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes chestnut oak, cluster 2 247

A98. Graph of predicted and actual standardized growth, Land Between the Lakes chestnut oak, cluster 2 247

A99. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes chestnut oak, cluster 2 248

A100. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes chestnut oak, cluster 3 251

A101. Graph of predicted and actual standardized growth, Land Between the Lakes chestnut oak, cluster 3 251

A102. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes chestnut oak, cluster 3 252

A103. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes chestnut oak, cluster 4 255

A104. Graph of predicted and actual standardized growth, Land Between the Lakes chestnut oak, cluster 4 255

A105. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes chestnut oak, cluster 4 256

A106. Graph of M-parameter and associated 95% confidence interval over time, Wayne County chestnut oak, cluster 1 259

A107. Graph of predicted and actual standardized growth, Wayne County chestnut oak, cluster 1 259

A108. Three dimensional graph of changes in parameter coefficients over time, Wayne County chestnut oak, cluster 1 260

A109. Graph of M-parameter and associated 95% confidence interval over time, Wayne County chestnut oak, cluster 2 264

A110. Graph of predicted and actual standardized growth, Wayne County chestnut oak, cluster 2 264

A111. Three dimensional graph of changes in parameter coefficients over time, Wayne County chestnut oak, cluster 2 265

A112. Graph of M-parameter and associated 95% confidence interval over time, Wayne County chestnut oak, cluster 3 268

A113. Graph of predicted and actual standardized growth, Wayne County chestnut oak, cluster 3 268

A114. Three dimensional graph of changes in parameter coefficients over time, Wayne County chestnut oak, cluster 3 269

A115. Graph of M-parameter and associated 95% confidence interval over time, Emory River northern red oak, cluster 1 273

A116. Graph of predicted and actual standardized growth, Emory River northern red oak, cluster 1 273

A117. Three dimensional graph of changes in parameter coefficients over time, Emory River northern red oak, cluster 1 274

A118. Graph of M-parameter and associated 95% confidence interval over time, Emory River northern red oak, cluster 2 277

A119. Graph of predicted and actual standardized growth, Emory River northern red oak, cluster 2 277

A120. Three dimensional graph of changes in parameter coefficients over time, Emory River northern red oak, cluster 2 278

A121. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes northern red oak, cluster 1 281

FIGURE PAGE

A122. Graph of predicted and actual standardized growth, Land Between the Lakes northern red oak, cluster 1 281

A123. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes northern red oak, cluster 1 282

A124. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes northern red oak, cluster 2 285

A125. Graph of predicted and actual standardized growth, Land Between the Lakes northern red oak, cluster 2 285

A126. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes northern red oak, cluster 2 286

A127. Graph of M-parameter and associated 95% confidence interval over time, Wayne County northern red oak, cluster 1 290

A128. Graph of predicted and actual standardized growth, Wayne County northern red oak, cluster 1 290

A129. Three dimensional graph of changes in parameter coefficients over time, Wayne County northern red oak, cluster 1 291

A130. Graph of M-parameter and associated 95% confidence interval over time, Wayne County northern red oak, cluster 2 294

A131. Graph of predicted and actual standardized growth, Wayne County northern red oak, cluster 2 294

A132. Three dimensional graph of changes in parameter coefficients over time, Wayne County northern red oak, cluster 2 295

A133. Graph of M-parameter and associated 95% confidence interval over time, Wayne County northern red oak, cluster 3 298

A134. Graph of predicted and actual standardized growth, Wayne County northern red oak, cluster 3 298

A135. Three dimensional graph of changes in parameter coefficients over time, Wayne County northern red oak, cluster 3 299

A136. Graph of M-parameter and associated 95% confidence interval over time, Emory River yellow-poplar, cluster 1 302

A137. Graph of predicted and actual standardized growth, Emory River yellow-poplar, cluster 1 302

A138. Three dimensional graph of changes in parameter coefficients over time, Emory River yellow-poplar, cluster 1 303

A139. Graph of M-parameter and associated 95% confidence interval over time, Emory River yellow-poplar, cluster 2 306

A140. Graph of predicted and actual standardized growth, Emory River yellow-poplar, cluster 2 306

A141. Three dimensional graph of changes in parameter coefficients over time, Emory River yellow-poplar, cluster 2 307

A142. Graph of M-parameter and associated 95% confidence interval over time, Emory River yellow-poplar, cluster 3 310

A143. Graph of predicted and actual standardized growth, Emory River yellow-poplar, cluster 3 310

A144. Three dimensional graph of changes in parameter coefficients over time, Emory River yellow-poplar, cluster 3 311

A145. Graph of M-parameter and associated 95% confidence interval over time, Emory River yellow-poplar, cluster 4 314

A146. Graph of predicted and actual standardized growth, Emory River yellow-poplar, cluster 4 314

A147. Three dimensional graph of changes in parameter coefficients over time, Emory River yellow-poplar, cluster 4 315

A148. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes yellow-poplar, cluster 1 318

FIGURE PAGE

A149. Graph of predicted and actual standardized growth, Land Between the Lakes yellow-poplar, cluster 1 318

A150. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes yellow-poplar, cluster 1 319

A151. Graph of M-parameter and associated 95% confidence interval over time, Wayne County yellow-poplar, cluster 1 322

A152. Graph of predicted and actual standardized growth, Wayne County yellow-poplar, cluster 1 322

A153. Three dimensional graph of changes in parameter coefficients over time, Wayne County yellow-poplar, cluster 1 323

A154. Graph of M-parameter and associated 95% confidence interval over time, Wayne County yellow-poplar, cluster 2 325

A155. Graph of predicted and actual standardized growth, Wayne County yellow-poplar, cluster 2 325

A156. Three dimensional graph of changes in parameter coefficients over time, Wayne County yellow-poplar, cluster 2 326

A157. Graph of M-parameter and associated 95% confidence interval over time, Wayne County yellow-poplar, cluster 3 329

A158. Graph of predicted and actual standardized growth, Wayne County yellow-poplar, cluster 3 329

A159. Three dimensional graph of changes in parameter coefficients over time, Wayne County yellow-poplar, cluster 3 330

A160. Graph of M-parameter and associated 95% confidence interval over time, Wayne County yellow-poplar, cluster 4 333

A161. Graph of predicted and actual standardized growth, Wayne County yellow-poplar, cluster 4 333

A162. Three dimensional graph of changes in parameter coefficients over time, Wayne County yellow-poplar, cluster 4 334

I. INTRODUCTION

Tree-ring analysis to study growth dynamics in mixed species hardwood stands holds much potential; however, it is a relatively new field of endeavor. As such, no single method of data collection, manipulation and analysis has yet been accepted as the standard, resulting in a variety of different techniques and statistical assumptions to be used leading to differences in interpretations and conclusions.

Recently, application of the uniformitarian assumption to closed canopy forests has been challenged. The uniformitarian assumption was one of the mainstays of traditional dendrochronology and simply states that current conditions are analogues for past conditions. This is questionable as regards the growth relationship with climate, since trees under a closed canopy exist in a dynamic environment that has the potential to modify both temperature and precipitation patterns within the forest. Other problems related to a dynamic environment have also incited controversy, e.g. the effects of aging and competition and how they should be addressed in chronology standardization.

Spatial variability can also cause problems as tree to tree variation within a stand is sometimes extreme. Tree-ring series must be grouped by some criteria; analysis of a mean, or site, chronology can give different results from what is observed in individuals, or according to what criteria are used to group "similar" trees. Similarity of growth response is potentially a function of site homogeneity,

physical characteristics such as the age of trees and presence of other stresses, and natural differences within a species due to genetic variability. Yet, little is known about interactions among environmental factors which may be important in determining the amount and distribution of growth variation either within a species or among different species.

The primary objective of this study was to characterize temporal and spatial variability in tree growth response to climate for four major hardwood species which occur within the Tennessee Valley region. The hypothesis that environmental factors could explain differences in growth response in terms of temporal and spatial variability was tested using corollary site information and multivariate statistics. These results would hopefully allow associations to be made between certain combinations of environmental factors and "typical" growth responses under those conditions. In addition, this type of information will be useful in the design of future studies, particularly in determination of sample design and intensity.

The second objective was to develop and evaluate a methodology for analyzing large data sets of tree-ring series collected from closed canopy, mixed species hardwood forests which are typically found in the southeastern U.S. A combination of techniques were used to standardize and group tree-ring series, then to select climate variables, and perform dendroclimatic modelling. Comparisons were made between resulting models and the analysis techniques were evaluated.

II. LITERATURE REVIEW

Introduction -

Climate is often considered one of the most prominent and consistent factors affecting year to year variability in tree growth and, depending on the existence of other growth limiting factors, may be one of the most difficult to understand (Fritts 1976). In areas such as the arid southwest United States where moisture is the limiting growth factor, response to rainfall fluctuations is strong and predictable, especially at the forest - desert interface where conditions are marginal for tree survival (Fritts et al. 1965, Stahle 1987). However, moving towards more mesic sites, where moisture is less limiting, response to climate becomes less predictable due to the effects of factors such as nutrient availability and stand competition and their interactions with climate. The dynamic nature of these factors along with their inherent variability further obscures direct climatic effects resulting in a great deal of temporal and spatial variability in tree growth response. As these relationships increase in complexity from the moisture limited "sensitive" trees of the arid southwest to the "complacent" trees growing on more mesic sites, the level of detail of investigation of other factors and the sophistication of analytical techniques must also increase if tree growth response to climate is to be understood.

Factors Influencing Spatial Variability -

Differences in site requirements for different species are well documented (e.g. see Fowells 1965, Eyre 1980) and readily apparent through comparison of species which prefer cool, moist sites such as *Picea rubens* to species which are more adapted to droughty conditions such as *Pinus taeda*. Climate is considered a range limiter due to its effect on site and, in arid areas of the southwest, climate does appear to be important in delineating a species' range (Cook and Cole, in prep.). Exceptions to strict climatic limitations in other areas indicate that factors other than climate may be influencing species establishment (Cook and Cole, in prep., Kavanagh and Kellman 1986, Rogers 1978). Examples would include microsite modification due to soil conditions and physiography. Unfavorable climate is an effective barrier to plant migration only when all the habitats within a region lie beyond the ecological amplitude of a species (Kozlowski 1979).

Several studies in areas that are not moisture limited have found that precipitation contributes little to explaining variations in annual tree growth (Cook and Cole, in prep., McLaughlin et al. 1987, Bartlein et al. 1986). One reason for this is that precipitation does not necessarily reflect moisture availability; this is more a function of soil physical properties (Pritchett and Fisher 1987, Zahner 1955). When the influence of soil factors is taken into account in predicting moisture stress, unexplained variability in growth response is reduced. Bassett (1964) calculated indices of soil moisture availability and found that they explained 95-97% of the variation in diameter growth in southern pines. Similar results were obtained

by Arp and Manasc (1987); the availability of soil water appeared to be the principal factor in relating a tree growth index to year by year climate variations. The Palmer Drought Severity Index, an index which reflects potential evapotranspiration in addition to soil water availability, has been used successfully to model climatic influences by Zahner (1987). Kim and Siccama (1986) constructed new climate variables that incorporated simulated soil moisture content. They found that these new variables outperformed the conventional variables of monthly means by climatic division and explained roughly 80% of the variation in growth of northern hardwood species.

Stand history may play an important part in spatial variations of growth response and in species distribution (Dale and Doyle 1987). Rogers (1978) found that the northern range limit of *Tsuga canadensis* is not temperature dependent. He suggested that the general preference of this species for westerly and northerly slopes was due to the effects of disturbance as expressed through modifications of soil properties on sites occupied by man. Clearing land for agriculture typically reduces soil productivity through destruction of soil physical structure and nutrient depletion from timber harvest and erosion (Carmean et al. 1976).

Localized fluctuations in climate are not reflected in the data that are typically available. The effects of topography may produce marked variations in intensity and duration of insolation (Daubenmire 1974) and precipitation (Cook and Cole, in prep.). Crown density may also influence the effect of climate on

individual tree growth (Haines and Cleveland 1981), as wind, relative humidity, soil moisture and temperature vary with a reduction in irradiance (Daubenmire 1974).

Degree and type (in terms of species composition) of competition may affect tree response to climate. As competition within a stand increases, all trees become more susceptible to stresses as one or more resources become limiting. Although competition was not actually demonstrated, Doyle (1983) concluded that competition among trees was much more pronounced in years of drought. In addition, species composition seemed to relate to competitive relations. White oak trees (*Quercus alba*) in the company of yellow-poplar (*Liriodendron tulipifera*) suffered less competitive effects than those in the presence of other white oaks. In contrast, yellow-poplar performed better in the company of other yellow-poplars than with white oak. Competitive ability differs by species and therefore differing species mixes exhibit varying degrees of climate-competition interaction.

Factors Influencing Temporal Variability -

As moisture becomes less limiting, other growth limiting factors increase in relative importance, particularly in that stress due to some other factor may predispose a tree to injury attributable to climate. Ermich et al. (1976) suggested that degree of variability among tree-ring chronologies within a stand may be used to evaluate site quality. They justified this idea by claiming that trees growing on poorer sites are less resistant to unfavorable climatic and biotic factors, therefore disturbances on these poorer sites are much more conspicuous and not uniformly

distributed. Site quality changes over time as a result of the natural aging processes of ecosystems as well as stochastic events which cause significant disturbances. These changes bring about both abrupt and gradual changes in soil properties and species composition before a constant vegetation composition associated with a mature soil is reached (Pritchett and Fisher 1987). Over the life of a forest stand, changes occur in 1) soil physical and chemical properties as well as soil biota; 2) the physiology of individual trees and their sensitivity to stresses; and 3) stand structure and competition among trees. In addition, site qualities which remain static may also induce variability through the timing of tree response as modified by its microsite.

Whittaker and Woodwell (1972) documented progressive soil development as forest stands mature. Typical changes in soil properties which provided improved growing conditions include increasing soil depth, accumulation of organic material and horizon differentiation. Carmean et al. (1976) found that soil conditions on abandoned agricultural lands improved after many years of tree cover. The degree of improvement was dependent on species composition. Comparing changes in soil characteristics on four sites, they found increased nutrient content on tree covered sites and significant differences in surface soil non-capillary pore volume, bulk density and organic material. This resulted in soils which had improved aeration, more favorable temperature relations, improved root respiration, reduced mechanical resistance to root extension and increased availability of nutrients and moisture. Changes in soil mycorrhizae populations also occur over time; as very

poor soils improve, mycorrhizal populations increase (Carmean et al. 1976, Grigal in prep.). However, mycorrhizae are usually less effective in fertile soils.

In old growth forests, improvement in soil conditions is discontinued and productivity may decline. Increased amounts of organic material coupled with decreased rates of decomposition and mineralization may result in limitations in available nutrients as they are tied up in the litter layer (Arp and Manasc 1987). Pastor et al. (1987) suggest that growth declines observed in red spruce in the northeastern United States may be a natural phenomenon related to carbon-nitrogen linkages which produce alternating sequences of dominance by early to late successional species.

Increased shading accompanying stand development modifies climatic effects and slows rates of decomposition through decreased soil temperatures (Haines and Cleveland 1981). Daubenmire (1974) states that one of the most detrimental aspects of a shade environment is the potential nitrogen deficiency brought about by a slow rate of decay. Alternatively, increased canopy density and numbers of trees may have beneficial effects in winter by reducing wind and fluctuations in temperature within the stand.

Increased competition occurs as individual trees grow and require increased resources for maintenance and as new trees become established within a stand. This may cause reductions in nutrients and moisture availability resulting in a decrease in growth rate. Hornbeck et al. (1986) suggest that this is what is happening in red spruce stands in the northeast. Van Deusen (1988) compared

growth in second growth red spruce stands with growth in old growth stands and found a decline in rate of growth only in the second growth. He concluded that the change in growth was due to competitive pressures which are a natural function of stand dynamics.

The extent to which climatic stress affects trees often depends on the phenological stage and the physiological status of the tree at the time of the stress (Kozlowski 1979). Individual trees may become less sensitive to detrimental climatic effects as they age. Juvenile trees are known to be less frost hardy than mature trees (Boyce 1961), and large, deep-rooted trees show less tendency towards drought stress than newly established trees (Waring and Cleary 1967). Timing and intensity of temperature or moisture stress figure prominently in the tree's response (Kim and Siccama 1987, Daubenmire 1974). Generally if temperature extremes occur as a gradual trend, the tree is able to adapt and shows no injury as a result of the extreme temperature. Otherwise, degree of tree response to climatic stress may be reflected in increases in lag response (Kozlowski 1979). Increased lag responses may also indicate a secondary injury following an earlier one, such as a combination of temperature and moisture stress. At sites where extreme climatic fluctuations occur regularly, trees have often become preconditioned to these stresses. If timed correctly, environmental preconditioning can carry through to influence tree behavior in the later stages of development (Kozlowski 1979). Sensitive periods for preconditioning seem to be at the initiation and formation of buds and seeds as well as the time when growth resumes after a dormant stage.

Significant microsite differences may occur as frequently as from tree to tree within a stand. Differences in soil characteristics may result in profound differences in how a tree responds to climate and thus increase overall variation due to a non-homogeneous growing environment. Duration and magnitude of growth response may be influenced by microsite in several ways. For example, root injury due to low temperatures is more pronounced in coarse than in fine-textured soils and light soils tend to warm up faster than heavy soils (Daubenmire 1974). The physiological state of trees on better sites may be different from those on poorer sites. Increases in resource availability result in enhanced growth early in a tree's life but it has been shown that trees on better sites either reach senescence earlier or use the available nutrients faster (Robichaud and Methven 1988). A tree growing in a better soil than its neighbor may therefore withstand late spring freezes easily, yet begin declining in growth earlier in its life. Heterogeneity of site conditions within the forest stand will result in heterogeneity in response to climate.

Analysis Techniques -

The discussion below generally follows the evolution of tree-ring analysis in all of its applications. "Dendrochronology" was initially developed to date archeological sites. This application relied heavily on the technique of matching patterns of wide and narrow rings, known as crossdating. Climatic modelling followed, utilizing trees that were climate sensitive to obtain insight into past climatic fluctuations. This use came to be known as "dendroclimatology" and

involved fairly simple standardization techniques and analyses based on ordinary least squares regression.

More recently, interest has developed in reconstructing tree growth trends to better understand ecological interactions and the effects of environmental stresses on forest productivity. This is sometimes called "dendroecology" and often involves less climate-sensitive trees whose growth is influenced by many factors in addition to climate. Because these factors are operating simultaneously, much of the recent work has been concerned with developing techniques that will allow separation of the effects of the different factors.

The *linear aggregate model* (Graybill 1982; Cook 1985) is often used as a starting point to describe the association of environmental factors that contribute to a tree's annual increment. With the observed ring width in year t represented by R_t, we have:

$$R_t = G_t + C_t + \delta D1_t + \delta D2_t + \delta P_t + E_t ,$$

where G_t is the natural growth trend associated with increasing tree age and size; C_t is the climate-related growth variation; $D1_t$ is the variation due to endogenous disturbances; $D2_t$ is the variation due to exogenous disturbances, other than pollution; P_t is the variation due to anthropogenic pollutants, affecting a whole stand; and E_t is a random component, unique to each tree.

Endogenous disturbances are localized, affecting a single tree or subset of trees in a stand. Exogenous disturbances affect the whole stand. Pollution, an exogenous disturbance, is considered separately in this model. The δ associated with the $D1_t$, $D2_t$, and P_t is a binary indicator of presence ($\delta = 1$) or absence ($\delta = 0$) of the component.

Data Collection -

Early dendrochronological studies sampled trees to establish historical climate trends; thus, selection of individuals was based on the expected strength of the climatic response rather than how the individual tree represented the population of trees (Fritts 1976). Typically, the oldest individuals were selected from sites where other growth limiting factors were at a minimum; this resulted in chronologies taken from open-grown trees occurring on moisture stressed sites, which would be considered atypical of the norm. Many later studies designed to assess growth trends under varying environmental conditions also employed a rather biased sampling strategy to obtain the longest possible growth record and minimal confounding with natural stand dynamics. These dendroecological studies concentrated on the largest dominant or codominant trees in the stand (Groton and Eagar 1988; McLaughlin et al. 1985); they often selected only trees that appeared to be healthy and growing vigorously to avoid declining trees that might be approaching death and to present a conservative estimate of what was a potentially alarming observed decline in stand productivity (Johnson and Siccama 1984). Again,

these studies were limited in their representativeness of the population under investigation, presenting a potentially biased picture of growth dynamics if extrapolated outside the characteristics of the sample.

Crossdating -

All types of tree-ring analysis, from archeological dating to climatic modelling, are based on the assumption that a particular ring increment is associated with a known year (Fritts 1976). Crossdating itself is based on the assumption that trees at one site tend to respond similarly to climatic fluctuations, e.g. a year with favorable climate produces a wide annual ring relative to a stressful year which produces a narrow tree ring. This is determined by comparing several tree-ring series of the same species and determining the location or date of "signal years" where the increment is relatively large or small as compared to other rings. Once the dates of these signal years are fairly well established, they are used to identify similar patterns in other samples. However, the dating process can be complicated by the presence of false rings or the absence of rings due to climatic anomalies, or stresses such as defoliation followed by refoliation. Dating of rings is further complicated if the series tends to exhibit autocorrelation, where a response to a particular climatic event continues for more than one year, or the physiological condition in one year preconditions the tree's response for following years.

Several automated systems which rely on cross-correlations have been developed; these may be used to check crossdating (Holmes 1983; Munro 1984;

Van Deusen 1989). However, these systems should not be relied on to perform the actual dating because recognition of patterns of wide and narrow rings by a trained dendrochronologist is acknowledged as the best method of crossdating (Wigely et al. 1987). In these automated systems, autocorrelation can cause problems with cross-correlations since it can introduce spurious correlation leading to erroneous inferences (Monserud 1986; Yamaguchi 1986). This problem can be addressed by first removing any autocorrelation *(prewhitening)* from the tree ring series if the dating of signal years varies in the sample or is otherwise questionable.

Standardization -

It is a well established fact that as trees get larger, their annual radial increment tends to get smaller. If a tree produces an equal amount of wood every year, it is spread over an ever-increasing base resulting in narrower rings. Effective standardization removes this natural growth trend and results in an index series that maintains signals due to climate and possibly some endogenous and exogenous disturbances (according to the objectives of the analysis). Standardization of tree-rings is typically accomplished by fitting a suitable growth curve to the annual tree core measurements or the tree-ring *series*. The series is then divided by the predicted growth to obtain the tree-ring indices used in further analyses:

$$g_{it} = y_{it} / \hat{y}_{it} ,$$

where g_{it} is the standardized index of fluctuations in growth that are associated with climatic fluctuations. The growth functions most commonly used to standardize series from sensitive sites include a simple linear (m = 1) or polynomial function in age:

$$y_{it} = b_0 + b_1 t + b_2 t^2 + \ldots b_m t^m + \epsilon_{it} ,$$

or a negative exponential function of age:

$$y_{it} = b_0 + b_1 e^{-at} + \epsilon_{it} ,$$

where y_{it} is the raw ring width for the ith core in year t; a, b_0, b_1, ... b_m are parameters determined by the sample data and ϵ_{it} is the error term (Fritts 1976).

In complacent species, competition effects may also be considered a function of time or stand age and are therefore confounded with the natural growth trend. Standardization techniques developed for these trees often attempt to simultaneously remove the effect of competition and the effect of the growth trend. Since competition can produce systematic deviations from the age-related growth trend, use of the linear or negative exponential function in the standardization may not be appropriate. Additionally, the effects of endogenous or exogenous disturbances can frequently cause long-term departures from the overall growth trend; removal of these effects may be desirable.

The use of cubic smoothing spline functions has been suggested as a suitable alternative for determining the expected growth trend under the conditions of increasing stand density and periodic disturbances (Cook and Peters 1981; Blasing, Duvick, and Cook 1983; and Cook 1985). Similar to a digital filter in that removal of variance occurring at a certain frequency may be specified, cubic splines consist of a succession of cubic polynomial curves which are fitted to the data in one pass. A potential problem is the arbitrary nature of determining how much variation to remove; too much smoothing may inadvertently remove part of the response to another factor; too little may allow the effects of competition or the growth trend to remain and may thus bias the resulting interpretation.

Other functions have been suggested to model the growth trend under these circumstances. Holmes (1986) developed a "double detrending" methodology that utilizes a linear or negative exponential model to remove the growth trend, then applies a spline function to the residuals to remove competitive effects. An asymptotic model of growth was suggested by Van Deusen (1987b, 1988):

$$D_{it} = b_0 \, (1 - e^{-\alpha t}) \, ,$$

where D_{it} is the diameter (cumulative ring width) for the ith core in year t. This model is most appropriate for young trees or recently released trees in the case of tolerant species as the initial portion of the growth curve reflects rapid growth followed by a leveling off that is effected as the stand canopy closes.

Standardization using first differences of the logarithms of raw ring width data has been suggested as appropriate to trees grown under any circumstances, including those that do not exhibit an initial period of rapid growth as might be observed in shade tolerant species (Van Deusen 1987a) Beginning with a model described by May (1976) that is similar to models used in tree ring analysis:

$$y_{t+1} = y_t exp[b(1-y_t)],$$

Van Deusen takes the natural logarithm of both sides of the model, rearranges and adds an intercept, resulting in:

$$ln(y_{t+1}) - ln(y_t) = a + b\ (1-y_t),$$

which suggests using the first differences of logarithms (Van Deusen, in review). This method of standardization accounts for some portion of the autocorrelation often present in tree-ring series through the term $(1-y_t)$ and tends to accentuate year to year variations rather than long-term trends. Since the use of logarithms puts the ring widths on a relative scale, Van Deusen (1987a) notes that the first difference of the logarithms is a numerical first derivative of relative growth, or a relative growth rate. In practice the standardization is accomplished using:

$$w_t = z_t - z_{t-1},$$

where w_t is the standardized growth increment at time t, and z_t is the logarithm of the annual radial ring increment for year t. First differences are widely used in time series modelling to standardize a series so that it remains stationary through time by removing increasing or decreasing trends (Pankratz 1983).

Response Function Analysis -

Once the data are satisfactorily standardized, dendroclimatic modelling can proceed. Typically this involves estimation of the variance of growth due to climate, free from the natural growth trend and endogenous and exogenous disturbances. Further analysis of residuals may indicate the influences of pollutants or other environmental stress. The first step is to group series into a site *chronology*, computed as a simple mean of the individual samples or preferably a biweight mean (Mosteller and Tukey 1977) to adjust for the influence of outliers. Obviously the formation of a site chronology by averaging individual standardized series may be questioned. Use of mean chronologies has been justified as a way to reduce non-climatic sources of variation (Graybill 1982) and highlight the climatic signal. However if the goals of the tree ring analysis are other than to model past climate (i.e. to determine if possible changes are occurring as a result of anthropogenic stress or to refine tree growth models), this technique may produce an oversimplification of the data. Additionally, if the spatial variability of the tree-ring series is pronounced, averaging over a large sample of cores may not improve

the amount of variation accounted for by the resulting dendroclimatic model (Peters, Jacoby and Cook 1981).

Recognition of this problem often leads to the grouping of tree-ring series based on some arbitrarily determined stratification based on the investigator's familiarity with the ecosystem and factors that influence differences in tree growth (Cook et al. 1987; McLaughlin et al. 1985). Multivariate methods have been used to a limited extent to determine groupings of tree ring series. Principal component analysis (PCA) has been suggested as a means of analyzing site heterogeneity and thus providing a method of grouping similar series (Peters, Jacoby, and Cook 1981; Enright 1984). This technique is intuitively suitable, since it maximizes the variance among series and produces groupings of data organized according to factors which are orthogonal (the principal components). PCA is applied to standardized series, and eigenvectors and amplitudes are computed. Examination of the loadings on the first eigenvector are used as an indication of site heterogeneity and series are typically grouped according to patterns of similar loadings. Separate climatic models produced for grouped series have shown improved fit with the climatic data over non-grouped series.

Dendroclimatic modelling as developed in climate sensitive areas typically relies on multiple regression techniques incorporating available climate variables:

$$\tau_t = L(\Omega_t, \beta) + \epsilon_t,$$

where L is a linear operator, Ω_t is the set of climate variables (usually monthly means of temperature and monthly totals of rainfall) for year t, and β is the set of model coefficients. Climate variables are usually selected based on their significance levels as determined using stepwise regression (Fritts 1962). Model verification is done to test the time-stability of resulting models (Cook, Johnson, and Blasing 1987). The technique involves model development using only a portion of the tree chronology (the calibration data set), then comparison with the remaining portion of the same chronology (the verification data set). However, use of the ordinary least squares (OLS) approach assumes that variation between variables remains constant, an assumption that may not apply to series that contain time-dependent autocorrelation, or non-independent error terms, or that are periodically influenced by factors other than climate. Other methods of verification involve the replication of model formulation on independent data sets.

Principal components analysis has also been used to reduce the number of climatic variables and the problems of multicollinearity. This technique of response function analysis incorporates climate factors that are linear combinations of different climate variables and are orthogonal (Fritts et al. 1971). Although widely applied today as a "standard" analysis technique, response function analysis requires several *a priori* decisions about appropriate climate variables to include, and *a posteriori* interpretations of resultant models that may be open to criticism (Blasing et al. 1984).

Concerns about autocorrelation in tree ring series and the potential for non-independent errors arising from correlations between time periods first prompted the use of lagged climate variables or mean indices from the previous one to three years in fitting the response function (Fritts 1962; Shulman and Bryson 1963; Jonsson 1969; Gove and Fairweather 1988). Time series analysis using Box-Jenkins methodology has recently been proposed by a number of investigators (Rose 1983; Cook 1985, 1987; Monserud 1986, 1987). In this type of procedure, autoregressive, moving average (ARMA) models are used to *prewhiten* a standardized mean chronology prior to fitting the response function.

Cook's ARSTAN (AutoRegressive Standardization) program (1985) is an attempt to separate a closed canopy tree ring chronology into climatic, age-related, endogenous disturbance, exogenous disturbance, and error components as described in the *linear aggregate model.* The user chooses a method of standardization from a list of growth trend options including: linear, negative exponential, or spline functions in addition to Holmes' "double detrending" option offered as the default. A multiple time series procedure is then used to estimate a pooled autoregressive (AR) model and separate AR models are then fit to each index series. The residuals are averaged to form a *mean value function* and the pooled AR model is added back to this function to account for *lost persistence* resulting in the "ARSTAN chronology".

The Kalman filter (Kalman 1960) has also been proposed to address problems arising from nonindependence (Van Deusen 1987, 1988; Visser 1986;

Visser and Molenaar 1987, 1988). A time-variant response function, the Kalman filter is explained in state space terminology as a reformulation of any linear model. The formulation used by Van Deusen is a generalization of an ordinary regression equation that allows for dynamic parameters. The system consists of the observation equation:

$$Y_t = X_t\beta_{t-1} + v_t ,$$

and the transition equation for the time varying parameter vector:

$$\beta_t = \beta_{t-1} + w_t ,$$

where Y_t is an estimate of the average ring width, X_t is a known matrix containing climate variables, and v_t and w_t are error vectors. The covariance matrices for the measurement and transition equation error terms must be specified and may also be time variant. Van Deusen assumes that v_t is distributed with mean zero independently of previous v_t's and of the transition error vector, w_t, which is also independent of past values and normally distributed with zero mean. The variances are specified as:

$$V_t = E[v_t v_t'] = \sigma_t^2 q_v , \text{ and}$$

$$W_t = E[w_t w_t'] = \sigma_t^2 \, DIAG[q_1,...,q_p].$$

Using the among tree variance in the standardized data, σ_t^2 is estimated as:

$$\hat{\sigma}_t^2 = [\Sigma_i (y_{it} - Y_t)^2]/[n_t(n_t - 1)],$$

where y_{it} is the ring width of the ith tree at time t, Y_t is the mean ring width for time t, and n_t is the number of trees at time t. The variance is allowed to change over time by including σ_t^2 to reflect among tree variance and to accommodate sample depth changing over time. The method of maximum likelihood is used to estimate the unknown q-parameters (Van Deusen and Koretz 1988).

Potential problems of illogical and uninterpretable results arising from multicollinearity among climate variables and the very large number of candidate independent variables are discussed by Meko (1981) and Arbaugh and Peterson (1989). Results of simulations imply that climatic regression models may be incorrectly specified when large portions of unexplained variability are present (Arbaugh and Peterson 1989). These issues indicate that great care must be taken in the development of dendroclimatic models. Tests for the presence of multicollinearity, attempts to reduce variation attributable to differences in site, and tests of model validity or misspecification, should each be an integral part of model development.

Past Analyses on "Complacent" Species -

Several studies of species growing in closed canopy stands on relatively mesic sites have attempted to characterize the climate/growth relationship and gain a better understanding of the ecology of the species (e.g. Fritts 1962, 1966). Estes (1970) observed black oak, white oak, and shortleaf pine growth in the central Mississippi Valley. Using an exponential or linear function to standardize the series followed by a bivariate frequency distribution to determine correlations with precipitation, he found that white oak responded to June and July precipitation. He also noted that within any species, the degree of similarity among individual tree chronologies decreased as the amount of site disturbance increased. Major changes in soil types influenced the number of narrow rings found in a series indicating variability in sensitivity to periods of low rainfall. More specifically, the growth of oaks was more variable and less influenced by climate conditions on cherty soils than on clay or loess.

Cook and Cole (in prep.) examined spatial structure in eastern hemlock response to climate by analyzing cores from the northeastern and Great Lakes region of the United States and eastern Canada. Using principal components analysis to group chronologies, they found that the series partitioned into six geographic clusters. Following dendroclimatic modelling they concluded that the differences among these six spatial patterns of rings was due to the regionality of climate rather than differences in tree response.

Episodes of high levels of oak decline and mortality have often prompted investigations into the possibility of drought-induced stress in hardwood forests. Following a severe drought in 1925 in the southern Appalachians, Hursh and Haasis (1931) observed that black oak, red oak and scarlet oak suffered the most decline and mortality relative to other species. Analysis of radial increment revealed that those trees that recovered showed little or no reduction in growth while those that died in the four years subsequent to the drought showed a definite reduction. Hursh and Haasis also concluded that unfavorable seasonal conditions reduced individual tree vigor and increased susceptibility to disease and insect damage.

Staley (1965) studied declining and dying red and scarlet oaks in Pennsylvania and found that they were affected by defoliation, root rot, late spring frost and drought. He found a relationship between annual increment and July through September precipitation of the previous year for scarlet oak. He also noted that dry periods with less intense rainfall events favored populations of defoliating insects such as the oak leaf roller.

Tainter et al. (1984) examined an unusually high incidence of northern red oak decline and death that occurred in the Nantahala National Forest of North Carolina and suggested that it was a result of stress initiated in 1963 by lower than normal February temperatures and a subsequent series of dry summers beginning in 1969 and worsening from 1973 to 1978. This caused irreversible damage to some trees on upper slopes while little decline was noted among survivors. Tree-

ring series from declining trees were standardized using best fit regression, and the climate relationship was analyzed using simple and multiple regression. Results of the dendroclimatic modelling indicated that temperature and precipitation for the previous July was positively correlated with growth, temperature for the previous August was negatively correlated, and May temperature and July precipitation of the current year were positively correlated.

Much of the recent work in tree-ring analysis was initiated to quantify trends in tree growth to evaluate the hypothesis that recently observed changes in tree growth and increases in mortality might be attributable to atmospheric deposition. One of the most significant studies in this area was the FORAST (Forest Response to Anthropogenic Stress) project (McLaughlin et al. 1985). This study considered tree-ring series collected from seventy sites located in the eastern U.S. under various forest cover types including mixed hardwood, spruce-fir, and hardwood-pine forests. Cores were collected from over 7000 dominant and codominant trees along with supplementary stand information. The tree-ring series were standardized using a cubic spline, grouped according to sample location, and analyzed with response function analysis using orthogonal climatic factors derived from a PCA. There was a great deal of variation among species in their relationships to the climatic factors. For example, McLaughlin et al. (1985) found that yellow-poplar was the species most sensitive to climate with an average of 39 percent of the variation in growth attributable to the climate factors. Progressively less sensitivity to climate was found for in white oak (35% variation explained), black oak (35%), hemlock (26%), red

oak (25%), shortleaf pine (21%), pitch pine (20%), and red spruce (15%). White oak, red oak and red spruce also differed in the variables selected for climate model development according to the different groupings of series.

After the climatic effect was removed, extensive residual analysis was performed to characterize the observed patterns of tree growth. The FORAST study concluded that four species (red spruce, Fraser fir, shortleaf pine, and pitch pine) exhibited a widespread and abrupt shift in growth throughout the Appalachian region around 1960. Other species in the region showed a slower shift in growth that became more pronounced in the last ten years, was more pronounced in softwoods than hardwoods and also was more apparent at the higher elevation sites. Many possible causes for these changes were cited including shifts in climate, natural disturbances, and stand dynamics. However correlations with changing patterns of atmospheric pollution over time and space were considered indicative of the importance of this factor to the changes in growth that were observed.

McClenahan and Dochinger (1985) obtained white oak cores near the Ohio River Valley according to a presumed pollution gradient. Using stepwise regression and orthogonally transformed climate factors, they found that only tree-ring series from trees closest to the pollution source showed non-climatic influences throughout the series. Additionally, they found that trees from all locations in the period of 1950 through 1966 showed non-climatic influences and from this inferred a possible regional effect of atmospheric pollution. Phipps and Whiton (1987) studied white oak cores collected throughout much of its range from Connecticut, to North

Carolina, and to Iowa. They converted the radial ring widths to basal area increment and standardized using a cubic spline. A linear regression of climate factors was developed from the pre-1950 portion of the data and extended to the post-1950 period. They found an abrupt, non-reversed decline in growth that occurred in the 50s that was not synchronous from tree to tree and that was not related to temperature or precipitation. Again, this observed decline was inferred to be resulting from some regionally occurring environmental stress such as air pollution.

Other studies have also used tree-ring analysis to suggest a possible relationship between atmospheric pollutants and current patterns of tree growth. Puckett (1982) studied annual increment in white pine, eastern hemlock, pitch pine, and chestnut oak in southeastern New York. He found that an apparent shift in growth trend beginning about 1954 suggested a change in the relationship of tree growth to climate. As no changes in temperature or precipitation were evidenced for this period, plus the fact that the shift in growth trend corresponded to an increase in air pollution at that time, Puckett concluded that the change could be a result of physiological stress induced by components of the acid rain-air pollution complex, causing climatic conditions to be more limiting to tree growth.

Much of the work done to investigate the possible role of atmospheric pollution on tree growth has centered on red spruce in the northeast (Siccama et al. 1982; Johnson and Siccama 1984) and in the southern Appalachians (McLaughlin et al. 1985; Van Deusen 1988). In contrast to the studies which implicate air

pollution in the tree growth decline, other studies have related similar changes in tree growth to natural stand dynamics or stand structure. Federer and Hornbeck (1987) related changes in growth for red spruce at low elevations in the northeast to stand table projections developed for managed, even-aged stands. Their argument was that heavy harvesting that occurred in the early part of this century produced residual stands that took on the characteristics of even-aged stands. Van Deusen (1989) found that the degree of decline in these same stands was related to the number of second growth trees that made up the stand.

Alternatively, episodes of winter damage have been implicated as an important initiating and synchronizing factor in the red spruce decline in the northeast (Johnson et al. 1988). Cook et al. (1987) found an association between ring widths and departures from mean summer and winter temperatures that coincided with past and present periods of decline. They conceded however, that the decline initiated in the late 50s in the northeast may have been aggravated by pollution stress.

III. METHODS

In 1986 the Tennessee Valley Authority initiated a study to assess factors contributing to forest condition with regard to the possible impact of atmospheric deposition. The research described here utilizes data collected in that study.

Selection and Description of Study Sites -

The TVA study was designed to determine growth trends in uneven-aged, mixed species, second growth natural hardwood stands occurring in the Tennessee Valley region and was built on an existing framework of permanent forest inventory plots. Since the objectives of the study were to determine the effects of natural factors on growth, plots were selected to represent a variety of sites and stocking levels. Three study sites (figure 1) were selected based on geographic distribution, spatial distribution of plots, and number of remeasurements; they are considered representative of the forests of the Tennessee Valley region.

The Emory River Land Company is a 36,520 acre (14,770 ha) private land ownership located in Morgan County in northeast Tennessee. Permanent inventory plots were first established in 1964; prior remeasurements were done in 1974 and 1984. Initial sampling intensity was 1 plot for every 207 acres. Soils are predominantly moderately deep, loamy, and stony soils derived from sandstone and shale (Springer and Elder 1980). Of the three study sites, Emory River has the greatest topographic relief, with elevations ranging from 1060 feet (323 m) to 3140 feet (957 m) above sea level. Climate data averaged over the climatic division

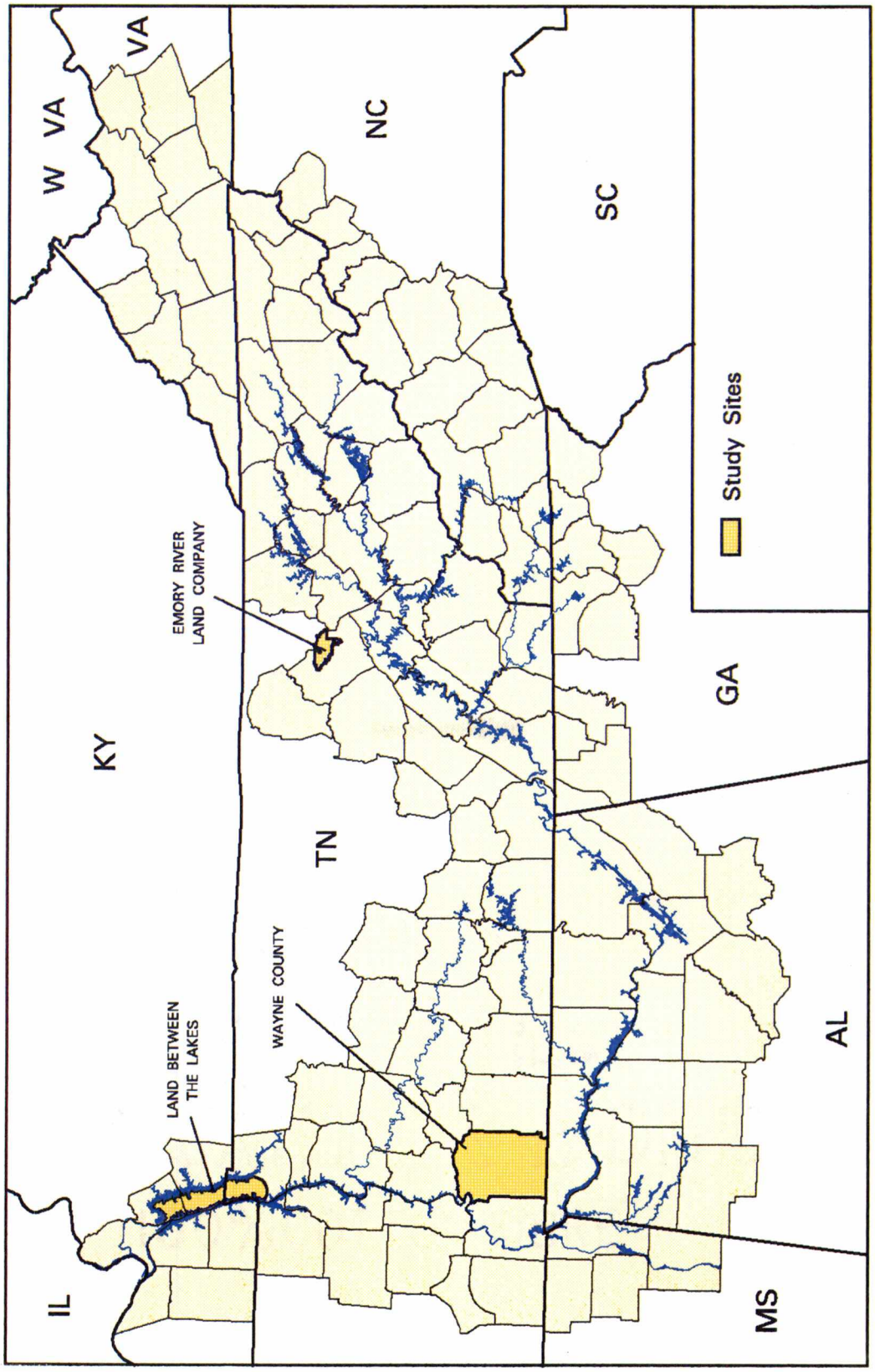


Figure 1. Map showing location of study sites.

indicate that rainfall averages 55.05 inches annually, and the mean annual temperature is 56.4° F. Plot data indicate that species composition is primarily the white oak group (30.5% of the basal area per acre) and soft hardwoods (28.2%) (figure 2) (see table C1, Appendix C for species included in species groupings). Periodic inventories on these plots indicate that over the last 23 years, little change has occurred in species composition; there has been a slight decrease in the proportions of white oaks and yellow pines, and an increase in the soft hardwoods group. Disturbance at the Emory River study site has been primarily due to fire and logging (table 1).

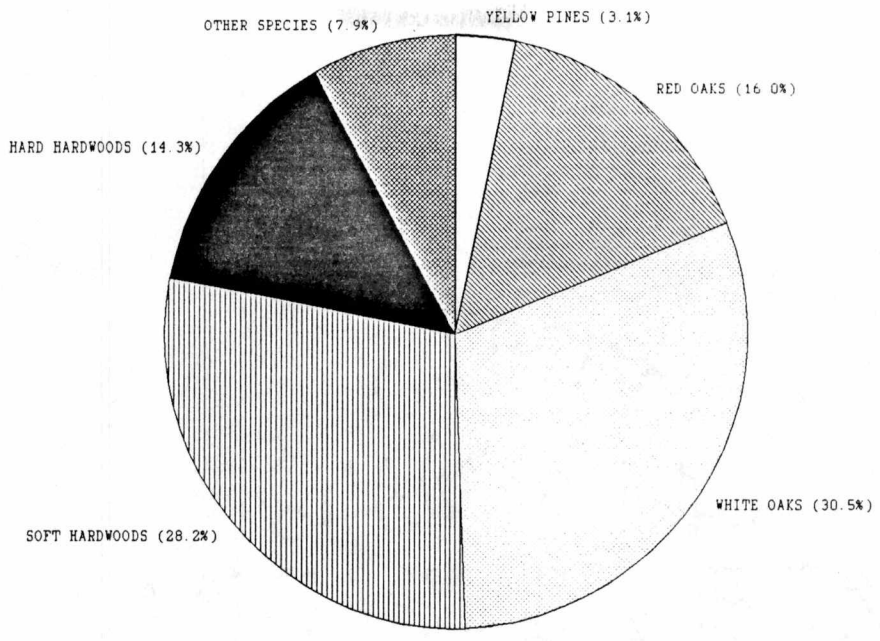


Figure 2. Percent of total basal area by species group for Emory River, 1987.

Table 1. Percent of plots disturbed by various agents at each site.

Site	Fire	Grazing	Disease	Logging	Other*
Emory River	76%	0	53%	72%	33%
LBL	5%	0	24%	58%	52%
Wayne County	32%	6%	44%	79%	59%

*Other includes the effects of mining, insects and weather.

The "Land Between The Lakes" (LBL) is a 170,000 acre (68,797 ha) national demonstration area managed by TVA and located in northwest Tennessee and southwest Kentucky. Permanent inventory plots were established in 1966 at a sample intensity of one plot for every 1033 acres; remeasurements have taken place at 10 year intervals, in 1976 and 1986. Soils are cherty and clayey, derived from limestone and well-drained silty soils derived from thin loess. Climatic division data indicate that the western portion of the state is both hotter and drier than east Tennessee. Average annual rainfall equals about 52.37" and average temperature equals 58.33° F. Species composition for the plots included at the LBL site is largely white oaks (45.3%), followed by red oaks (23.6%) (figure 3). Over the last 21 years, the inventory data indicate a decrease in the proportion of red oaks and increases in white oaks and yellow pines. The greatest amount of disturbance at LBL is attributable to logging.

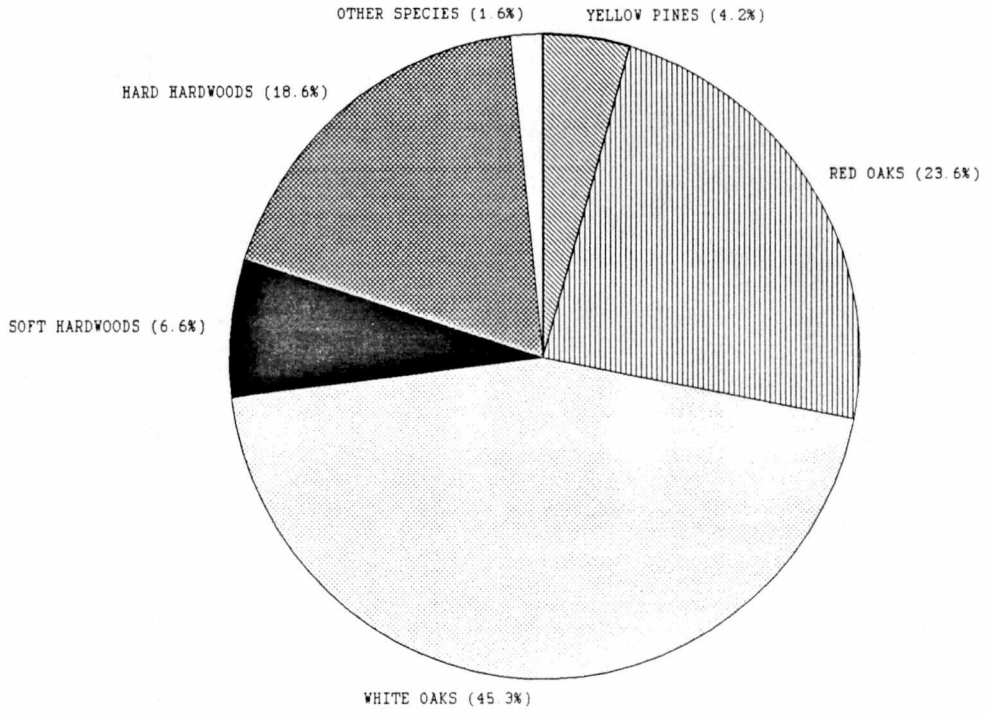


Figure 3. Percent of total basal area by species group for Land Between the Lakes, 1986.

Wayne County, located in southwest Tennessee, was first inventoried in 1969 as a county unit when TVA periodically conducted resource assessments throughout the Tennessee Valley region. Established at an initial sampling intensity of one plot for every 2,325 acres, these plots were remeasured once, in 1979. Total area of Wayne County is 474,200 acres (191,903 ha). Soils in this county consist of well-drained, clayey soils and excessively drained cherty soils derived from coastal plain sediment and cherty limestone. Some silty soils derived from thin loess also occur. Elevations at Wayne County range from 173 feet (53 m) to 1040 feet (317 m) above sea level. Climate at Wayne County is similar to LBL. As a percentage of total basal area white oaks (39.9%) are again the predominant species group at this study

site. The hard hardwood group is the next largest group (35%) (figure 4). Very little change over time has occurred in species' relative proportions; yellow pines have decreased slightly and hard hardwoods have increased slightly. Widespread disturbance at this site is primarily the result of logging.

Plot sample locations were initially determined by overlaying a grid on a 7-1/2 minute topographic map; intersections of the grid were used as plot centers. Details of the plot locations along with the forest inventory protocol may be found in the *TVA Forest Inventory Field Manual* (Bateson and Hitchcock 1976). Plots are 1/5 acre fixed radius circular plots with smaller subplots nested within (see figure 5). Plots included in the study were selected from the total inventory based on forest

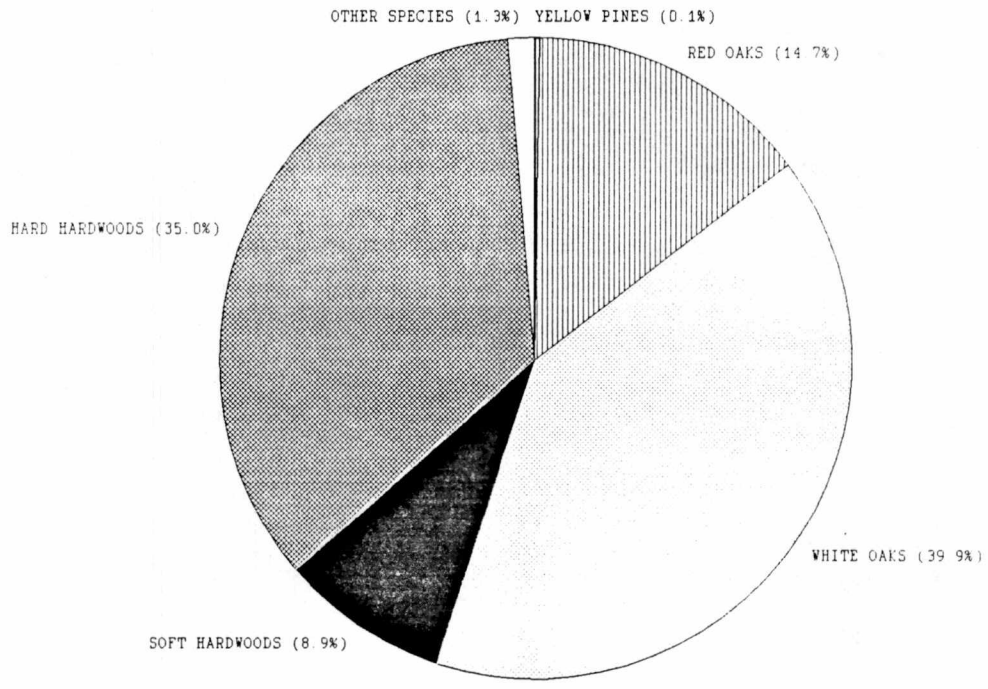


Figure 4. Percent of total basal area by species group for Wayne County, 1987.

Three sizes of plots are used to obtain tree tally and reproduction:

1. One fifth-acre plot, radius 52.7 feet on level ground. Tally all trees 11.0 inches dbh and larger.
2. One twentieth-acre plot, radius 26.3 feet. Tally all trees 5.0 inches dbh and larger.
3. Five one-one hundredth acre plots, radius 11.8 feet, are used to record reproduction.

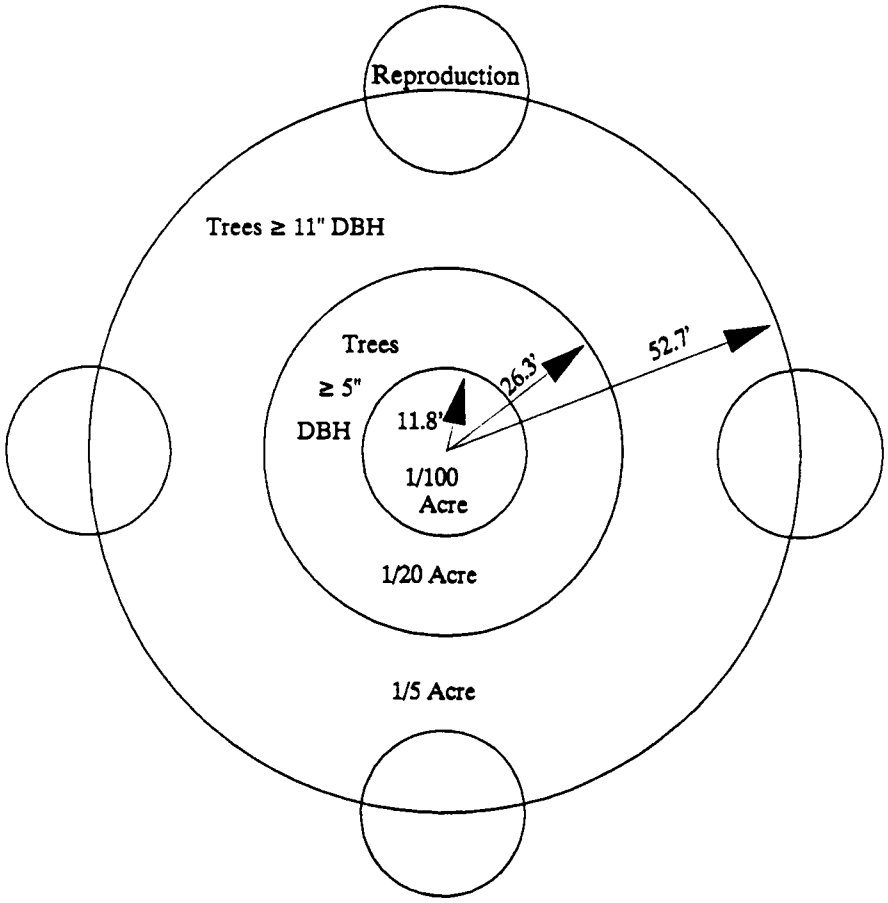


Figure 5. Schematic of TVA's Continuous Forest Inventory System plot layout.

type (white oak--black oak--northern red oak forest cover type and variants, Eyre 1980) and size of trees (predominantly large sawtimber size trees -- greater than or equal to 11.0" dbh). A total of 267 plots were actually remeasured in the spring and summer of 1987 after preliminary screening for tree species and sizes. Plots that had undergone substantial harvesting since the last remeasurement were deleted (table 2).

Table 2. Number of plots and remeasurement years for study sites.

Site:	Emory River	LBL	Wayne County
Sample Size:	85	122	60
Survey Dates:	1964	1966	1969
	1974	1976	1979
	1984	1986	

Data Collection -

Increment Cores and Tree Data -

Increment cores were collected from every living dominant and codominant tree on the plot (regardless of health). Additional cores were collected from trees off the plot but in the immediate vicinity to increase core tree sample size. Ideally, five samples per species were collected but because of time constraints the total number of cored trees did not exceed 15 (unless more than 15 dominant and

codominant trees occurred on the plot). Tree cores were immediately stored in plastic drinking straws labeled with study site, plot number, and tree number, and taped at both ends. Species and diameter at breast height (dbh) were recorded for all core trees. A prism count was made around every cored tree as a measure of individual competitive pressure. The prism count was done by holding the prism next to the tree to approximate tree center as closely as possible. Notes regarding injury or other conditions affecting growth were also recorded for each core tree.

Supplementary Environmental Data -

A number of stand-level parameters available from the forest inventory data were used to represent site characteristics. TVA inventory methodology includes classifications of topographic site (dry upland, upland flats, moist upland, and bottomland) and stand size class (large sawtimber, small sawtimber, poletimber and seedlings, and saplings). Topographic position, slope, aspect, and additional site descriptive information, including diagrams of slope position, are also included in the plot record and were used in the analyses.

Within the TVA system of continuous forest inventory, individual trees are mapped by recording azimuth and distance from plot center allowing assessments of changes in individual productivity and health. A copy of the data recorded at the previous inventory was taken to the field so that past measurements could be verified. Tree dbh was measured on all trees greater than or equal to 5.0 inches in diameter using a diameter tape marked in inches. Consistency in height of

measurement was maintained by using a "dbh stick" allowing direct measurement at a height of 4.5 feet (1.37m). Basal area and number of stems per acre were estimated using the data collected on the fixed area plot.

Measures of individual tree vigor included tree crown class (position in the canopy), and identification of damage or injury. For injury, TVA uses a system of 10 codes representing no injury, or indicators of injury from fire, insect, disease, animal, weather, suppression, timber stand improvement (TSI), logging and unknown. Symptoms and signs of injury are described in the comments section of the tally sheet. Quantification of injury is reflected in percent cull; TVA estimates total and rotten cull percent for each tallied tree. These estimates are based on cull volume present in each 10 foot section and reflect suitability as a timber product. These data are useful in determining areas impacted by disease, insects, fire, or some other disturbance. Percent of the total number of trees affected by each inventory code was calculated for each plot.

Disturbance history was determined for each plot using the remeasurement data, series of TVA aerial photographs available from different acquisition dates (table 3), records of management activities maintained by landowners, and verbal history accounts. A disturbance history checklist similar to that used in the Southern Appalachian Regional Resource Management Cooperative's assessment of spruce-fir (Pyle and Schafale 1985) was also included as part of the field tally (see Appendix C). In addition, detailed descriptions of changes in forest type and stand structure, and evidence of past disturbances were recorded by the field crew

Table 3. Acquisition years for aerial photography available for determining site history.

		LBL		
Wayne	Morgan	Stewart	Lyon	Trigg
1957	1959	1957	1959	1959
1958	1970	1969	1965	1965
1963				
1974				

1939 photo mosaics covering the entire Tennessee River Watershed - available for all sites.

as they travelled into the plot. Disturbance histories were reviewed after tree core analysis to identify patterns associated with tree growth.

Preliminary soil series were identified for each individual plot utilizing existing soil surveys for the LBL study area; ongoing soil surveys for Wayne County; and soil descriptions provided by the Soil Conservation Service in 1969 for individual plots at the Emory River Land Company. To verify or reclassify these identified soil series a trained TVA soil scientist visited each site.

Soil sampling intensity to verify the assigned soil series was determined in the field depending on the homogeneity of the site. Several areas were sampled down to bedrock with a soil auger. Based on the soil's physical characteristics along with site characteristics, the series classification was either verified or rejected and replaced with a new classification. Physical characteristics consisted of identification of horizons, with depths and textures for each horizon. Site and soil descriptions

were documented along with reasons for verifying or rejecting the assigned soil series. Often, more than one series occurred on a plot. When this happened, a diagram was included in the field description to approximate where the series changed and an estimate was made of the percent of the 1/5 acre plot that was included in each identified series. In later analyses, the predominant series was used as representative for the whole plot.

Climate data, consisting of monthly averages of temperature and monthly totals for precipitation, for the period 1895 through 1986 were made available from Oak Ridge National Laboratory (ORNL) for state climatic divisions in which the study sites occurred. These were Tennessee Climatic Division 2 for the Emory River site and Tennessee Climatic Division 3 for LBL and Wayne County (figure 6).

Increment Core Preparation and Measurement -

Tree cores were mounted according to the procedures described by Phipps (1985) and sorted by species. Crossdating and measurement proceeded by species' abundance; white oak was measured first, followed by chestnut oak, yellow-poplar, and northern red oak. Surface preparation consisted of sanding the mounted cores with progressively finer sandpaper until there was no evidence of scratching and a smooth, glass-like surface was attained. Crossdating was done by standard dendrochronological technique; developing a "skeleton" (pattern of narrow and large rings) for each species at each site, from which that species' "signature" (consistent narrow or large rings for known years) was determined.

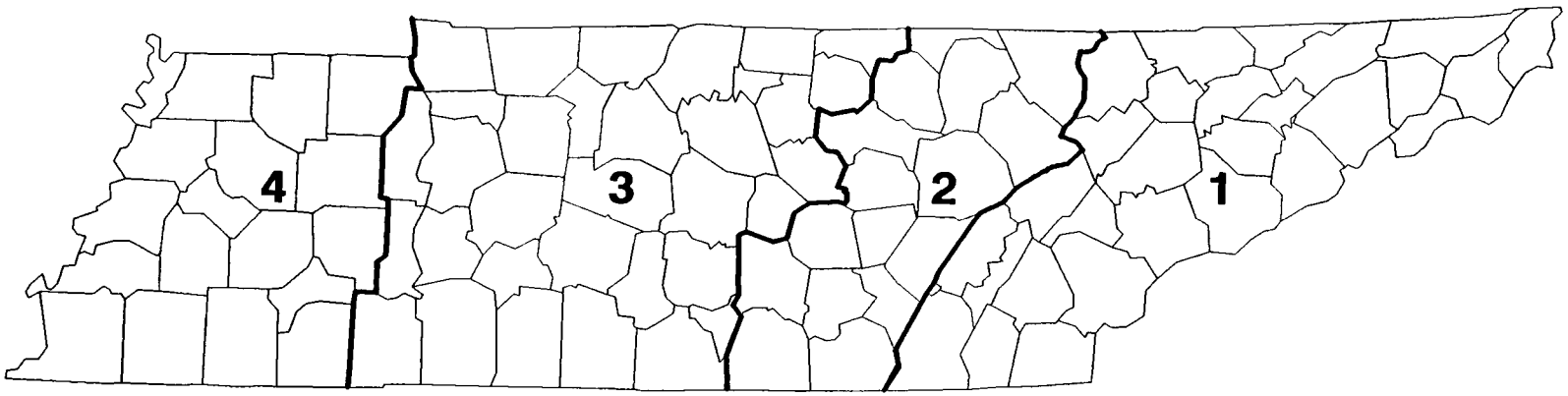


Figure 6. Map showing National Weather Service Climatic Divisions for the state of Tennessee.

Crossdating was verified by a computer program COFECHA (Holmes 1985). This program calculates a master series as a mean of all measured series with the exception of the tree-ring series that is being verified. Then correlations are determined between individual ring widths for segments that are 50 years long. Years of poor correlation are flagged and alternate segments of higher correlation are identified, allowing the measurer to recheck questionable series. Measurement accuracy was validated by remeasuring a minimum of five percent of the sample and comparing results. During all phases of core measurement, a logbook was kept where comments regarding the quality of the core were recorded as well as decisions which were made about dating the rings or including in the final data set.

Measurement of annual radial increment from individual trees was done using equipment supplied from ORNL. Equipment consists of a Bannister incremental measuring device linked to an IBM-XT microcomputer. The tree ring measuring devices were calibrated once a week on Mondays and the calibration was recorded. No drifts in calibration were apparent.

Analysis -

Tree-ring series from a total of 1843 trees were analyzed in this study (table 4). A wide range of ages was represented in each species sample with the youngest tree being a yellow-poplar at LBL with an estimated age of 34 years up to a total estimated age of 319 years for an individual chestnut oak at Emory River.

Table 4. Number of trees and range of ages by site and species.

	White oaks	Chestnut oaks	Northern red oaks	Yellow-poplar
Emory River	229 trees (48-206 yrs.)	276 trees (49-319 yrs.)	143 trees (48-185 yrs.)	237 trees (34-161 yrs.)
LBL	384 trees (39-214 yrs.)	123 trees (51-267 yrs.)	15 trees (65-136 yrs.)	26 trees (34-130 yrs.)
Wayne County	193 trees (47-256 yrs.)	106 trees (42-157 yrs.)	62 trees (60-151 yrs.)	49 trees (42-127 yrs.)
Total trees:	806	505	220	312

Analysis consisted of first standardizing the data, then grouping the standardized series into smaller units that were statistically similar and small enough to meet the memory limitations of the statistical software used (figure 7). Models of tree growth as predicted by climate were then determined by first selecting climate variables using stepwise regression. This was done simply because of time restraints, as stepwise regression provided a relatively fast means of selecting climate variables according to their significance in explaining average tree growth over a period of time. The variables that were selected in the stepwise regression were then used as independent variables in a time-variant model of tree growth to determine changes that might be occurring in this relationship over time. Later, multivariate statistics (discriminant analysis) were used to determine if environmental factors could be used to explain groupings, and thus be related to different response functions.

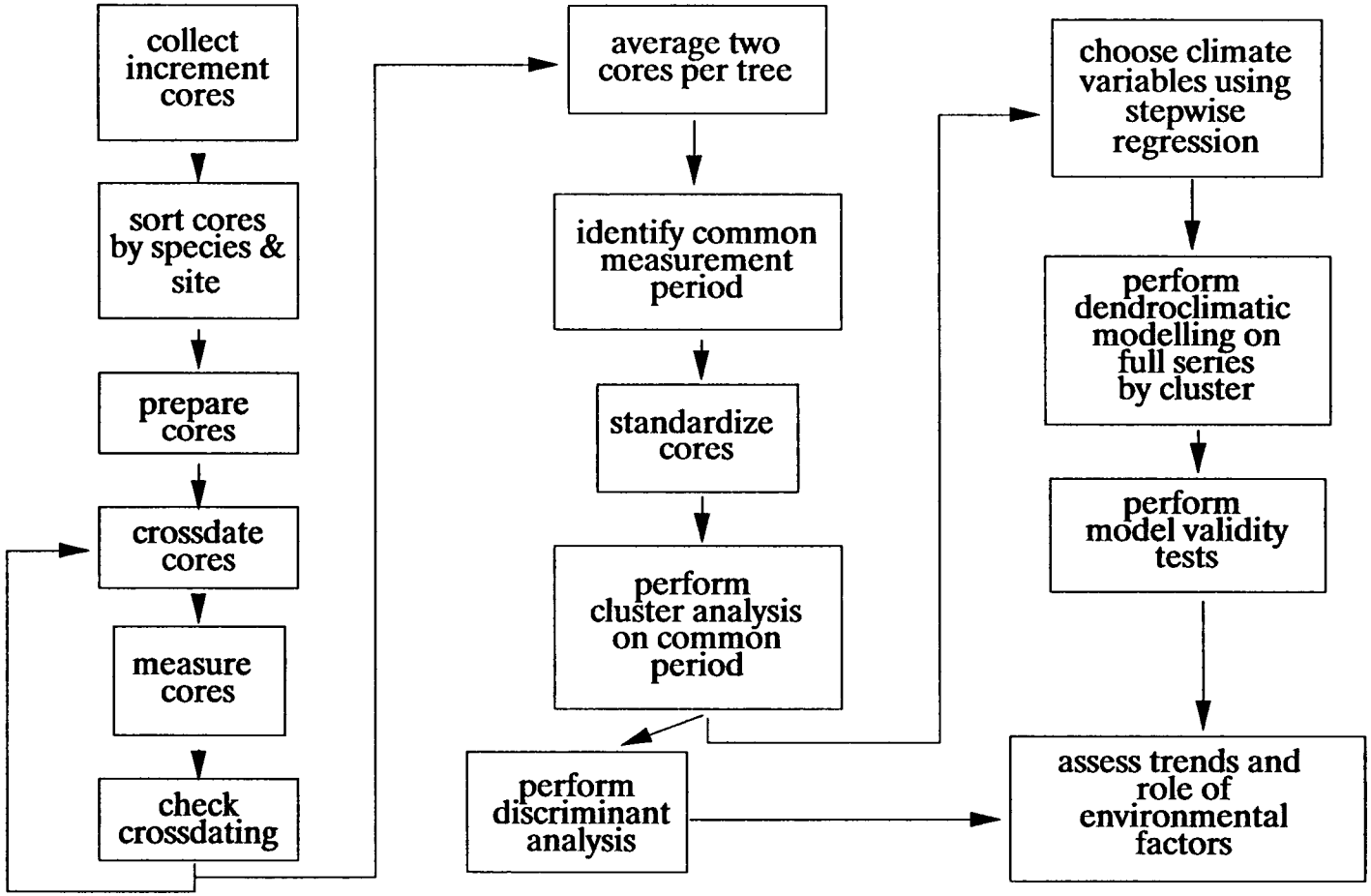


Figure 7. Flowchart showing steps of analysis.

Standardization -

The DYNACLIM tree-ring analysis package (Van Deusen and Koretz 1987) run with GAUSS software was used to standardize tree-ring series using first differences of logarithms. Climate data were standardized similarly by taking differences from year to year for each month.

Clustering -

All series from one species collected from each of the three study sites were scanned to identify a period for which there were measurements in common. For example, the latest date that a series began in the white oaks at Emory River was 1949 and the earliest ending year was 1983 (table 5). A cluster analysis was run on standardized data from this common period, 1949 to 1983, to identify trees that had similar growth patterns. Cluster analysis was considered appropriate for grouping similar tree-ring chronologies as it is reasonable to assume that differences in growth might be attributable to interactions of environmental factors. In contrast to PCA, which has been used by others in the past to group chronologies (Peters et al. 1981, Enright 1984), cluster analysis requires no decision as to the number of important factors driving the response and therefore may be appropriate for extremely large data sets containing series from a wide variety of sites.

Table 5. Common measurement period used for clustering tree-ring data.

Site and Species	measurement period	number of years
Emory River white oak	1949 - 1983	35
LBL white oak	1952 - 1986	35
Wayne Co. white oak	1956 - 1986	31
Emory River chestnut oak	1951 - 1986	36
LBL chestnut oak	1947 - 1986	40
Wayne Co. chestnut oak	1955 - 1986	32
Emory River northern red oak	1956 - 1986	31
LBL northern red oak	1942 - 1986	45
Wayne Co. northern red oak	1948 - 1986	39
Emory River yellow-poplar	1968 - 1986	19
LBL yellow-poplar	1968 - 1986	19
Wayne County yellow-poplar	1960 - 1986	27

The FASTCLUS procedure in SAS was run iteratively to group tree-ring series in clusters that were similar in overall variation. FASTCLUS performs a disjoint cluster analysis on the basis of Euclidean distances computed from one or more variables, which in were individual measures of annual increment for the common measurement period in this case. FASTCLUS utilizes *nearest centroid sorting* (SAS 1985). In this procedure, n clusters are specified and a set of n points known as *cluster seeds* are selected as a first guess of means of the clusters. Each observation is then assigned to the nearest cluster and the cluster seeds are updated according to these temporary cluster groupings. The process is repeated until no further changes occur in the clusters.

Initial sizes of clusters were determined based on the limitations of the software used in the following analyses; due to memory limitations, GAUSS can only handle matrices that contain at most 7921 elements, meaning each cluster could have a maximum of 87 series with 91 years of data per series (climate data from 1895-1986 minus one year from the differencing). After working with the white oak data, a criterion was established of cluster sizes having a maximum distance from seed to observation equal to or less than approximately 2.5. The initialization method used by FASTCLUS makes it sensitive to outliers; clusters that contained four or less series were discarded as outliers.

A correlation analysis was done between clusters at each study site for each species. A mean chronology was developed for each cluster and the SAS CORR procedure was run using mean standardized annual increment as the variable, with up to 91 observations represented with the data from 1885 through 1986.

Selection of Climate Variables -

Due to the large amount of data processed in this study, climate variables were selected for each cluster using multiple regression techniques rather than fitting a Kalman filter model one parameter at a time because the latter is a very time-intensive technique. Several models were developed using the Kalman filter technique to select climate variables to compare with variable selection using stepwise regression. The techniques performed similarly; the Kalman filter technique usually selected one or two climate variables; stepwise regression selected

these same variables as the first to enter the model, then had from one to several additional variables enter. Apparently, the Kalman filter technique is more rigorous in the significance requirements for entering variables. However, the stepwise regression technique was considered more appropriate as it suggested greater differences between cluster groupings through differences in variables selected that is more consistent with the focus of this study.

A stepwise regression was performed using annual values from a cluster mean chronology as the dependent variable and climatic variables for the current year through the end of the growing season and variables lagged one year as independent variables. To enter the model, variables had to be significant at the 0.15 level, and to remain in the model the parameter had to be significant at the 0.05 level. Coincident with fitting the regression, tolerance values were calculated for the variables used in each of the models to determine if there was a potential problem with multicollinearity. Tolerance values are defined as $1-R^2$ for a variable with respect to all other regressor variables in the model (SAS 1985).

A correlation analysis was done on all climate variables within each climatic division. Climate variables were screened using graphical analysis to determine if there were any apparent trends in the data available. Additionally, the climate data were analyzed using time series analysis (ARMA models) to determine if the data were stationary or if there was any apparent autocorrelation in these series on a year to year basis (e.g. if June temperature showed any autocorrelation with June temperature of the previous year).

Dendroclimatic Modelling -

Once climate variables were selected from the stepwise regression, dendroclimatic modelling using the Kalman filter proceeded. DYNACLIM was again run using GAUSS software. Models were specified using a non-varying intercept while all climate variables were allowed to vary (Van Deusen and Koretz 1988). A later version of DYNACLIM allows the user to specify that the intercept could vary; however this version was not available until most of the dendroclimatic modelling had been completed and thus was not used.

DYNACLIM software produced smoothed parameter estimates for each of the climate variables for every year and their associated variances. Assuming a normal distribution for the variance among individual trees, ninety-five percent confidence intervals were calculated for each of these parameters to assess if these values were significantly different from zero. Three-dimensional graphs of the changes in parameter values over time were produced to allow an overall assessment of changes in the climate/growth relationship for each cluster of tree-ring series.

Observed trends in parameter coefficients were tested using a "runs" test (Draper and Smith 1981) to determine if changes in coefficient values followed a pattern that might be associated with a change in sensitivity to climate or if they occurred randomly and therefore did not reflect true changes in sensitivity. The "runs" test was performed by calculating a mean coefficient over time for specific climate parameters that were common to a large proportion of the clusters over

each site. Deviations from the mean were calculated on a year by year basis and assigned a value of "+" if they were greater than zero and "-" if less than zero. Changes in sign within a sequence of pluses and minuses denote the beginning of a new run. The statistics described in Draper and Smith (1981) were used to determine if the number of runs is an "extreme" arrangement as opposed to one which would occur randomly. Given n signs in a sequence, with n_1 pluses, n_2 minuses, and u runs, and assuming a normal distribution,

$$\mu = (2n_1n_2/(n_1+n_2)) + 1, \text{ and}$$

$$\sigma^2 = [2n_1n_2\ (2n_1n_2 - n_1 - n_2)]/(n_1 + n_2)^2\ (n_1 + n_2 - 1),$$

where μ is the mean and σ^2 is the variance of the discrete distribution of u. To test for *too few runs* a Z statistic is calculated:

$$Z = (u - \mu + \tfrac{1}{2}) / \sigma\ ,$$

where the $\frac{1}{2}$ is a *continuity correction* to compensate for using a continuous distribution to approximate a discrete distribution in the lower tail.

The climate models were verified according to methods suggested by Van Deusen (in review). Percent autocorrelation for model residuals was calculated and

displayed graphically for lags up to five years. A modified Von Neumann ratio (MVNR) was calculated, along with an approximate 95% confidence interval. The MVNR is similar to the Durbin-Watson statistic (Durbin and Watson 1950, 1951) used to test for autocorrelation between estimation residuals by determining the ratio between the first differences of residuals and the total residual variance. Harvey (1981) gives the formulation of the MVNR as:

$$\text{MVNR} = [(T\text{-}p)/(T\text{-}p\text{-}1)]\left[\sum_{t=p+2}^{T} (e_t - e_{t-1})^2 / \sum_{t=p+1}^{T} e_t^2 \right],$$

where T is the number of time periods and p is the number of parameters. The distribution of the MVNR is approximately normal with mean 2 and variance 4/(T-p) under a correctly specified model. This test may be conservative, but an estimated MVNR which lies outside of its confidence interval may suggest model misspecification.

Graphical plots of the cumulative sum of the prediction errors and their associated confidence intervals provided a further check of model validity by indicating how well the data are tracked by the model. The cumulative sum of the prediction error is defined as:

$$C_t = \hat{\sigma}^{-1} \sum_{j=p+1}^{t} e_j \, , \; t=p+1,\ldots,T \, ,$$

where

$$\hat{\sigma}^2 = \sum_{t=p+1}^{T} (e_t - \bar{e})^2/(T\text{-}p\text{-}1)$$

Another test statistic used for recursive models is calculated from the cumulative sum of the prediction errors at time T:

$$C^* = C_T/[(T\text{-}p)]^{1/2},$$

where p is the number of parameters. A crude confidence interval around this line is calculated as:

$$CI = \pm\{a(T\text{-}p)^{1/2} + 2a(t\text{-}p)/(T\text{-}p)^{1/2}\},$$

where $a = 0.948$ for a significance level of 0.05, and $a = 0.850$ for a significance level of 0.10 (Brown et al. 1975). When the model is correctly specified, C^* has a t-distribution with $T\text{-}p\text{-}1$ degrees of freedom, so a two-sided t-test may be performed. This statistic is particularly effective if the prediction errors are either all negative or all positive.

Discriminant Analysis -

The last part of the analysis in this study was to determine which environmental factors could be associated with different clusterings and might therefore affect differences in response to climatic fluctuations. This was accomplished using a discriminant analysis on a set of environmental factors that was associated with each individual increment core tree. Each tree was identified with a cluster number and the environmental factors (quantitative variables) were used to discriminate the trees into cluster groupings (classification variables).

Environmental factors consisted of variables associated with individual trees and site variables determined for each plot. Individual tree data consisted of the dbh of the core tree, an estimated age based on average annual increment and tree radius, and the prism count collected for each tree. Site information included descriptive variables such as elevation, slope percent, topographic classification, aspect, and fire and grazing codes.

Information calculated from the inventory data included: a productivity index calculated as average annual basal area increment for the plot; relative frequency of the core tree species; an importance value for the core tree species calculated as that species basal area per acre divided by total basal area per acre; mean age of cored trees; basal area of mortality trees; basal area of cut trees; and percent of trees in the stand affected by the different injury classifications.

Soils data consisted of horizon depth and texture for each plot. Horizons were aggregated into an A and E horizon and a B horizon -- deeper horizon data

were not included. Soil textures were assigned a categorical name in the field. These data were then ranked according to a gradient reflecting change in texture from fine to coarse and assigned a numerical value representative of this gradient (table 6). Presence of an argillic zone (Bt horizon) or a fragipan (Bx horizon) was indicated with a presence code of 1 or an absence code of 0 for a variable for each type of horizon.

Canonical discriminant analysis was applied to the data using the SAS procedure CANDISC. This procedure is a dimension-reduction technique related to PCA and canonical correlation. CANDISC calculates linear combinations of the quantitative variables (known as *canonical variables*) that summarize between-class variations and that have the highest possible multiple correlation with the groups, then tests the hypothesis that resulting canonical correlations are zero in the population. A variable's importance in determining groupings can be evaluated by observing the value of the standardized canonical coefficients associated with individual variables. CANDISC also performs univariate one-way analyses of variance. Optional univariate statistics for each of the quantitative variables provide means, standard deviations, R^2's, and F statistics with associated probability levels.

A classificatory discriminant analysis was also performed on the data using the SAS procedure DISCRIM. This procedure generates a linear discriminant function for each group of data as well as probabilities of misclassification (error rates). This was considered desirable as it provides an evaluation of how well the environmental factors explain the cluster groupings of tree growth.

Table 6. Ranking of soil textures -- fine to coarse.

Texture	Abbreviation	Rank
Clay	C	1
Silty clay	SiC	2
Sandy clay	SC	3
Silty clay loam	SiCL	4
Sandy clay loam	SCL	5
Clay loam	CL	6
Silt	Si	7
Silty loam	SiL	8
Loam	L	9
Sandy loam	SL	10
Cherty clay	ChC	11
Cherty silty clay loam	ChSiCL	12
Cherty silt loam	ChSiL	13
Cherty sandy loam	ChSL	14
Shaley silty clay loam	ShSiCL	15
Gravelly silty clay loam	GSiCL	16
Gravelly sandy clay loam	GSCL	17
Gravelly clay loam	GCL	18
Gravelly silt loam	GSiL	19
Gravelly loam	GL	20
Gravelly sandy loam	GSL	21
Very cherty silty clay	VChSiC	22
Very cherty sandy clay	VChSC	23
Very cherty silty clay loam	VChSiCL	24
Very cherty silt loam	VChSiL	25
Very shaley silty clay	VShSiC	26
Very gravelly silty clay loam	VGSiCL	27
Very gravelly clay loam	VGCL	28
Very gravelly silt loam	VGSiL	29
Very gravelly sandy loam	VGSL	30
Extremely cherty silty clay loam	EChSiCL	31
Extremely cherty silt loam	EChSiL	32
Extremely gravelly silty clay	EGSiC	33
Extremely gravelly silt clay loam	EGSiCL	34
Extremely gravelly clay loam	EGCL	35
Extremely gravelly silty loam	EGSiL	36
Loamy sand	LS	37
Sand	S	38

IV. RESULTS

Evaluation of Climate Data -

The highest correlations among climate variables were between January rain and temperature, at 0.45 for Climatic Division 2, and 0.43 for Climatic Division 3. Autoregressive Moving Average (ARMA) modelling of the climate data from both climatic divisions indicated no significant autoregressive trends from year to year. No clear trends were observed from the graphs of monthly values of climatic data, as year to year variation was extremely high (figures 8-11).

Clustering of Tree-ring Data -

Clustering based on a maximum distance of 2.5 standard units from cluster seed to individual observations within a cluster resulted in a total of 54 clusters which were each analyzed separately to determine their relationship with climate (table 7). In the white oaks, Emory River had the smallest mean cluster size and the greatest overall variability in cluster sizes. The greatest coverage by white oaks occurred at Wayne County, with cores collected from 68% of the plots. LBL had the largest mean cluster size with the lowest variation.

In contrast, Emory River had the greatest coverage of chestnut oak (cores collected from 75% of the plots), and the largest mean cluster size. This site also had the greatest coverage for northern red oak and yellow-poplar, with the largest mean cluster size and lowest variation for both species.

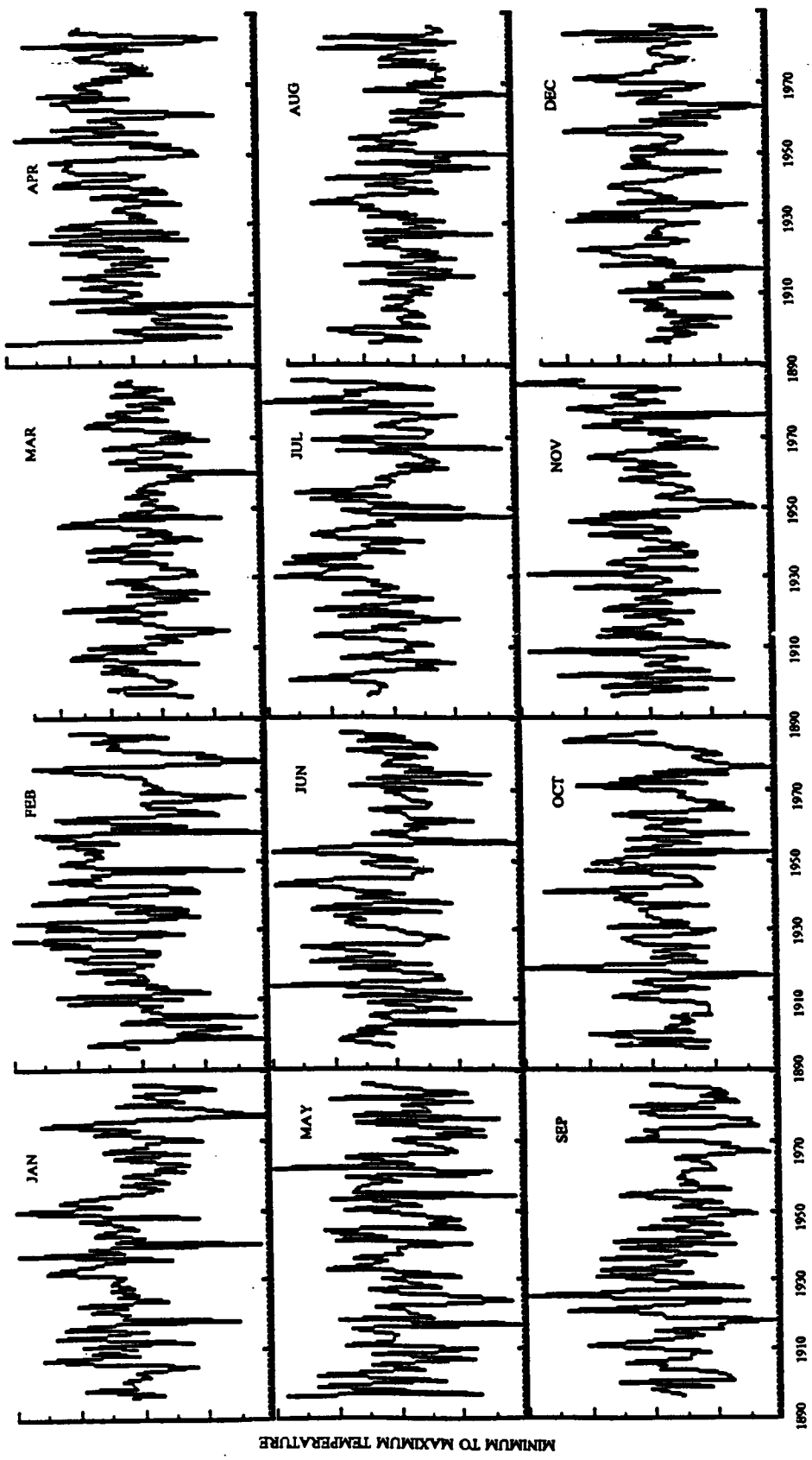


Figure 8. Graphs of total monthly precipitation by year, Tennessee Climatic Division 2, 1895-1986.

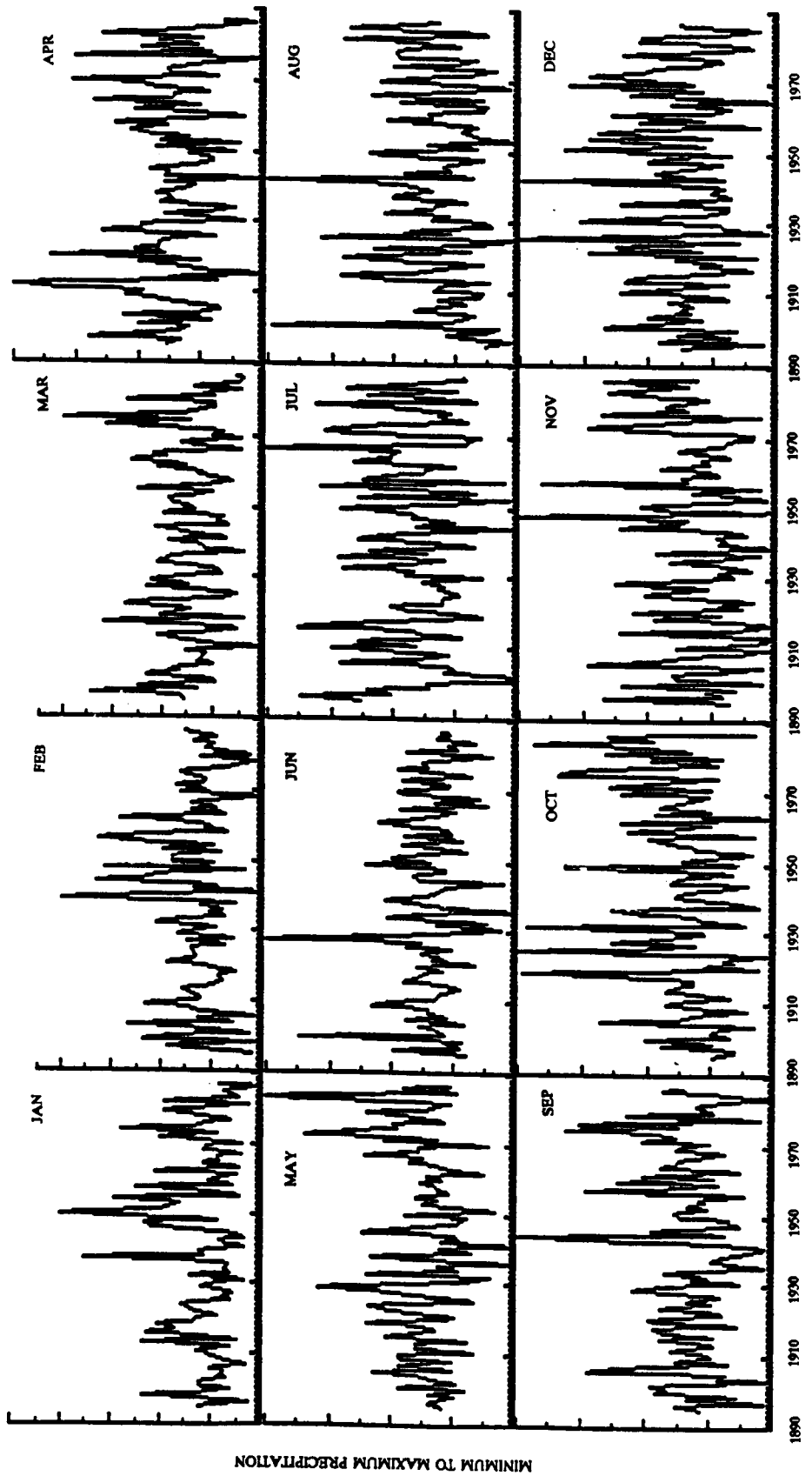


Figure 9. Graphs of total monthly precipitation by year, Tennessee Climatic Division 2, 1895-1986.

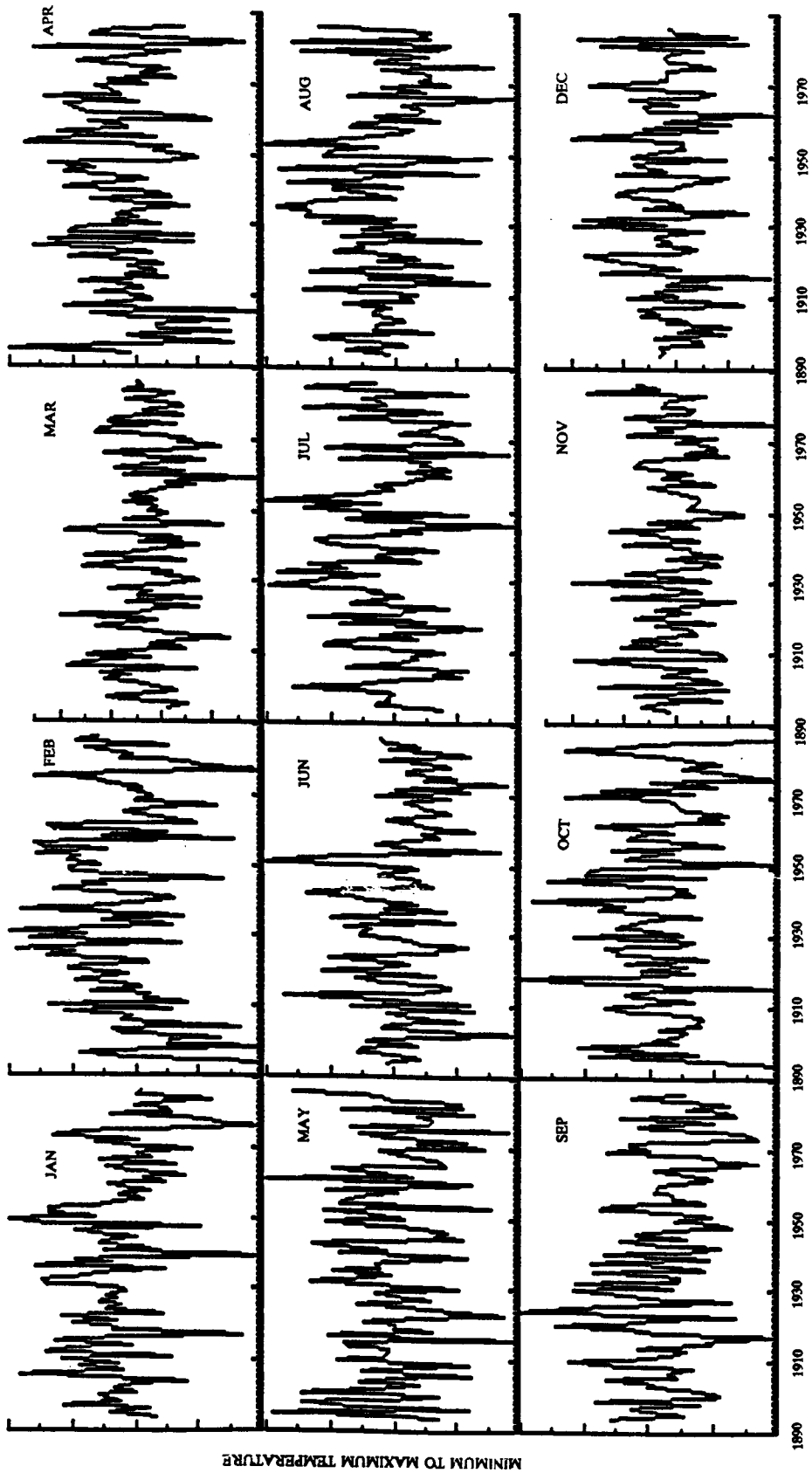


Figure 10. Graphs of average monthly temperature by year, Tennessee Climatic Division 3, 1895-1986.

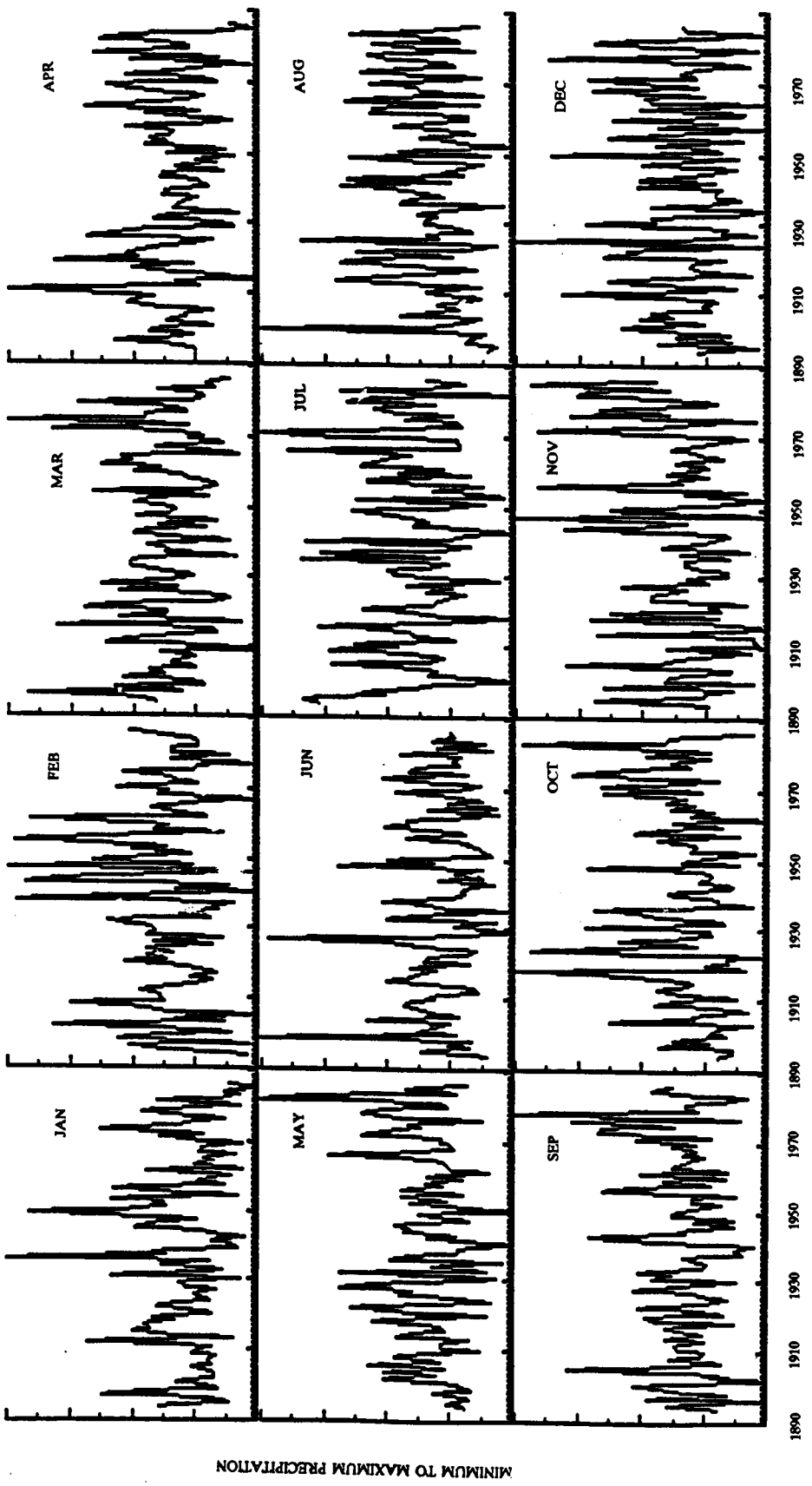


Figure 11. Graphs of total monthly precipitation by year, Tennessee Climatic Division 3, 1895-1986.

Table 7. Cluster statistics for each species at the three study sites.

Species/ Site[1]	Percent of Plots with Species	Number of Resulting Clusters	Mean Cluster Size (trees)	Coefficient of Variation for Cluster Size
White oaks				
ER	68	9	24.3	96%
LBL	63	9	42.7	48%
WC	75	6	32.2	67%
Chestnut oaks				
ER	75	7	39.4	64%
LBL	17	4	30.8	55%
WC	42	3	35.3	71%
Northern red oaks				
ER	58	2	71.5	13%
LBL	6	2	7.5	47%
WC	35	3	20.7	44%
Yellow-poplars				
ER	48	4	59.3	41%
LBL	6	1	23.0	-
WC	28	4	12.3	52%

[1] ER = Emory River, LBL = Land Between the Lakes, and WC = Wayne County.

An estimate of annual changes in a chronology is obtained by calculating the M-parameter, which according to Van Deusen and Koretz (1988) is determined using:

$$m_t = b_0 + b_{1,t-1}C_{1,t} + ... + b_{n,t-1}C_{n,t} + w_{mt}$$

where the expected value of m_t is the M-parameter at time t, predicted using $\hat{b}_0$ as the intercept and coefficients $\hat{b}_1$, ..., $\hat{b}_n$ calculated from observations at time t-1 multiplied by climate variables C_1, ..., C_n. The error term w_{mt} has an associated variance that is assumed to be normally distributed, allowing the calculation of a

95% confidence interval for each year's estimate. Graphs of the M-parameter and associated confidence interval by year reveal that variance among individuals within a cluster is very small (see plots of M-parameter in Appendix A). Most clusters show larger confidence intervals at the beginning of the chronology, a function of a small initial sample size and the fact that cluster variables were obtained from standardized annual increments occurring at the end of the series. Graphs of the M-parameter also reveal that year-to-year variations in annual growth were greatest in the early portion of the chronology; recent growth rate changes have leveled off relative to early growth.

Cluster groupings were observed on a plot-to-plot basis in order to determine the degree of spatial heterogeneity that was occurring for each species-site combination. A count was made of the number of plots, with more than one sample tree, on which all of the trees of a species were grouped into a single cluster. This revealed an enormous amount of spatial variability even on this scale with a range of values showing plot homogeneity on only 2% of the plots with chestnut oak at Emory River, up to a high of 39% for northern red oak at Emory River (table 8.) Plots with many cluster groupings were compared to those with a single cluster grouping to see if any differences were apparent to explain the degree of heterogeneity. Examination of soils diagrams made in the field showed that the number of cluster groupings could not be explained by differences in soils. Disturbance history accounts were also compared. Plots that were very

Table 8. Percent of plots in which all trees of one species clustered into the same group.

	White oaks	Chestnut oaks	Northern red oaks	Yellow-poplar
Emory River	5%	2%	39%	24%
LBL	29%	29%	14%	-
Wayne County	24%	16%	33%	18%

homogeneous in tree growth response included histories that indicated no apparent disturbance, disturbance by TSI, insects, disease, fire, and widespread mortality.

Correlations between mean cluster chronologies were compared within and between sites for each species. For white oaks, within site cluster correlations ranged from 48% to 93% at Emory River, 73% to 96% at LBL, and between 82% and 91% at Wayne County (table 9). Correlations between Emory River and LBL clusters ranged from 48% to 81%; between Emory River and Wayne County, from 36% to 89%; and between LBL and Wayne County, from 51% to 87%.

For chestnut oaks, similar comparisons within sites revealed correlation ranging from 62% to 95% at Emory River, 72% to 88% at LBL, and 58% to 81% at Wayne County (table 10). Between site cluster correlations ranged from 50% to 71% for Emory River and LBL, 44% to 70 for Emory River and Wayne County, and 47% to 83% for LBL and Wayne County.

Correlations between mean cluster chronologies for northern red oak were very different. The two clusters at Emory River showed 84% correlation; the two

Table 9. Correlation matrix for white oak clusters, all sites.

Cluster[1]:	E1	E2	E3	E4	E5	E6	E7	E8	E9	L1	L2	L3	L4	L5	L6	L7	L8	L9	W1	W2	W3	W4	W5	W6
E1	1.00	0.58	0.79	0.78	0.77	0.73	0.52	0.71	0.66	0.63	0.63	0.48	0.50	0.60	0.60	0.54	0.58	0.57	0.50	0.50	0.56	0.47	0.49	0.55
E2		1.00	0.71	0.75	0.67	0.59	0.68	0.50	0.60	0.70	0.65	0.51	0.60	0.63	0.67	0.56	0.60	0.58	0.80	0.76	0.75	0.76	0.72	0.73
E3			1.00	0.93	0.89	0.86	0.69	0.79	0.72	0.78	0.75	0.63	0.68	0.73	0.73	0.67	0.71	0.73	0.65	0.66	0.67	0.63	0.68	0.71
E4				1.00	0.91	0.87	0.70	0.75	0.71	0.81	0.77	0.63	0.70	0.74	0.76	0.71	0.73	0.76	0.69	0.71	0.71	0.67	0.70	0.74
E5					1.00	0.86	0.65	0.84	0.71	0.77	0.74	0.58	0.67	0.70	0.73	0.66	0.70	0.72	0.67	0.62	0.65	0.60	0.65	0.73
E6						1.00	0.62	0.80	0.70	0.73	0.68	0.56	0.58	0.66	0.70	0.67	0.65	0.67	0.59	0.59	0.59	0.54	0.59	0.65
E7							1.00	0.48	0.58	0.76	0.69	0.57	0.62	0.70	0.72	0.58	0.66	0.66	0.75	0.82	0.81	0.80	0.89	0.82
E8								1.00	0.70	0.65	0.65	0.52	0.58	0.61	0.61	0.58	0.62	0.61	0.45	0.38	0.44	0.36	0.41	0.56
E9									1.00	0.69	0.65	0.52	0.61	0.63	0.59	0.59	0.63	0.61	0.51	0.50	0.54	0.54	0.51	0.58
L1										1.00	0.94	0.76	0.87	0.95	0.95	0.88	0.92	0.93	0.77	0.80	0.83	0.79	0.75	0.87
L2											1.00	0.77	0.86	0.96	0.92	0.85	0.90	0.89	0.76	0.76	0.81	0.74	0.69	0.84
L3												1.00	0.73	0.75	0.74	0.75	0.79	0.79	0.54	0.54	0.61	0.54	0.51	0.63
L4													1.00	0.87	0.89	0.89	0.94	0.89	0.68	0.67	0.72	0.64	0.66	0.75
L5														1.00	0.94	0.87	0.91	0.90	0.74	0.76	0.82	0.77	0.72	0.82
L6															1.00	0.89	0.92	0.91	0.77	0.79	0.83	0.75	0.74	0.83
L7																1.00	0.93	0.89	0.65	0.66	0.71	0.64	0.61	0.74
L8																	1.00	0.94	0.71	0.71	0.76	0.68	0.66	0.78
L9																		1.00	0.67	0.73	0.75	0.70	0.66	0.80
W1																			1.00	0.82	0.91	0.83	0.83	0.86
W2																				1.00	0.89	0.90	0.89	0.90
W3																					1.00	0.89	0.86	0.91
W4																						1.00	0.84	0.87
W5																							1.00	0.84
W6																								1.00

[1]Cluster identification consists of a letter designating study site: E = Emory River, L = Land Between the Lakes, and W = Wayne County; plus the cluster number within the site.

Table 10. Correlation matrix for chestnut oak clusters, all sites.

Cluster[1]:	E1	E2	E3	E4	E5	E6	E7	L1	L2	L3	L4	W1	W2	W3
E1	1.00	0.93	0.89	0.88	0.80	0.94	0.85	0.67	0.57	0.65	0.68	0.65	0.59	0.63
E2		1.00	0.92	0.88	0.80	0.95	0.83	0.66	0.59	0.65	0.68	0.64	0.58	0.60
E3			1.00	0.87	0.80	0.91	0.83	0.69	0.60	0.65	0.67	0.66	0.61	0.66
E4				1.00	0.73	0.88	0.81	0.60	0.55	0.60	0.61	0.62	0.51	0.65
E5					1.00	0.84	0.62	0.69	0.54	0.57	0.71	0.66	0.65	0.55
E6						1.00	0.84	0.67	0.61	0.68	0.71	0.70	0.62	0.66
E7							1.00	0.52	0.50	0.56	0.55	0.57	0.44	0.67
L1								1.00	0.73	0.72	0.83	0.83	0.82	0.64
L2									1.00	0.88	0.85	0.64	0.47	0.59
L3										1.00	0.83	0.71	0.54	0.62
L4											1.00	0.77	0.65	0.61
W1												1.00	0.81	0.72
W2													1.00	0.58
W3														1.00

[1]Cluster identification consists of a letter designating study site: E = Emory River, L = Land Between the Lakes, and W = Wayne County; plus the cluster number within the site.

clusters at LBL showed -23% correlation and; the three clusters at Wayne County showed 69%, 51%, and 70% correlation (table 11). Between site correlations for Emory River and LBL ranged from -4% to 57%; between Emory River and Wayne County from 41% to 49% and; between LBL and Wayne County from -8% to 49%. Correlations between clusters of yellow-poplar at Emory River ranged from 74% to 86% (table 12), and at Wayne County from 73% to 93%; only one cluster was formed for the 23 yellow-poplar trees cored at LBL. Correlations between Emory River and LBL clusters ranged from 32% to 52%; between Emory River and Wayne County clusters, from 36% to 69%, and; between LBL and Wayne County clusters, from 37% to 61%.

Table 11. Correlation matrix for northern red oak clusters, all sites.

Cluster[1]:	E1	E2	L1	L2	W1	W2	W3
E1	1.00	0.84	0.57	-0.05	0.48	0.46	0.59
E2		1.00	0.48	-0.04	0.41	0.45	0.49
L1			1.00	-0.23	0.29	0.49	0.48
L2				1.00	-0.08	-0.17	-0.20
W1					1.00	0.69	0.51
W2						1.00	0.70
W3							1.00

[1]Cluster identification consists of a letter designating study site: E = Emory River, L = Land Between the Lakes, and W = Wayne County; plus the cluster number within the site.

Selection of Climate Variables -

For white oaks, June temperature was overall the most important variable selected in the stepwise regression (table 13); every cluster except Emory River 2 had June temperature enter first in the model. Later variables that entered the climate models differed somewhat by site -- at Emory River, generally past August rainfall was the next most important variable, while at LBL past December rain usually entered the model second, and at Wayne County, each cluster had a different variable entering in the second place position.

June temperature was also the most important variable for chestnut oak, although at Emory River, May rain was a close competitor for first place (table 14). June rain was also important, especially at LBL. Northern red oaks behaved

Table 12. Correlation matrix for yellow-poplar clusters, all sites.

Cluster[1]:	E1	E2	E3	E4	L1	W1	W2	W3	W4
E1	1.00	0.75	0.85	0.74	0.42	0.64	0.68	0.57	0.51
E2		1.00	0.86	0.83	0.32	0.59	0.65	0.46	0.41
E3			1.00	0.78	0.52	0.61	0.66	0.69	0.51
E4				1.00	0.40	0.49	0.52	0.47	0.36
L1					1.00	0.61	0.56	0.37	0.41
W1						1.00	0.93	0.85	0.82
W2							1.00	0.84	0.84
W3								1.00	0.73
W4									1.00

[1]Cluster identification consists of a letter designating study site: E = Emory River, L = Land Between the Lakes, and W = Wayne County; plus the cluster number within the site.

similarly, with June temperature the unanimous choice for first entry (table 15). Past August rain was important at Emory River, showing similar trends with the white oaks. Summer rains were important to Emory River yellow-poplar, especially June rain (table 16). No other clear trends were apparent for a species or site.

Table 13. Rank of climate variables selected using stepwise regression, white oak clusters.

Climate Variable	Emory River, Cluster #										Land Between the Lakes, Cluster #										Wayne County, Cluster #						
	1	2	3	4	5	6	7	8	9	all	1	2	3	4	5	6	7	8	9	all	1	2	3	4	5	6	all
January temperature	4																		6								
February temperature		4							4						5	5	7								6		
March temperature																								3			
April temperature		5					6																				9
May temperature												3		2		3		4	3	3	4		2		2	2	2
June temperature	1	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
July temperature		1																									
August temperature			7	6	4	5	5		5								6					4		6	4		
September temperature																	4										
past February temperature	3		5																								
past March temperature						6																					10
past April temperature			6											4	6												
past May temperature				5							3				3							2		7			
past June temperature		2											5									9					
past July temperature														5			8										
past August temperature													6														
past November temperature		8																									
past December temperature							4												7		3	5		2			12
February rain																						11		4			
April rain											8																
May rain			2	2		3	3			3											2		4		5		7
June rain			4	4	3	4	2		3	4	5		4				9		5	6	6	3	5	5	3	4	4
July rain		3																				8					5
August rain										5							5										
October rain											7																8
past March rain											6						2			7		6					11
past April rain																	10		4			7					6
past May rain																						10					
past June rain																							6				
past August rain	2		3	3	2	2	7	2	2	2	4	4	2	3	4	4		3	2	4	5		3				
past October rain													3	6				5		5							
past November rain		6																									
past December rain											2	2		7	2	2	3	2		2				8		3	3
# of variables	4	8	7	6	4	6	7	2	5	5	8	4	6	7	6	5	10	5	7	7	6	11	6	8	6	4	12
adjusted R^2 (%)	33	60	54	54	42	44	59	27	39	51	73	58	51	65	64	58	72	62	64	69	54	69	62	69	60	59	72
number of trees	7	6	39	74	52	11	7	25	8	229	66	45	10	38	63	43	19	68	32	384	14	38	40	20	12	69	193

Table 14. Rank of climate variables selected using stepwise regression, chestnut oak clusters.

Climate Variable	Emory River, Cluster #								LBL, Cluster #					Wayne Co., Cluster #			
	1	2	3	4	5	6	7	all	1	2	3	4	all	1	2	3	all
March temperature																9	
April temperature									6				5				
May temperature			6				5	6	4			3	4	2	2		4
June temperature	1	4	2	1	1	1	2	1	1	1	1	1	1	1	1	1	1
August temperature	7		4		4				9								
September temperature	6	5					3	5								6	
October temperature														10			
past January temperature																11	
past February temperature																7	
past March temperature												5		3			7
past April temperature				6													
past May temperature		6															
past June temperature	5																
past August temperature				5													
past October temperature													9				
past December temperature						4					2		8	8			
January rain															5		
April rain																8	
May rain	2	1	1	2	2	2	1	2	3	3	3		4	4		2	2
June rain	3	2	3	3	3	3	6	3	2	2			3	5	4	3	3
July rain							8										
August rain							7										
September rain														9		5	
October rain										4	4						
past January rain																10	
past February rain									7						6		
past March rain															3	4	
past May rain																	
past June rain									8				7	6			6
past July rain												4					
past August rain	4	3	5	4			4	4	5				6	7			5
past December rain												2	2				
# of variables	7	6	6	6	4	4	8	6	9	4	4	5	9	10	6	11	7
adjusted R^2 (%)	54	48	47	50	44	45	45	53	61	38	37	53	60	60	47	60	51
number of trees	54	62	41	25	9	74	11	276	24	20	23	56	123	61	34	11	106

Table 15. Rank of climate variables selected using stepwise regression, northern red oak clusters.

Climate Variable	Emory River, Cluster # 1	2	all	LBL, Cluster # 1	2	all	Wayne County, Cluster # 1	2	3	all
January temperature						4				
February temperature	5			4					3	
April temperature					8					
May temperature					6					
June temperature	1	1	1	1	1	1	1	1	1	1
September temperature					3					
past February temperature					9					
past April temperature				2						
past May temperature							5			
past September temperature					4					
past October temperature				3	5					
May rain	2					3				4
June rain		4	4			2	3			2
July rain					7					
August rain		5								
past February rain					10					
past March rain							2			3
past May rain		3	3					2		
past June rain	4						4	3		
past August rain	3	2	2		2					
past December rain									2	
# of variables	5	5	4	4	10	4	5	3	3	4
adjusted R^2 (%)	41	47	43	32	61	34	46	45	21	51
number of trees	78	65	143	5	10	15	22	29	11	62

Table 16. Rank of climate variables selected using stepwise regression, yellow-poplar clusters.

Climate Variable	Emory River, Cluster # 1	2	3	4	all	LBL, Cluster 1	Wayne County, Cluster # 1	2	3	4	all
January temperature				4				5	4	2	
February temperature											4
March temperature						5					
May temperature						6		3	5	3	
June temperature	1				4	1		1	6	4	
July temperature			2								
August temperature										5	
September temperature					6			8			
past January temperature											6
past March temperature											5
past May temperature						4					1
past July temperature											
past August temperature								2		6	
past September temperature		5					5				
past December temperature	4	3			3						
January rain							1				
February rain							2				
April rain								6			
May rain				1							
June rain	2	2	1	2	1	2					
July rain	3	1			2			7			
past January rain											3
past February rain											
past March rain		4						4		1	
past April rain			3	3							
past July rain									1	2	
past August rain	5				5	3	3		2		
past October rain							4		3		
# of variables	5	5	3	4	6	6	5	8	6	6	6
adjusted R^2 (%)	39	44	38	36	39	47	39	53	33	58	36
number of trees	79	73	25	60	237	23	6	21	9	13	49

Tests of Model Misspecification -

Calculated modified Von Neumann ratios were outside their 95% confidence intervals for 14 of the 54 models of tree growth response to climate (table 17). Five of the nine white oak clusters at LBL had MVNR values that indicated possible model misspecification. Two of four yellow-poplar clusters at Wayne County were also outside their intervals. Individual clusters within a species/site that showed problems with the MVNR included one white oak cluster at Emory River and one at Wayne County; one chestnut oak cluster at Emory River and one at LBL; one northern red oak cluster at LBL and one at Wayne County, and; one yellow-poplar cluster at Emory River. Other test statistics on these clusters did not indicate problems.

Graphical analysis of the cumulative sum of the prediction errors showed that all values were within their confidence limits. Also, graphs of error autocorrelations lagged up to five years showed varying amounts of autocorrelation, both negative and positive -- but in amounts considered negligible.

The cumulative sum of prediction errors statistic (C^*) showed no problems for any of the models developed for each of the clusters. The smallest probability value calculated for the chance of obtaining a larger C^* value was 0.0981 for LBL white oak cluster 3, well above an arbitrarily selected value of 0.05. The lowest minimum tolerance value calculated was 0.57 for Wayne County yellow-poplar cluster 4. This value indicates that there may be some multicollinearity problems

Table 17. Results of model misspecification tests: modified Von Neumann ratio (MVNR), cumulative sum of prediction errors statistic (C*), and minimum tolerance value for independent variables.

Cluster[1]	MVNR	MVNR interval	C*	Probability of larger C*	Minimum Tolerance
White oaks:					
E1	2.3090	1.5661 - 2.4339	-0.3801	0.7048	0.97
E2	1.8284	1.5113 - 2.4887	-0.7059	0.4828	0.59
E3	2.3027	1.5583 - 2.4417	-0.0155	0.9876	0.87
E4	2.4330	1.5609 - 2.4391	-0.2250	0.8225	0.87
E5	1.9478	1.5661 - 2.4339	-0.8197	0.4147	0.94
E6	2.2788	1.5609 - 2.4391	-0.9120	0.3644	0.82
E7	2.2216	1.5583 - 2.4417	-1.1109	0.2699	0.84
E8	2.6193	1.5712 - 2.4288	0.5969	0.5521	1.00
E9	2.3849	1.4920 - 2.5080	-0.3937	0.6952	0.93
L1	2.5121	1.5556 - 2.4444	-1.0398	0.3015	0.77
L2	0.9969	1.5661 - 2.4339	-1.0128	0.3140	0.89
L3	2.1534	1.5381 - 2.4619	-1.6753	0.0981	0.73
L4	2.0470	1.5583 - 2.4417	0.0631	0.9499	0.86
L5	2.3105	1.5609 - 2.4391	-0.5635	0.5746	0.88
L6	2.6575	1.5636 - 2.4364	-0.0426	0.9661	0.89
L7	2.5618	1.5500 - 2.4500	0.3221	0.7482	0.75
L8	2.5973	1.5636 - 2.4364	-0.2836	0.7775	0.88
L9	2.1108	1.5583 - 2.4417	-0.6881	0.4934	0.83
W1	2.4679	1.5609 - 2.4391	0.5127	0.6095	0.81
W2	2.2472	1.5471 - 2.4529	-0.7186	0.4746	0.65
W3	1.9397	1.5609 - 2.4391	-0.3606	0.7193	0.66
W4	2.1761	1.5556 - 2.4444	-0.8373	0.4049	0.74
W5	2.2921	1.5609 - 2.4391	-0.5780	0.5648	0.81
W6	2.2447	1.5661 - 2.4339	0.2977	0.7667	0.89
Chestnut oaks:					
E1	1.9578	1.5583 - 2.4417	-0.2378	0.8126	0.83
E2	2.4723	1.5609 - 2.4391	-0.2955	0.7683	0.88
E3	2.5779	1.5609 - 2.4391	-0.9840	0.3280	0.85
E4	2.2265	1.5609 - 2.4391	0.3947	0.6941	0.88
E5	2.2379	1.5442 - 2.4558	0.2514	0.8021	0.91
E6	2.0075	1.5661 - 2.4339	-1.2846	0.2024	0.94
E7	1.6643	1.5412 - 2.4588	-0.8811	0.3811	0.70

Table 17. Continued.

Cluster	MVNR	MVNR interval	C*	Probability of larger C*	Minimum Tolerance
L1	2.3329	1.5528 - 2.4472	-0.4625	0.6450	0.63
L2	2.2783	1.5661 - 2.4339	-0.3894	0.6980	0.78
L3	2.4344	1.5661 - 2.4339	0.3973	0.6921	0.86
L4	2.2310	1.5636 - 2.4364	-0.3665	0.7149	0.86
W1	1.9549	1.5500 - 2.4500	-0.6964	0.4882	0.60
W2	2.2516	1.5609 - 2.4391	0.7052	0.4827	0.84
W3	1.7881	1.5149 - 2.4851	1.4455	0.1527	0.68
Northern red oaks:					
E1	2.1776	1.5636 - 2.4364	0.0134	0.9893	0.94
E2	2.0123	1.5636 - 2.4364	-1.1004	0.2743	0.74
L1	2.4100	1.5556 - 2.4444	0.1770	0.8600	0.89
L2	2.8177	1.5000 - 2.5000	0.2270	0.8212	0.71
W1	1.1266	1.5636 - 2.4364	1.1416	0.2569	0.65
W2	2.1162	1.5687 - 2.4313	-0.0613	0.9513	0.82
W3	2.0069	1.5609 - 2.4391	0.5534	0.5815	0.99
Yellow-poplars:					
E1	2.0980	1.5636 - 2.4364	0.8610	0.3917	0.91
E2	2.5807	1.5636 - 2.4364	0.2801	0.7801	0.90
E3	2.2866	1.4453 - 2.5547	-1.1423	0.2587	1.00
E4	2.0638	1.5076 - 2.4924	-0.3043	0.7619	0.97
L1	1.8295	1.5318 - 2.4682	-0.4537	0.6514	0.63
W1	1.2454	1.3595 - 2.6405	0.6700	0.5069	0.78
W2	2.3398	1.4557 - 2.5443	-0.2177	0.8285	0.83
W3	2.4637	1.5500 - 2.4500	-0.0710	0.9436	0.90
W4	1.7202	1.4748 - 2.5252	-0.2144	0.8310	0.57

[1]Cluster identification consists of a letter designating study site: E = Emory River, L = Land Between the Lakes, and W = Wayne County; plus the cluster number within the site.

with this model. Most other tolerance values were satisfactorily high, indicating only slight problems with multicollinearity.

Dendroclimatic Modelling -

Kalman filter estimates of parameter values for each of the 54 tree-ring clusters indicated some interesting differences and similarities between species and overall time trends in the climate/growth relationship. All but three clusters showed a great deal of time-variability in climate parameter estimates. The clusters that appear to be time-stable include clusters 1 and 6 of the white oaks at Wayne County, and Wayne County northern red oak cluster 2 (see Appendix A). Changes in parameter coefficients over time were compared with graphs of monthly climatic data over time to determine if changes were coincident with trends in climate. No associations were determined.

For the most part, each cluster model revealed that through time, these trees become less sensitive to climate variables such as summer temperature and rainfall. For example, for Emory River white oaks, cluster one, the three-dimensional graph indicated decreasing sensitivity to both June temperature and past August rainfall (figure A3). The time axis extends from 1896 to 1986 and the different parameters are indicated on the bottom axis, with parameter coefficient values on the left axis. The first parameter is the intercept, b_0, which has a constant value of 0.021. June temperature is b_2 in this model, ranging from a low of -0.049 in 1914 up to -0.016 in 1986. Past August rain is b_4 and its coefficient value peaks in 1951 at 0.076, then

declines to 0.007 in 1986. Smaller coefficient values mean that climate variables have less of an effect on growth, thus the tree is less sensitive to climate. In many clusters the trend towards decreased sensitivity has been reversed for some variables, resulting in what appears to be a recent trend towards increasing sensitivity (see graphs of parameter coefficient estimates by year in Appendix A).

In the white oak clusters, June temperature seemed to be very significant, often for the whole time period analyzed (1895-1986), and time-varying with the overall trend towards less sensitivity which often changes towards increased sensitivity at the end of the time period. In the Emory River clusters, the coefficients for June temperature were significantly different from zero (at $P \leq 0.05$) for clusters 2 and 3 for the entire period and for the other clusters from the beginning of the time period until some time between the 1940s to 1970s (see tables A1-A9, Appendix A). The trend in June temperature was towards less sensitivity, with a change towards increased sensitivity apparent in eight of the nine clusters. Past August rain was important in each cluster except cluster 2, and continued to be significant to the most recent time period in each cluster except clusters 1 and 3, where it was not significantly different from zero since the early 1970s.

At Land Between the Lakes, white oaks were again very sensitive to June temperature, with significant coefficient values for the entire time period or beginning a few years into the time period and continuing to the present. The trend was generally towards less sensitivity although six of the nine clusters showed the reversed trend towards increased sensitivity (see three dimensional graphs,

Appendix A). Past December rain was significant in seven of the nine clusters, although often for a shorter period beginning in the 1930s to 1950s and ending in the late 1960s to early 1970s, characterized by an increase then a decrease in sensitivity.

June temperature was always significant for all of the Wayne County clusters of white oaks except cluster 5 which showed coefficients that were significantly different from zero only from 1941 through 1978 (tables A19-A24, Appendix A). Clusters 2, 4 and 5 showed the change in sensitivity to June temperature from less to more sensitive (see three dimensional graphs, Appendix A).

June temperature appeared to be an important predictor of chestnut oak tree growth, although not for as many of the clusters as in white oak. June temperature also seemed to be less time variant for chestnut oak than white oak, especially at the Emory River site where clusters 2, 3, and 4 showed no change in coefficient value through time (see three dimensional graphs, Appendix A). June rain was significant in five of the seven clusters beginning in the late 1920s to early 1930s and continuing through the late 1940s or early 1950s (tables A25-A31, Appendix A). Only cluster 5 showed the change in sensitivity to June temperature, although a similar trend was observed in June rain in five clusters and in September temperature in two clusters.

At Land Between the Lakes clusters 1 and 3 of the chestnut oaks had coefficient values for June temperature that were always significant yet showed no change in value over time (tables A32-A35, Appendix A). May rain was similar in

clusters 1 and 2; always significant yet not time-varying. Changes in sensitivity were apparent for June temperature in clusters 2 and 4.

June temperature was always significant with little or no change in value over time for chestnut oaks at Wayne County (tables A36-A38, Appendix A). May rain was significant with no change over time in clusters 1 and 3. Changes in sensitivity from less to more were seen in past August rain for cluster 1 and May temperature and January rain in cluster 2.

In the northern red oaks June rain seemed to be more important than temperature, and it was also less time variant. At Emory River, June temperature was significant from the beginning of the time period for cluster 2 (table A40, Appendix A) and later in the 1920s for cluster 1 (table A39, Appendix A), and discontinued with significant values in the 1950s for both clusters. Cluster 1 showed recent increased sensitivity to June temperature and past August rain. At LBL, June temperature was significant in cluster 1 until 1958 (table A41, Appendix A), and always in cluster 2 (table A42, Appendix A). There were no apparent reversals in sensitivity to climate. At Wayne County in cluster 1 of the northern red oaks, there was an unusual trend towards increasing sensitivity to June temperature throughout the entire time period (table A43, Appendix A). No parameters in Wayne County northern red oak growth models showed a reversal in sensitivity trends.

The yellow-poplars were much more variable in individual model response to climate than any of the other species, possibly due to the smaller sample size. At

Emory River, June rain was important in all clusters; always for cluster 2 and 4 (tables A47 and A49, Appendix A), and beginning in the 1930s for clusters 1 and 3 (tables A46 and A48, Appendix A). Cluster 1 showed a reversal in sensitivities in June temperature and June rainfall. In the one cluster at LBL, June rain was always significant with no change over time (table A50, Appendix A). June temperature was significant from 1911 until 1973, becoming less important over time. Each cluster at Wayne County behaved differently; January rain was always important in cluster 1 with no change over time (table A51, Appendix A); June temperature was always important in cluster 2, with no change over time (table A52, Appendix A); past July rain was important to cluster 3 throughout the time period with very little change over time (table A53, Appendix A), and; past March rain was significant to cluster 4 only from 1921 until 1938 (table A54, Appendix A). Cluster 3 showed a decrease then an increase in sensitivity to June temperature.

Trends in coefficient values for June temperature and past August rain were assessed for all clusters which incorporated these parameters in the dendroclimatic model. These variables were not always the most significant for each cluster, however, they were the most prevalent overall and therefore were used to gain insight into the general relationship between climate and tree growth. Figures 12-17 show the percentage of clusters that had a coefficient that was significantly different from zero by year. This graphical display provides an overview of what appears to be a general trend towards decreasing sensitivity to climate. In each graph except for past August rain in Wayne County (figure 17), there is first a trend

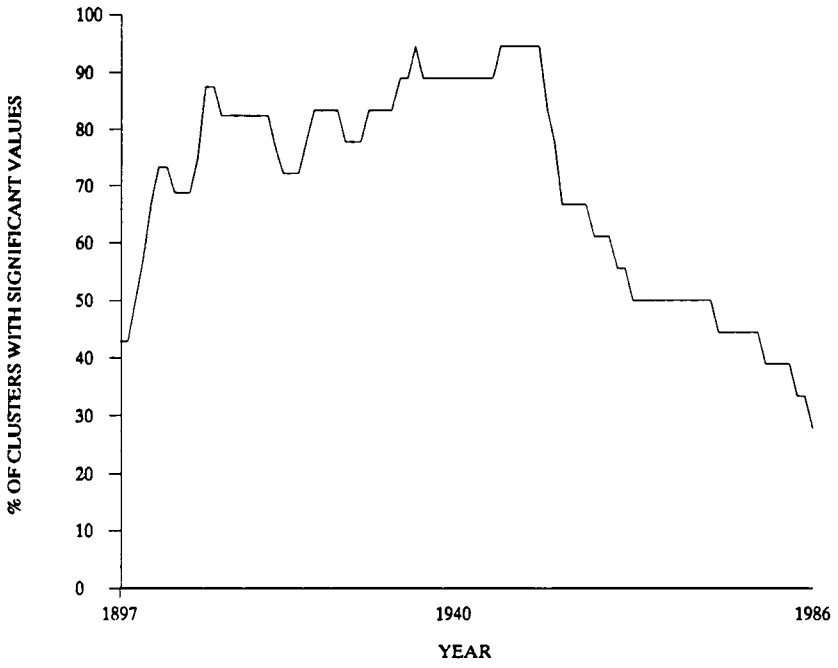


Figure 12. Percent of Emory River clusters with June temperature coefficients that are significantly different than zero by year.

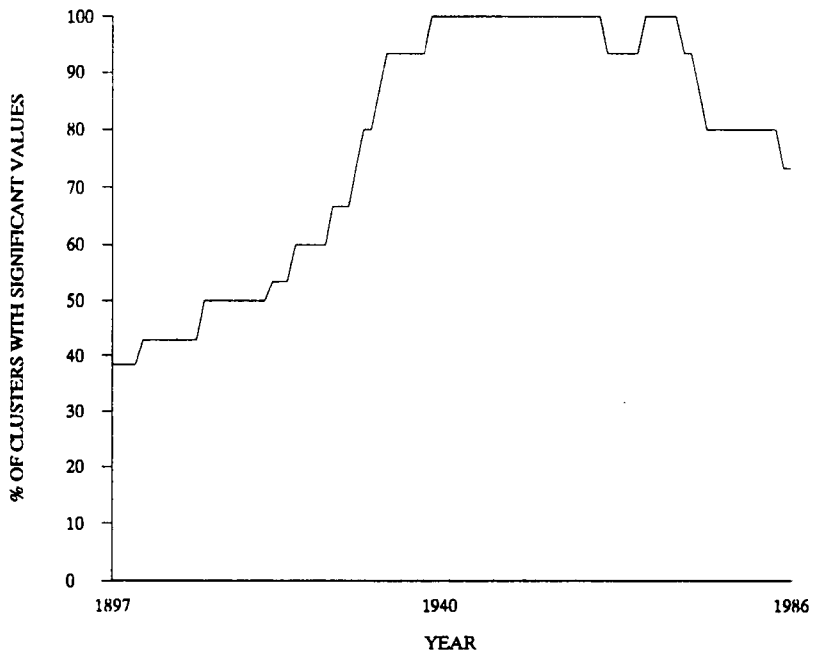


Figure 13. Percent of Emory River clusters with past August rain coefficients that are significantly different than zero by year.

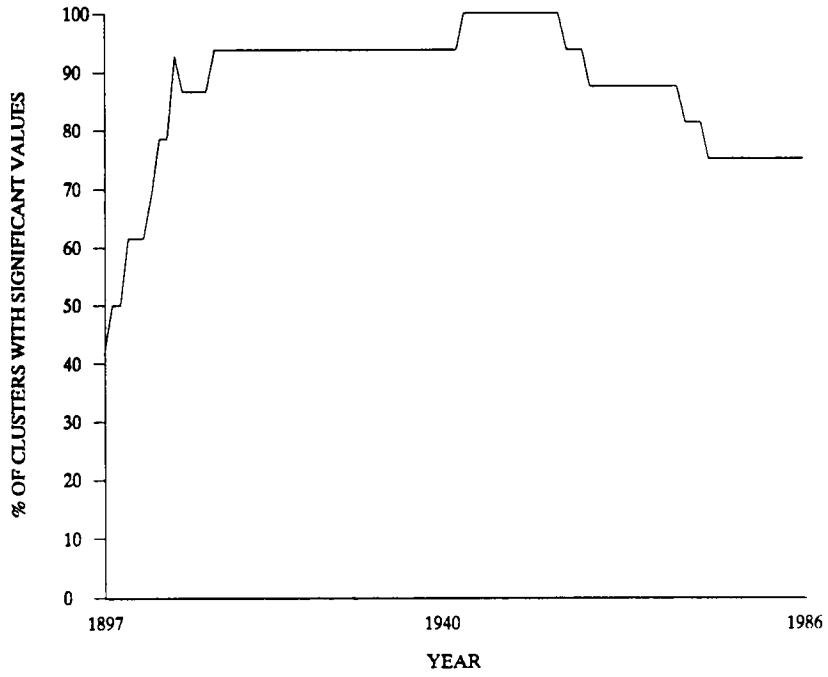


Figure 14. Percent of Land Between the Lakes clusters with June temperature coefficients that are significantly different than zero by year.

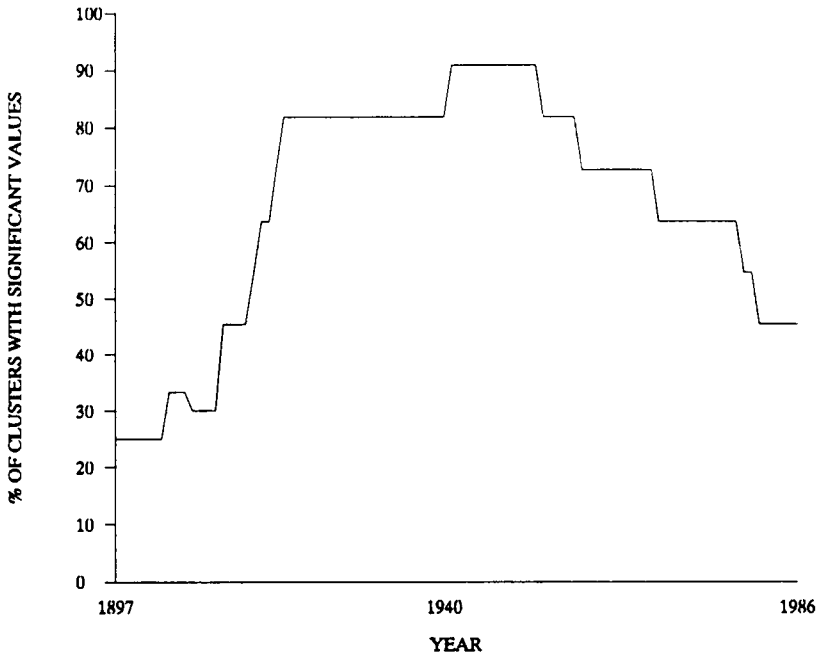


Figure 15. Percent of Land Between the Lakes clusters with past August rain coefficients that are significantly different than zero by year.

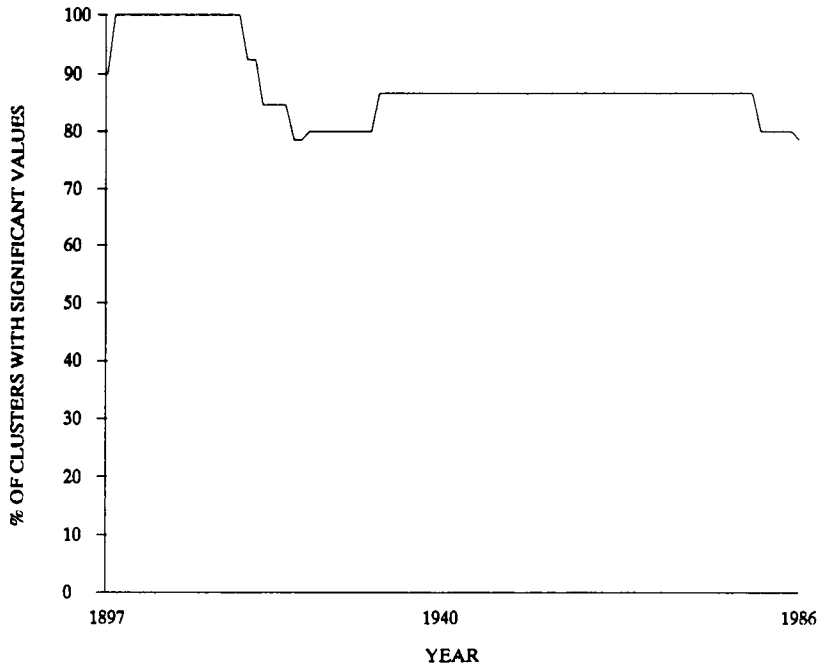


Figure 16. Percent of Wayne County clusters with June temperature coefficients that are significantly different than zero by year.

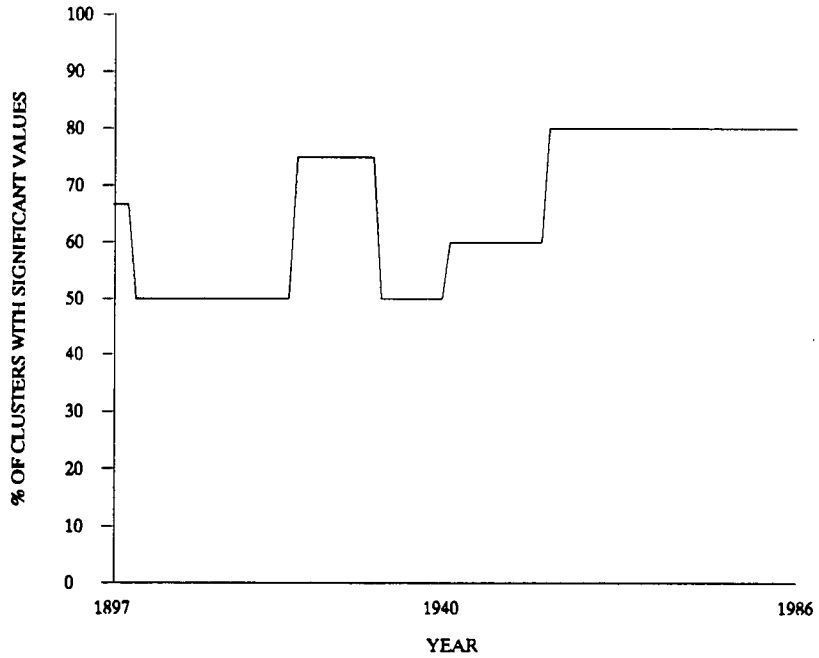
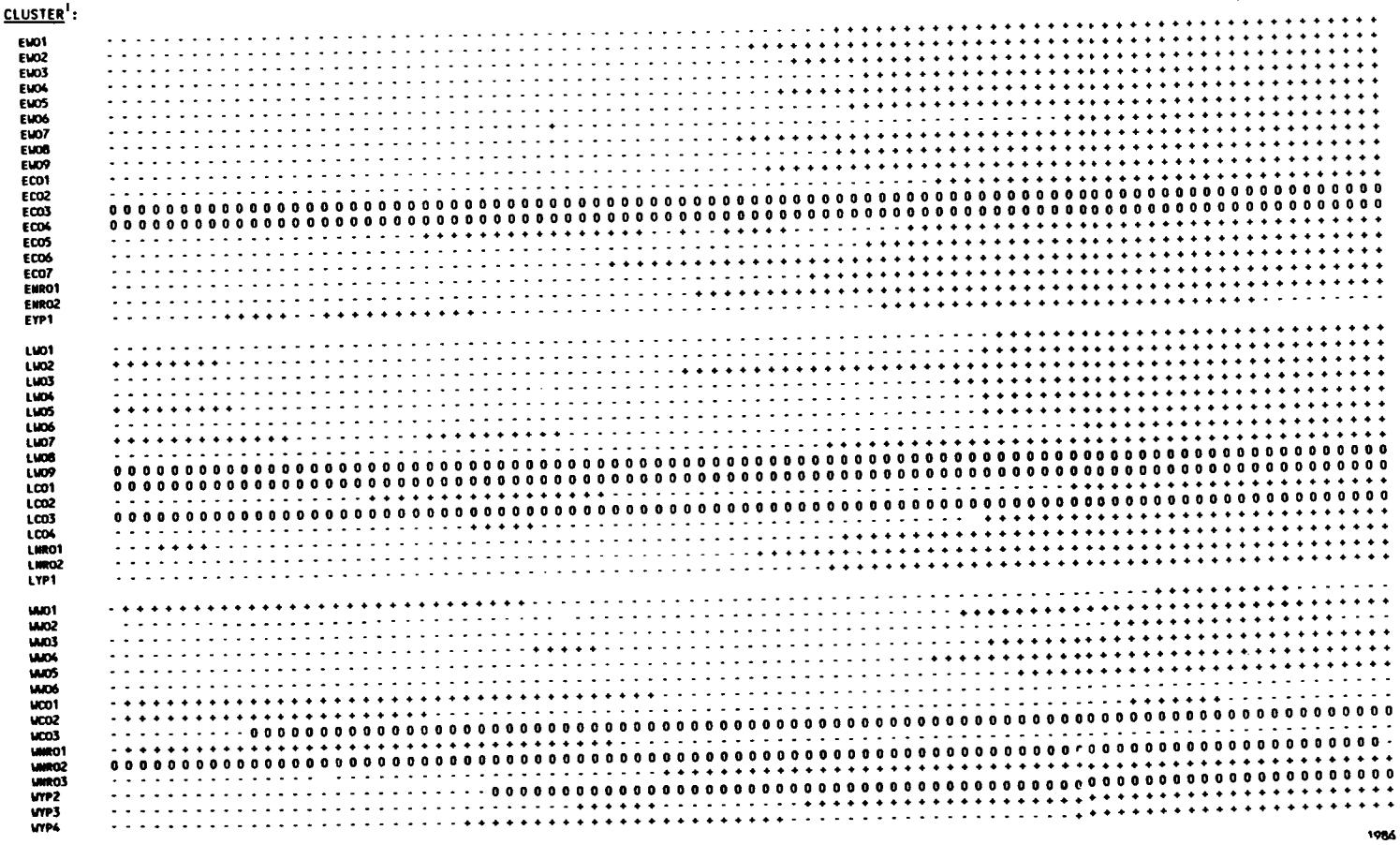


Figure 17. Percent of Wayne County clusters with past August rain coefficients that are significantly different than zero by year.

towards increasing significance in coefficient values, followed by a drop in the percent of clusters which included values that were significantly different from zero. The early low values reflect relatively wide confidence intervals for each coefficient value resulting from a large amount of variation between individuals. Later decreases in the percentages of significant values are associated with coefficient values that approach zero over time, reflecting a decreasing sensitivity to these climate variables for most trees.

A runs test was also done on June temperature and past August rain for those clusters in which these variables contributed to the explanation of variation in growth. Decreased sensitivity to June temperature is when there is a change towards less negative coefficients (relative to the mean value) (denoted by a plus sign), while a change towards more negative coefficients (denoted by a minus sign) means increased sensitivity. At Emory River, all clusters that exhibit temporal variation in coefficient value showed a trend towards decreasing sensitivity to June temperature that was significantly different than randomly produced changes in growth (figure 18). One yellow-poplar cluster (number 1) showed a reversal in this trend, towards increased sensitivity. Similar trends were observed for all species at LBL, except where there was no temporal variability in June temperature coefficients. At Wayne County, the pattern was more confused. All white oaks again showed a trend towards decreased sensitivity. Two clusters, chestnut oak number 1 and northern red oak number 1, showed a reversed trend, towards increased sensitivity.



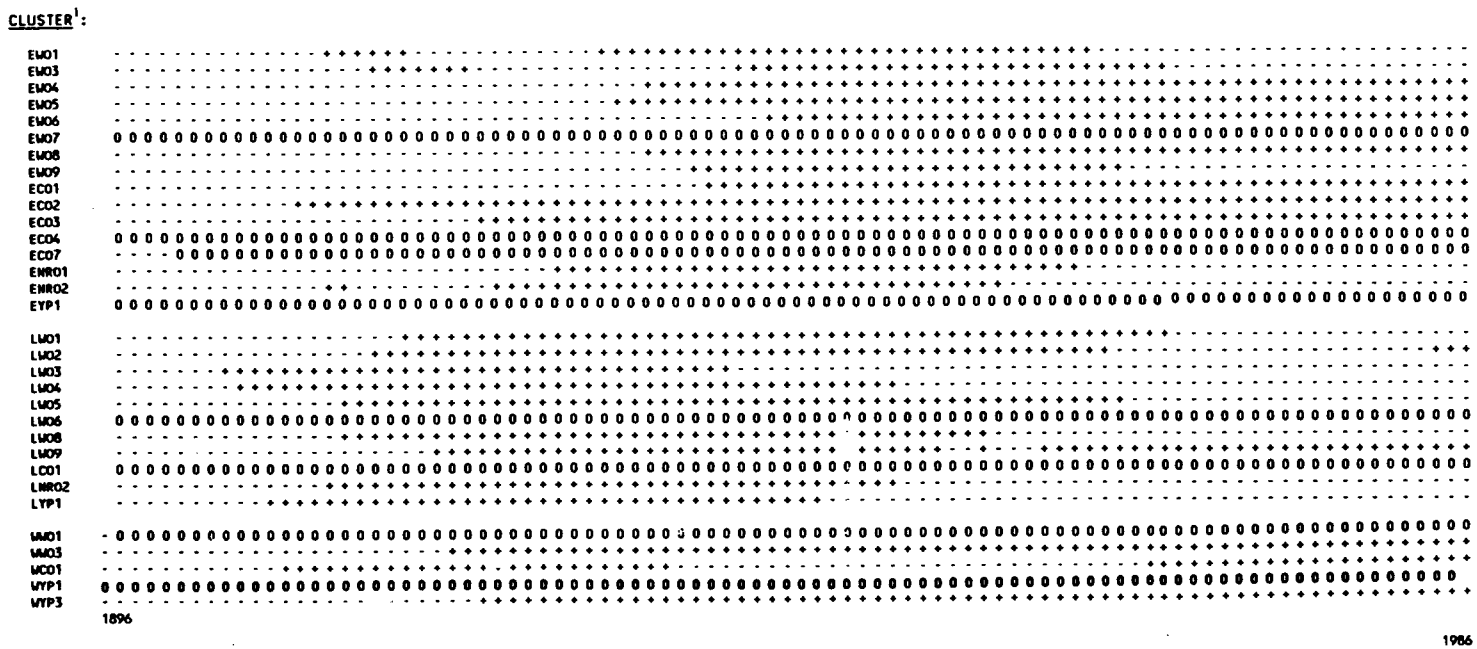
[1]Cluster identification consists of first a letter designating study site: E = Emory River, L = Land Between the Lakes, and W = Wayne County; plus two or three letters designating species: WO = white oak, CO = chestnut oak, NRO = northern red oak, and YP = yellow-poplar; plus the cluster number.

A "0" indicates that the parameter coefficient is steady over time; a "+" indicates that the parameter coefficient for a particular year is greater than the mean value of the coefficient; a "-" indicates that the parameter coefficient is less than the mean.

Figure 18. Runs in the time sequence of deviations from the mean for June temperature coefficients.

Changes in sensitivity to past August rainfall were not as apparent, although general patterns do exist. Decreased sensitivity to past August rain was signified by a less positive coefficient (denoted by a minus). A more positive coefficient (denoted by a plus sign) indicates increased sensitivity. No temporal variation was represented by zeros. Of the 16 clusters at Emory River, four showed no temporal variation, five showed a significant trend towards decreased sensitivity, and seven showed a trend towards increased sensitivity (figure 19). At LBL, all clusters except white oak number 9 showed a significant trend towards decreased sensitivity. In white oak number 5 there was a recent change towards increased sensitivity. Of the five clusters incorporating past August rain at Wayne County, two showed no temporal variability, and the remaining three showed increased sensitivity to this variable.

Recent changes in the general trend towards decreased sensitivity to all climate variables were observed in 30 clusters out of the total 54 (table 18). As the trend towards decreased sensitivity is exhibited as a change in coefficient value that approaches a zero value, a change in direction towards increased sensitivity in the last 10 to 25 years of a series rarely shows coefficient values that are significantly different than zero if a 95% confidence interval is considered. Therefore tests for the significance of this change in trend did not yet indicate that there was a change occurring. Additional data are needed to verify that this observed trend is not simply a random pattern of variation that may change back towards zero over time.



[1]Cluster identification consists of first a letter designating study site: E = Emory River, L = Land Between the Lakes, and W = Wayne County; plus two or three letters designating species: WO = white oak, CO = chestnut oak, NRO = northern red oak, and YP = yellow-poplar; plus the cluster number.

A "0" indicates that the parameter coefficient is steady over time; a "+" indicates that the parameter coefficient for a particular year is greater than the mean value of the coefficient; a "-" indicates that the parameter coefficient is less than the mean.

Figure 19. Runs in the time sequence of deviations from the mean for past August rain coefficients.

Table 18. Clusters which show recent increases in sensitivity to climatic variables and dates of apparent change in coefficient trends.

Cluster[1]	Variable	Date
ERWO3	August temperature	1962
ERWO4	June temperature	1974
ERWO5	June temperature	1965
	June rain	1969
ERWO6	June temperature	1974
ERWO8	June temperature	1977
ERWO9	June temperature	1962
LBLWO1	June temperature	1974
LBLWO2	June temperature	1979
LBLWO4	June temperature	1973
LBLWO5	June temperature	1979
LBLWO6	June temperature	1973
LBLWO7	June temperature	1973
LBLWO8	May temperature	1964
	past August rain	1973
WCWO2	June temperature	1979
	past December temperature	1964
	past May rain	1970
WCWO4	June temperature	1979
ERCO1	June rain	1968
ERCO2	September temperature	1966
ERCO3	June rain	1968
ERCO5	June rain	1959
ERCO6	July rain	1964
ERCO7	September temperature	1963
	June rain	1968
LBLCO2	June temperature	1973
LBLCO4	June temperature	1976
WCCO1	past August rain	1950
WCCO2	May temperature	1951
ERNRO1	June temperature	1979
LBLNRO1	past April temperature	1976
ERYP1	June temperature	1974
ERYP2	July rain	1968
WCUP3	June temperature	1979

[1]Cluster identification consists of the first letter designating study site: E = Emory River, L = Land Between the Lakes, and W = Wayne County; plus two or three letters designating species: WO = white oak, CO = chestnut oak, NRO = northern red oak, and YP = yellow-poplar; plus the cluster number.

Discriminant Analysis -

Discriminant analysis based on environmental variables collected in the study was generally successful in reclassifying tree-ring clusters. Total error count estimates ranged from 0% for northern red oaks at LBL, up to 75% for chestnut oaks at Emory River (table 19). Overall, site statistics outperformed individual tree statistics in discriminatory power, and when analyzed as multivariate data, presence and predominance of competing species was the most important factor influencing tree-ring groupings.

Univariate statistics for Emory River white oak indicated that basal area of mortality trees, northern red oak frequency, injury due to fire and animals, and presence of a fragipan influenced cluster groupings (table B1, Appendix B). The highest R^2 value for individual variables was for the presence of a fragipan at 0.21 followed by injury due to animals at 0.16. Standardized canonical coefficients were greatest for white oak frequency and importance, yellow-poplar frequency and importance, chestnut oak frequency and importance, northern red oak frequency and importance, and presence of a fragipan (table B2, Appendix B).

Univariate statistics for white oaks at LBL indicated that aspect, northern red oak frequency, the importance value and frequency of yellow-poplar, presence of weather damage, forest stand improvement, elevation, and size and age of the individual tree were significant in determining cluster groupings. The highest R^2 for one-way analysis of variance was for elevation at 0.24, followed by texture of the A and E horizon at 0.17 (table B3, Appendix B). Canonical coefficients for the first

Table 19. Error count estimates (percent) for linear discriminant functions on non-tranformed data.

Species/Site[1]	Cluster # 1	2	3	4	5	6	7	8	9	Total
White oaks										
ER	50	25	29	41	60	50	0	26	33	42
LBL	15	56	11	44	33	35	53	32	28	36
WC	23	26	30	26	40	24				27
Chestnut oaks										
ER	54	63	60	52	63	53	75			57
LBL	50	47	11	23						28
WC	7	27	22							14
Northern red oaks										
ER	21	20								21
LBL	0	0								0
WC	6	8	22							10
Yellow-poplars										
ER	25	32	37	32						30
LBL	-									-
WC	0	11	43	27						20

[1]ER = Emory River; LBL = Land Between the Lakes; WC = Wayne County.

canonical variable indicate that when interactions between variables are considered, white oak frequency and importance, yellow-poplar frequency and importance, and soil texture in the A and E horizon are the most important variables (table B4, Appendix B).

Wayne County white oaks had a number of significant univariate variables, including: topographic site, slope, aspect, basal area of mortality trees, white oak frequency and importance, yellow-poplar frequency and importance, presence of injury due to fire, elevation, and texture of the B horizon (table B5, Appendix B). The highest R^2 value was obtained from injury due to disease at 27%, followed by elevation at 21%. Standardized canonical coefficients indicate that white oak frequency and importance, northern red oak frequency and importance, yellow-poplar frequency and importance, current basal area, and elevation were important factors (table B6, Appendix B).

At Emory River, chestnut oaks had no significant univariate statistics at the 0.05 level; the most significant variable was the prism count done for core trees at $P \leq 0.0561$ (table B7, Appendix B). Prism count also had the highest R^2 value at 0.05. Canonical variables were not significant; however, coefficients for the first canonical variable showed the greatest contribution to cluster groupings was northern red oak frequency and importance, topographic site, and presence of an argillic horizon (table B8, Appendix B).

Chestnut oak groupings at LBL were influenced by aspect, chestnut oak frequency and importance, texture of the A and E horizon, average basal area

increment, presence of injury due to fire and insects, and presence of a fragipan, when these variables are considered individually (table B9, Appendix B). Canonical coefficient values indicated that white oak frequency and importance, northern red oak frequency and importance, chestnut oak frequency and importance, and aspect were influential in forming tree-ring clusters (table B10, Appendix B).

At Wayne County, almost no variables were useful in determining chestnut oak clusters when considered individually; injury due to animals and elevation were significant at $P \leq 0.05$ (table B11, Appendix B). Canonical coefficients indicated that northern red oak frequency and importance, yellow-poplar frequency and importance, white oak frequency and importance, aspect, topographic site, and presence of injury due to insects were important (table B12, Appendix B).

Univariate statistics were significant for Emory River northern red oak variables including frequency and importance of chestnut oak, and elevation (table B13, Appendix B). Elevation had the highest R^2 value at 0.16. Standardized canonical coefficients indicated that chestnut oak frequency and importance, northern red oak frequency and importance, yellow-poplar importance, elevation, depth and texture of the A and E horizon were important in cluster groupings (table B14, Appendix B).

No variables were significant when considered univariately for LBL northern red oak. However, white oak importance gave an R^2 value of 24% followed by white oak frequency at 20% in explaining cluster groupings (table B15, Appendix B). Important variables as determined from the standardized canonical coefficients

included current basal area, size of the trees on the plot, basal area of mortality trees, slope, topographic site, and aspect (table B16, Appendix B).

Univariate statistics for Wayne County northern red oak indicated that current stand basal area, and white oak frequency and importance were significant in determining cluster groupings (table B17, Appendix B). The highest R^2 value obtained was for white oak importance at 38% variance explained. Canonical coefficients indicated that white oak frequency and importance, yellow-poplar frequency and importance, chestnut oak frequency and importance, northern red oak frequency and importance, grazing damage, and aspect were important classification criteria (table B18, Appendix B).

Univariate statistics for Emory River yellow-poplar indicated that northern red oak frequency and dominance, injury due to disease, and elevation were influential in groupings (table B19, Appendix B). Northern red oak importance had the highest R^2 value at 0.08. Canonical coefficients indicated that chestnut oak frequency and dominance, yellow-poplar frequency and dominance, white oak frequency and dominance, aspect, basal area of dead trees, and depth and texture of the B horizon were important variables (table B20, Appendix B).

A discriminant analysis was not done for LBL yellow-poplar as only one cluster was formed from the standardized chronologies from that site. At Wayne County, almost no variables were significant in the one-way ANOVA's; the individual tree prism count had the highest significance level at $P \leq 0.0137$ (table B21, Appendix B). Prism count also had the highest R^2 value at 25%.

Standardized canonical coefficients were greatest for chestnut oak frequency and importance, white oak frequency and importance, slope, current stand basal area, basal area of cut trees, basal area of mortality trees, and individual core tree age (table B22, Appendix B).

V. DISCUSSION AND CONCLUSIONS

The literature on forest tree growth indicates that there is a great deal of both temporal and spatial variability in tree growth response to climate, and that reasons for the variability are not obvious. The results of this study were similar to those reported in the literature. Temporal variability in the growth response to climate can be generally characterized as a trend towards decreased sensitivity to climate that apparently occurs primarily as a result of stand development rather than as a function of changes in individual trees. Spatial variability was profound, occurring in part as a result of changes in site conditions and potentially as a function of competitive interactions among individual trees of different species. Environmental factors were generally useful in explaining similarities in growth response to climate among individual trees, as long as interactions between factors were incorporated into the analysis. Use of additional site variables, information specific to individual trees, and more detailed climate data might provide a better understanding of what response to climate might be expected under various combinations of environmental factors. In the absence of detailed information on a tree's growing environment, it seems appropriate to utilize tree-ring analysis methodologies that do not require *a priori* decisions about which factors are important in producing differences in tree growth response and that allow greater flexibility in statistical assumptions, both in the time-variability aspect of models

which are produced, and in the potentially dynamic nature of variation of individual trees.

Dendroclimatic modelling using the Kalman filter provides yearly estimates of the climate parameters, updated using each new year's data with an adjustment based on the error in estimation from the previous year. Thus, as would be expected, predicted tree growth is very close to actual, though often not quite coinciding with the very high or low values that are in the real data. The Kalman filter does provide information on when climatic variables are significant by taking into consideration the variation among individuals, and also provides insight into the dynamic relationship that exists between closed canopy trees and weather. Resulting models can provide information on the effects of changing stand conditions (Van Deusen 1989) or various environmental stresses on tree growth (Visser and Molenaar 1987).

The fifty-four models that were developed for the clustered groups of tree-ring data show that a great deal of temporal variability exists in estimates of growth obtained from climatic variables. Changes in model parameter estimates were not found to be related to short-term trends in climate variables. In general, trends observed were a gradual desensitization to climate -- seen either in a negative coefficient, such as June temperature, becoming less negative over time, or in a positive coefficient, such as August rainfall, becoming less positive. Tests to determine if trends in coefficient values over time were significant indicate that patterns of change are not due to random variation in yearly values, but instead

reflect a steady trend towards decreased sensitivity. This might be expected due to the tree's maturation which includes development of an extensive root system that makes it less susceptible to drought as it is better able to exploit soil moisture reserves (Waring and Cleary 1967), and stand development that modifies climatic extremes through increased shading and structural changes that affect wind pattern and velocity.

Greater sensitivity to climate in the early part of a tree-ring chronology can also be seen as greater variability in year to year increment. Standardized annual increments for every cluster studied revealed that changes in relative growth rate were much greater in the first part of the chronology; current fluctuations appear to have leveled off relative to the past. This is probably more a function of changing stand conditions rather than changes in individual trees as core tree age was not a significant factor in determining groupings of trees and each cluster included individuals from many age classes. Others have also concluded that stand dynamics influence variability in tree growth response to climate, particularly in how trees of one age class behave differently according to differences in stand structure (Van Deusen 1989; Federer and Hornbeck 1986). Most of the forests of the Tennessee Valley region are second-growth stands that have developed after extensive harvesting that occurred throughout the region in the first quarter of this century and later (Groton and Brooks 1987). As such, in the earlier part of most tree-ring series, stands were usually understocked. Following increased fire protection and better management practices, increased stocking levels have resulted

in less intense temperatures and reductions in loss of potential soil moisture available for tree growth through evaporation or runoff. Thus, fewer temperature extremes and reduced rainfall loss result in a smaller fluctuations in growth.

Another interesting phenomenon that was observed in models developed for clusters that exhibited temporal variability was that the climate variables that change over time were often paired. This was observed particularly in white oak, where a change in sensitivity to June temperature was associated with a change of similar magnitude in response to August rainfall. As the trees become less impacted by the negative effects of a hot June, the effects of August rainfall become less beneficial. Changes towards increased sensitivity to summer temperature were likewise associated with changes towards higher coefficients for later summer precipitation.

The majority of tree-ring clusters (30 out of the 54) showed a change in the trend of decreasing sensitivity to climate in recent years. Although the current climate variables are most often not significantly different from zero because the trend in these variables has been an approach towards zero through the years, parameter estimations consistently show a reversal towards increasing sensitivity in the last ten to twenty-five years in these clusters. This is supported by other tree-ring studies designed to assess forest health; the FORAST study (McLaughlin et al. 1985) found an apparent increased sensitivity to climate in a number of species, and recent investigations into the growth of red spruce in the Southern Appalachians also concluded that there had been a shift towards increasing climate sensitivity (Van Deusen 1988; Cook 1988). No reason for this change in relationship was

observed: coincident changes were not apparent in the graphs of monthly precipitation or temperature values through the period 1895 -1986, and no widespread, synchronous change in forest stand structure occurred. One possible explanation is that there has been a change in climate that is not apparent in monthly values of temperature and precipitation. A shift in timing of extremes or a change in the variance associated with mean values could effect a response which could then be evaluated as a change in sensitivity to the data that are used to perform the analyses.

A great deal of spatial variability was also observed in the tree-ring series. Obviously, there is spatial variation on a large scale when comparing a species from site to site. Most models developed for different clusters within a species included similar climatic variables, particularly those variables that were most significant in explaining variation in growth, as determined using stepwise regression. However, less significant variables differed substantially by site. For example, June temperature was almost always the most significant variable influencing white oak growth. Variables that were less important but included in the individual cluster models were late spring and early summer rains at Emory River, and previous December rain at LBL, while at Wayne County, each cluster had a different set of parameters that entered after June temperature. Similar trends were observed in the other species at the three sites. One possible reason for changes in the parameters chosen for each model is that there are localized fluctuations in the climate data, particularly in precipitation values. The data used in this study

actually serves as a surrogate for climatic fluctuations that occur at the site. The data that are used also are not necessarily designed to reflect biological processes; i.e. rainfall from a period beginning in late May and ending in early June may have more biological significance than either May or June rain.

Comparisons of mean chronologies using correlation analysis indicated that white oak at Emory River was more variable in annual growth than the other two sites. The growth patterns of white oaks in Wayne County and at LBL were more similar to each other than to Emory River; and Emory River white oaks were more similar to LBL white oaks than to those in Wayne County. The growth patterns of chestnut oaks were similar across sites to those of white oaks, with LBL and Wayne County being the two more similar sites in terms of chestnut oak growth. However, for northern red oak, Emory River was more similar to Wayne County than either of the two were to LBL. Yellow-poplar behaved the same as northern red oak; Emory River trees were more similar to Wayne County trees than either were to LBL trees.

Spatial variability was also pronounced when examined on a much smaller scale, down to sites which showed a great deal of heterogeneity in tree growth on one plot. Based on the number of plots for which all sampled trees were grouped into the same cluster, this small-scale site variability was much more pronounced among both white oaks and chestnut oaks at the Emory River site, while white oaks showed similar amounts of homogeneity at Wayne County and LBL, and chestnut oak growth was much less variable at LBL than at Wayne County. The growth of

northern red oak and yellow-poplar were more homogeneous at Emory River and Wayne County and LBL, although the sample size for yellow-poplar at LBL was very small. A possible factor influencing this observed variability might be how well suited the species is to its site. Other studies have related site quality for a particular species to variability in growth response to climate (Estes 1970; Ermich et al. 1976) explaining that trees growing on poor sites are more susceptible to other stresses. The abundance of yellow-poplar at Emory River indicates that it particularly well-suited to this site, which has higher annual precipitation and cooler average annual temperatures than the other sites, and it responds to climate in a somewhat uniform manner relative to the other sites where it is less abundant. The same situation can be seen for white oak at LBL. It is the most abundant species at this site, and occupies a much larger proportion of the forest than at Emory River or Wayne County. White oak within a forest stand at LBL responds much more uniformly to climate than white oak at Wayne County or Emory River.

Discriminant analysis using environmental factors to classify individual trees into the cluster groupings determined from standardized series of annual increment was surprisingly successful considering the amount of spatial variability that occurred. Of course, the success of the discriminant analysis might be influenced by the size of the clusters. An increase in cluster size might result in increased success in reclassifying trees using environmental factors, as one would expect more trees with similar site conditions to be grouped in a cluster. However, within the size constraints of the software used, valuable information was obtained on which

environmental factors were most important in producing similarities in growth response and the possible influence of these environmental factors on both temporal and spatial variability in growth response to climatic fluctuations.

Overall the most important factors influencing tree-core groupings seemed to be the frequency and importance value of the species under consideration and the frequency and importance value of other species that occur in association with that species. This suggests that differences in species' response to climate may be the result of competitive interactions that occur within the mixed species forest. Doyle (1983) also found that changes in competitive interactions were related to changes in response to climate stress. This supports the observation that a species is more homogeneous in its response to climate on those sites to which it is well suited -- these would also be sites where that species would have a competitive advantage.

Competitive interactions did not appear to be important for northern red oak at LBL. Variables that did show some discriminatory ability included current stand basal area, size of the trees in the stand, basal area of mortality trees, and topographic site and aspect. These variables may suggest a difference in drought resistance. It has been observed that mortality of red oaks at LBL has been unusually high in the last few years, following a period of extended drought, while volume of white oak has increased (Groton, Field, and Pullin 1988). Similar changes were not apparent at the other study sites.

In addition to frequency and importance of chestnut oak and white oak, yellow-poplar series at Wayne County seem to be grouped based on current basal area, basal area of both cut and mortality trees, and core tree age. This suggests that a difference in degree or timing of disturbance may be influencing yellow-poplar response to climate at this site. Establishment of yellow-poplar is much more recent at the Wayne County site, as evidenced by shorter chronologies. Yellow-poplar is a pioneer tree, but once established as a major component of a more mature stand (as the majority of trees at the other sites are), changes in growth pattern appear to be more influenced by stand dynamics, similar to other species.

For species that are suited to a particular site it appeared that after competitive pressures were accounted for at the site, soil characteristics provided further definition of differences in growth pattern. White oak groupings at LBL were influenced by the texture of the A and E horizon, yellow-poplar at Emory River was influenced by the depth and texture of the B horizon, and northern red oak at Emory River was influenced by the depth and texture of the A and E horizon. These relationships probably reflect the moisture holding capacity of a soil or the sensitivity of a soil to drought. Indices of moisture holding capacity have been used successfully to account for variation in growth in addition to straight climate variables (Bassett 1964; Arp and Manasc 1987; Zahner 1987; Kim and Siccama 1986). Texture and depth of soils within the rooting zone of a tree can

buffer or exaggerate climatic extremes based on how quickly the soil dries out or responds to changes in temperature.

This research has shown that temporal and spatial variability in tree growth response to climate can be substantial in mixed species hardwood forests and should be considered in any study designed to assess growth trends using tree-ring analysis. The methodologies utilized in this study provide an objective means of grouping tree-ring series and an efficient method for developing growth models. Differences in grouping criteria have been known to result in models that include different climate variables and which perform differently in explaining variation (McLaughlin et al. 1986). Past studies have found poor relationships between growth and climate, based on chronologies collected from a number of trees within what is considered a homogeneous stand (Cook and Cole, in prep.; McLaughlin et al. 1986; Bartlein et al. 1986), but which may in fact exhibit a great deal of variability that obfuscates any relationship that exists. Cluster analysis provides a means of grouping tree-ring series that does not require an evaluation of conditions that influence site homogeneity. By objectively grouping tree-ring series based on similarities in relative growth rates over a period of time, variation among individuals is reduced and resulting dendroclimatic models are superior in their capacity to emulate changes in growth that result from climatic fluctuations. Cluster groupings utilized in this study were demonstrably different in their relationships with climate and confidence intervals calculated for grouped chronologies indicated that variation among individuals within a cluster was minimal.

The use of stepwise regression to select climate variables was judged to be satisfactory under the constraints of a very large data set and limited time to perform analyses. Tests of model misspecification generally showed no discernible problems, and similarities in the choice of variables among clusters provided a form of model validation through the use of independent data sets. However, some of the models developed in this manner may be questionable in that they included variables that were never significantly different from zero when variation among individuals was considered. In addition, there is the potential that parameters that are significant for only a short period of time may be essentially overlooked when using a mean chronology and years as observations. Use of a variable selection technique that incorporates variation among individuals and allows for time-varying parameters would be preferable where time and resources allow.

The research conducted in this study could be enhanced by several additional analyses. The observed change in sensitivity to climate could be investigated with more detailed climate data that contains information on variation of mean monthly temperature values, and timing and duration of total monthly precipitation. These data could then be used in model development to determine if the more recent change in sensitivity is real or simply a function of the climate data. The effects of changes in species and size of competing trees on growth sensitivity to climate could also be evaluated by incorporating more detailed information on individual core trees, and possibly historical plot reconstruction using the inventory data and tree increment cores for all trees on the plot.

Additional testing of the validity of climate variable selection using stepwise regression is suggested, perhaps through additional comparisons with other selection techniques. Although tests of model misspecification indicate little problem with the models that were developed in this study, consideration of the effects of variation among individuals may result in a totally different model than one in which a mean chronology is used to represent a number of individuals.

The relationship between tree growth and climate appears to be strongest in young forest stands, declining over time as the developing stand buffers climatic extremes and interactions between individuals and other environmental factors increase in importance. Spatial variability in sensitivity to temperature and precipitation occurs on a variety of scales, but seems to increase as site suitability for a particular species decreases. This effect is manifested through differences in competitive interactions, where an individual species has less competitive advantage on sites to which it is not well suited.

Questions remain about the effects of extreme climate events and changes in seasonality, particularly in their influence on observed increases in sensitivity to climate. Until the factors affecting the tree growth/climate relationship can be further defined, use of analytical techniques that assume temporal stability of, or spatial homogeneity among tree-ring series should be avoided.

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APPENDICES

APPENDIX A

Results of Dendroclimatic Modelling

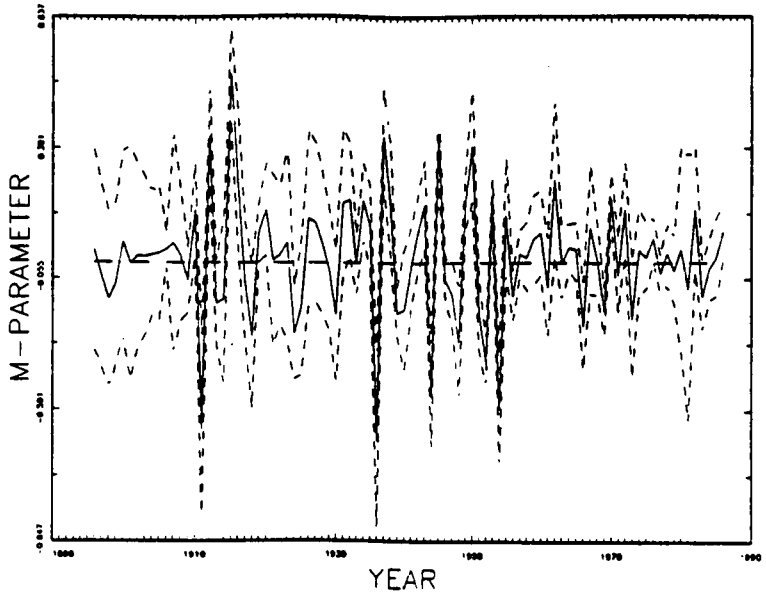


Figure A1. Graph of M-parameter and associated 95% confidence interval over time. Emory River white oak, cluster 1.

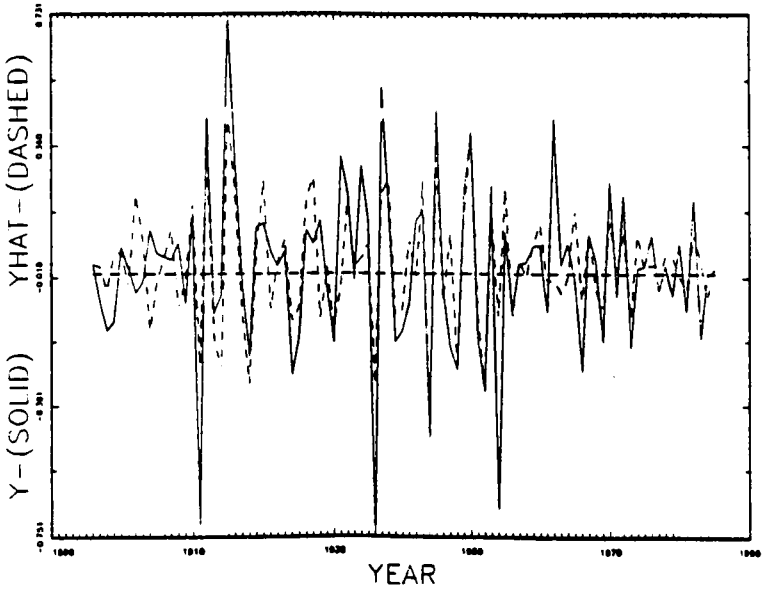
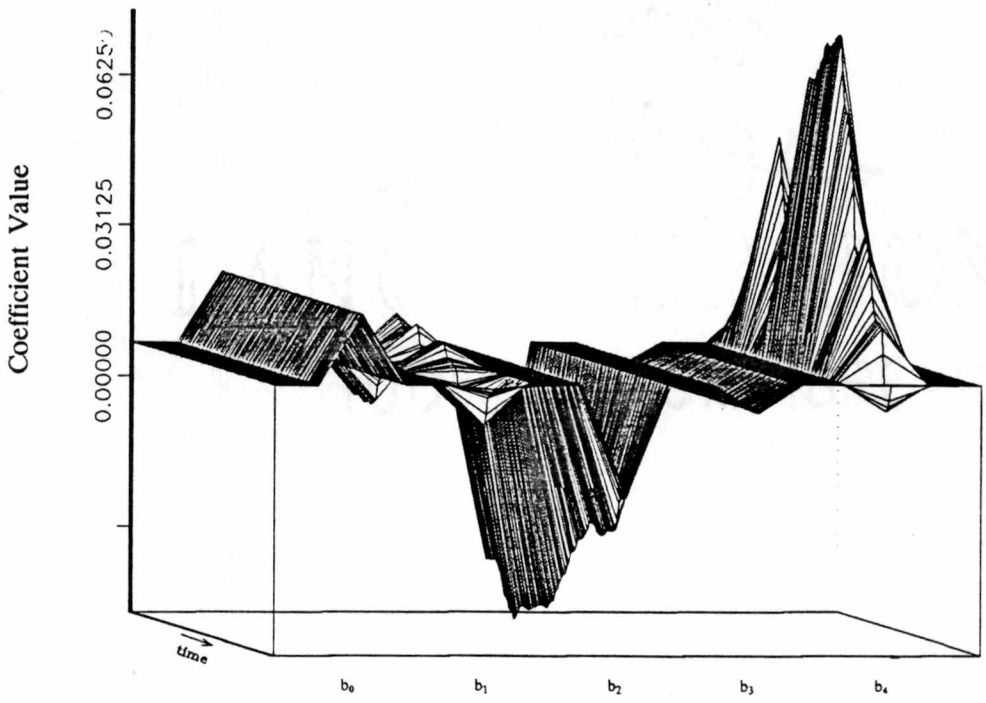


Figure A2. Graph of predicted and actual standardized growth, Emory River white oak, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = January temperature
b_2 = June temperature
b_3 = past February temperature
b_4 = past August rain

Figure A3. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 1.

Table A1. Climate parameter estimates for Emory River white oak, cluster 1.

YEAR	January temperature b_1	June temperature b_2	Past February temperature b_3	Past August rain b_4
1897	-0.004	-0.038	0.002	0.014
1898	-0.003	-0.038	0.002	0.014
1899	-0.004	-0.038	0.002	0.015
1900	-0.004	-0.038	0.002	0.016
1901	-0.004	-0.038*	0.002	0.017
1902	-0.004	-0.038*	0.002	0.024
1903	-0.005	-0.038*	0.002	0.026
1904	-0.004	-0.039*	0.002	0.029
1905	-0.004	-0.040*	0.002	0.031
1906	-0.004	-0.040*	0.002	0.031
1907	-0.005	-0.043*	0.002	0.036
1908	-0.004	-0.044*	0.002	0.038
1909	-0.004	-0.045*	0.002	0.039
1910	-0.004	-0.045*	0.002	0.040
1911	-0.001	-0.047*	0.002	0.046
1912	0.000	-0.047*	0.002	0.047
1913	0.001	-0.047*	0.002	0.047
1914	0.003	-0.049*	0.002	0.051
1915	0.005	-0.048*	0.002	0.049
1916	0.007	-0.047*	0.002	0.043
1917	0.009	-0.047*	0.002	0.040
1918	0.012	-0.046*	0.002	0.034
1919	0.012	-0.045*	0.002	0.034
1920	0.013	-0.045*	0.002	0.034
1921	0.013	-0.045*	0.002	0.031
1922	0.014	-0.046*	0.002	0.030
1923	0.015	-0.046*	0.002	0.026
1924	0.015	-0.046*	0.002	0.027
1925	0.015	-0.045*	0.002	0.028
1926	0.014	-0.045*	0.002	0.029
1927	0.013	-0.045*	0.002	0.033
1928	0.013	-0.045*	0.002	0.040
1929	0.013	-0.044*	0.001	0.046
1930	0.013	-0.044*	0.001	0.052*
1931	0.013	-0.044*	0.001	0.060*
1932	0.013	-0.044*	0.001	0.064*
1933	0.013	-0.044*	0.001	0.065*
1934	0.013	-0.044*	0.001	0.065*
1935	0.013	-0.044*	0.001	0.065*
1936	0.014*	-0.043*	0.001	0.065*
1937	0.013*	-0.043*	0.001	0.066*
1938	0.010*	-0.043*	0.001	0.067*
1939	0.010	-0.042*	0.001	0.068*
1940	0.008	-0.041*	0.001	0.069*
1941	0.008	-0.040*	0.001	0.070*
1942	0.008	-0.039*	0.001	0.071*
1943	0.008	-0.039*	0.001	0.073*
1944	0.009	-0.037*	0.001	0.074*
1945	0.009	-0.037*	0.001	0.073*
1946	0.009	-0.036*	0.001	0.073*
1947	0.010*	-0.036*	0.001	0.073*
1948	0.012*	-0.034*	0.001	0.074*
1949	0.012*	-0.034*	0.001	0.074*
1950	0.012*	-0.032*	0.001	0.075*
1951	0.012*	-0.031*	0.001	0.076*

Table A1. Continued.

YEAR	b_1	b_2	b_3	b_4
1952	0.012*	-0.031*	0.001	0.076*
1953	0.012*	-0.031*	0.001	0.076*
1954	0.011	-0.029*	0.001	0.069*
1955	0.010	-0.028*	0.001	0.062*
1956	0.009	-0.028*	0.001	0.061*
1957	0.009	-0.028*	0.001	0.060*
1958	0.009	-0.027*	0.001	0.057*
1959	0.008	-0.027*	0.001	0.053*
1960	0.008	-0.026*	0.001	0.050*
1961	0.007	-0.025*	0.001	0.045*
1962	0.005	-0.024*	0.001	0.033
1963	0.004	-0.024*	0.001	0.031
1964	0.004	-0.024*	0.001	0.031
1965	0.004	-0.024*	0.001	0.032
1966	0.002	-0.024*	0.001	0.032
1967	-0.001	-0.025*	0.001	0.034*
1968	-0.001	-0.026*	0.001	0.036*
1969	-0.002	-0.026*	0.001	0.035*
1970	-0.002	-0.026*	0.001	0.034*
1971	-0.002	-0.026*	0.001	0.032*
1972	-0.002	-0.025*	0.001	0.029
1973	-0.003	-0.025*	0.001	0.024
1974	-0.003	-0.024*	0.001	0.021
1975	-0.002	-0.024*	0.001	0.019
1976	-0.002	-0.024*	0.001	0.019
1977	-0.002	-0.024*	0.001	0.019
1978	-0.002	-0.024*	0.001	0.018
1979	-0.002	-0.024*	0.001	0.018
1980	0.000	-0.022	0.001	0.013
1981	0.004	-0.018	0.001	0.004
1982	0.005	-0.017	0.001	0.001
1983	0.005	-0.017	0.001	0.002
1984	0.005	-0.017	0.001	0.004
1985	0.006	-0.016	0.001	0.007
1986	0.006	-0.016	0.001	0.007

* Indicates coefficient is significant at $P \leq 0.05$.

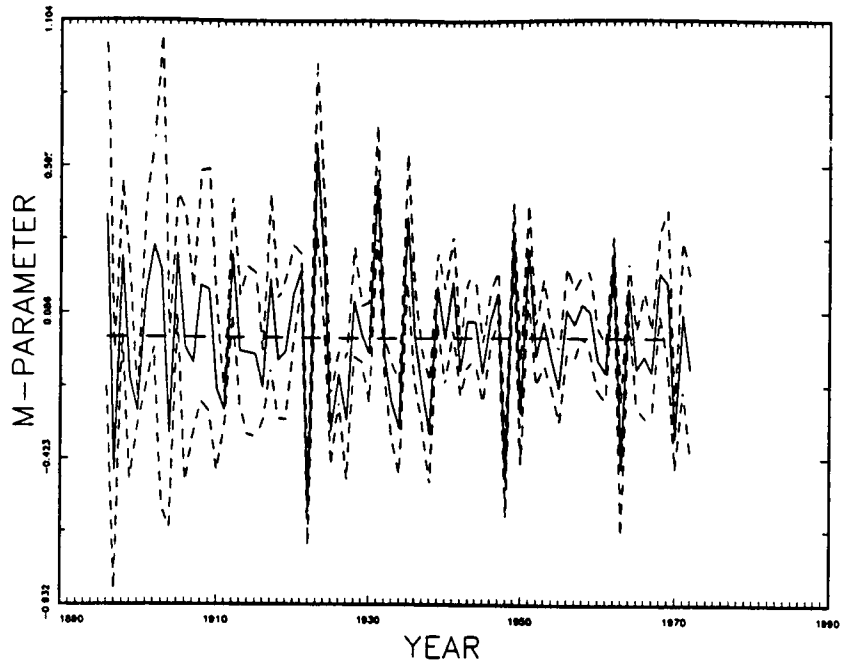


Figure A4. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 2.

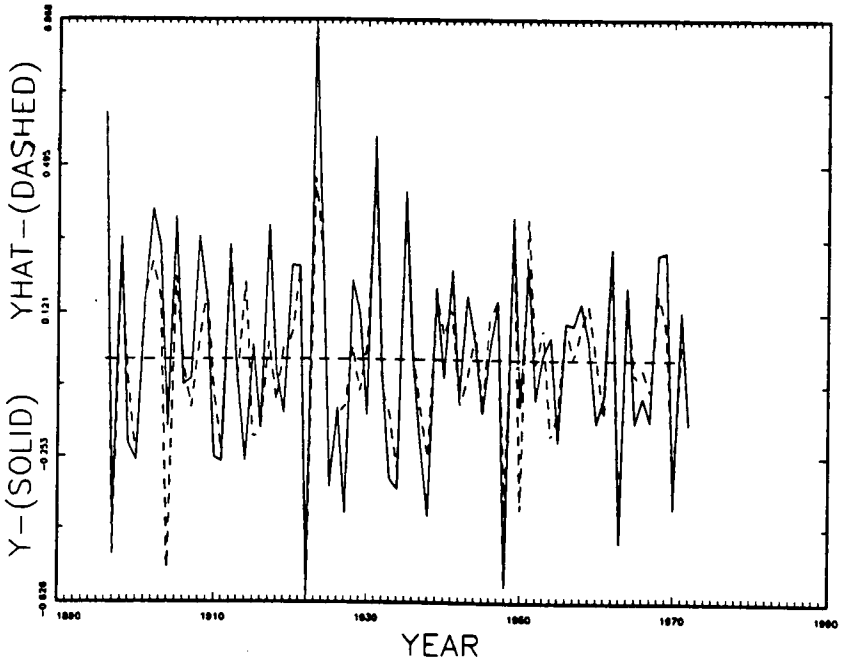
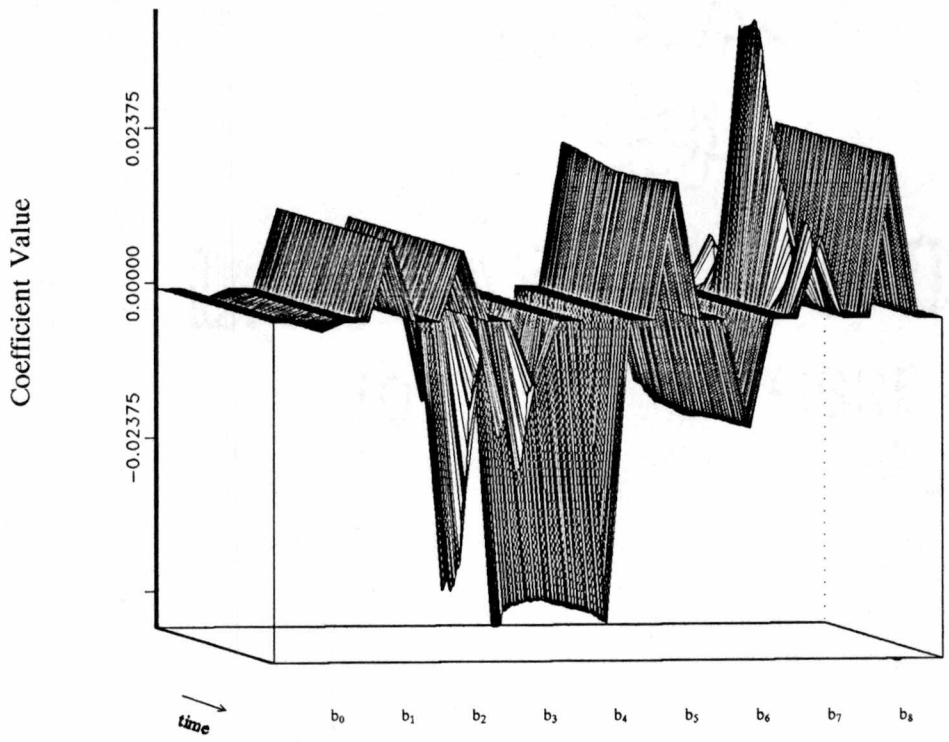


Figure A5. Graph of predicted and actual standardized growth, Emory River white oak, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = February temperature
b_2 = April temperature
b_3 = June temperature
b_4 = July temperature
b_5 = past June temperature
b_6 = past November temperature
b_7 = July rain
b_8 = past November rain

Figure A6. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 2.

Table A2. Climate parameter estimates for Emory River white oak, cluster 2.

YEAR	February temp. b_1	April temp. b_2	June temp. b_3	July temp. b_4	Past June temp. b_5	Past November temp. b_6	July rain b_7	Past November rain b_8
1910	0.011*	0.010*	-0.023	-0.053*	0.021	-0.015	0.023	0.025*
1911	0.011*	0.010*	-0.023	-0.053*	0.021	-0.015	0.024	0.025*
1912	0.011*	0.010*	-0.023	-0.053*	0.021	-0.015	0.024	0.025*
1913	0.011*	0.010*	-0.023	-0.053*	0.021	-0.015	0.024	0.025*
1914	0.011*	0.010*	-0.023	-0.053*	0.021	-0.015	0.024	0.025*
1915	0.011*	0.010*	-0.023	-0.052*	0.021*	-0.016	0.024	0.025*
1916	0.011*	0.010*	-0.023	-0.052*	0.021*	-0.016	0.024	0.025*
1917	0.011*	0.010*	-0.023	-0.050*	0.021*	-0.017	0.024	0.025*
1918	0.011*	0.010*	-0.024	-0.049*	0.021*	-0.017	0.024	0.025*
1919	0.011*	0.010*	-0.024	-0.049*	0.021*	-0.017	0.024	0.025*
1920	0.011*	0.010*	-0.024	-0.049*	0.021*	-0.018*	0.024	0.025*
1921	0.011*	0.010*	-0.024	-0.049*	0.021*	-0.018*	0.024	0.025*
1922	0.011*	0.010*	-0.025*	-0.049*	0.021*	-0.019*	0.025	0.025*
1923	0.011*	0.010*	-0.025*	-0.049*	0.021*	-0.019*	0.026	0.025*
1924	0.011*	0.010*	-0.025*	-0.049*	0.021*	-0.019*	0.026	0.025*
1925	0.011*	0.010*	-0.025*	-0.049*	0.021*	-0.019*	0.026	0.025*
1926	0.011*	0.010*	-0.025*	-0.049*	0.021*	-0.019*	0.026	0.025*
1927	0.011*	0.010*	-0.025*	-0.049*	0.021*	-0.019*	0.026	0.025*
1928	0.011*	0.010*	-0.025*	-0.048*	0.020*	-0.019*	0.027	0.025*
1929	0.011*	0.010*	-0.025*	-0.048*	0.020*	-0.019*	0.028*	0.025*
1930	0.011*	0.010*	-0.025*	-0.048*	0.020*	-0.019*	0.028*	0.025*
1931	0.011*	0.010*	-0.024*	-0.048*	0.020*	-0.019*	0.030*	0.025*
1932	0.011*	0.010*	-0.024*	-0.048*	0.020*	-0.019*	0.031*	0.025*
1933	0.011*	0.010*	-0.024*	-0.048*	0.020*	-0.019*	0.032*	0.025*
1934	0.011*	0.010*	-0.024*	-0.048*	0.019*	-0.019*	0.032*	0.025*
1935	0.011*	0.010*	-0.024*	-0.048*	0.019*	-0.019*	0.031*	0.025*
1936	0.011*	0.010*	-0.024*	-0.048*	0.019*	-0.019*	0.031*	0.025*
1937	0.011*	0.010*	-0.023*	-0.048*	0.019*	-0.020*	0.030*	0.025*
1938	0.011*	0.010*	-0.023*	-0.047*	0.019*	-0.020*	0.030*	0.025*
1939	0.011*	0.010*	-0.022*	-0.047*	0.019*	-0.020*	0.029*	0.025*
1940	0.011*	0.010*	-0.022*	-0.047*	0.019*	-0.020*	0.029*	0.025*
1941	0.011*	0.010*	-0.022*	-0.047*	0.019*	-0.020*	0.029*	0.025*
1942	0.011*	0.010*	-0.021*	-0.047*	0.018*	-0.020*	0.028*	0.025*
1943	0.011*	0.010*	-0.021*	-0.047*	0.018*	-0.020*	0.028*	0.025*
1944	0.011*	0.010*	-0.021*	-0.047*	0.018*	-0.020*	0.028*	0.025*
1945	0.011*	0.010*	-0.021*	-0.047*	0.018*	-0.020*	0.027*	0.025*
1946	0.011*	0.010*	-0.021*	-0.047*	0.018*	-0.020*	0.027*	0.025*
1947	0.011*	0.010*	-0.021*	-0.047*	0.018*	-0.020*	0.027*	0.025*
1948	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.020*	0.026*	0.025*
1949	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.020*	0.024*	0.025*
1950	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.019*	0.024*	0.025*
1951	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.019*	0.023*	0.025*
1952	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.019*	0.023	0.025*
1953	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.019*	0.022	0.025*
1954	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.019*	0.022	0.025*
1955	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.019*	0.021	0.025*
1956	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.019*	0.021	0.025*
1957	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.018*	0.020	0.025*
1958	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.018*	0.020	0.025*
1959	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.018*	0.019	0.025*
1960	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.018*	0.019	0.025*
1961	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.018*	0.019	0.025*
1962	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.018*	0.019	0.025*
1963	0.011*	0.010*	-0.020*	-0.047*	0.018*	-0.018*	0.019	0.025*
1964	0.011*	0.010*	-0.020*	-0.047*	0.019*	-0.018*	0.018	0.025*

Table A2. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
1965	0.011*	0.010*	-0.020*	-0.047*	0.019*	-0.018*	0.017	0.025*
1966	0.011*	0.010*	-0.020*	-0.047*	0.019*	-0.018*	0.017	0.025*
1967	0.011*	0.010*	-0.020*	-0.047*	0.019*	-0.018*	0.016	0.025*
1968	0.011*	0.010*	-0.020*	-0.047*	0.019*	-0.018*	0.016	0.025*
1969	0.011*	0.010*	-0.020*	-0.047*	0.019*	-0.018*	0.016	0.025*
1970	0.011*	0.010*	-0.021*	-0.047*	0.019*	-0.017*	0.016	0.025*
1971	0.011*	0.010*	-0.021*	-0.047*	0.019*	-0.017*	0.016	0.025*
1972	0.011*	0.010*	-0.021*	-0.047*	0.019*	-0.017*	0.016	0.025*
1973	0.011*	0.010*	-0.021*	-0.047*	0.019*	-0.018*	0.017	0.025*
1974	0.011*	0.010*	-0.021*	-0.047*	0.019*	-0.018*	0.017	0.025*
1975	0.011*	0.010*	-0.021*	-0.047*	0.019*	-0.018*	0.017	0.025*
1976	0.011*	0.010*	-0.021*	-0.047*	0.019*	-0.018*	0.017	0.025*
1977	0.011*	0.010*	-0.020*	-0.048*	0.019*	-0.017*	0.016	0.025*
1978	0.011*	0.010*	-0.020*	-0.048*	0.019*	-0.017*	0.016	0.025*
1979	0.011*	0.010*	-0.020*	-0.048*	0.019*	-0.017*	0.016	0.025*
1980	0.011*	0.010*	-0.020*	-0.048*	0.019*	-0.017*	0.015	0.025*
1981	0.011*	0.010*	-0.020*	-0.048*	0.019*	-0.017*	0.015	0.025*
1982	0.011*	0.010*	-0.020*	-0.048*	0.019*	-0.017*	0.015	0.025*
1983	0.011*	0.010*	-0.019*	-0.048*	0.019*	-0.017*	0.015	0.025*
1984	0.011*	0.010*	-0.019*	-0.048*	0.019*	-0.017*	0.015	0.025*
1985	0.011*	0.010*	-0.019*	-0.048*	0.019*	-0.017*	0.015	0.025*
1986	0.011*	0.010*	-0.019	-0.048*	0.019*	-0.017	0.015	0.025*

* Indicates coefficient is significant at $P \leq 0.05$.

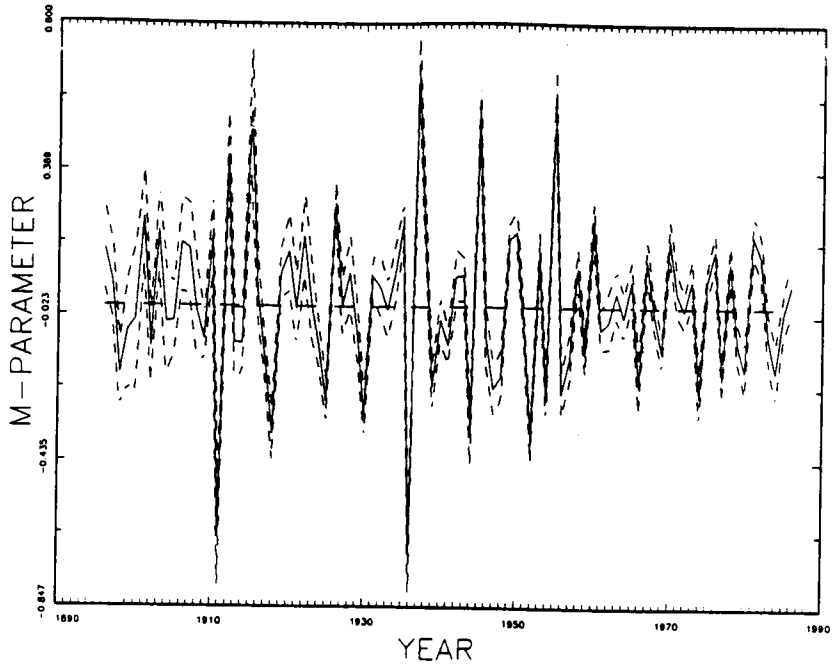


Figure A7. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 3.

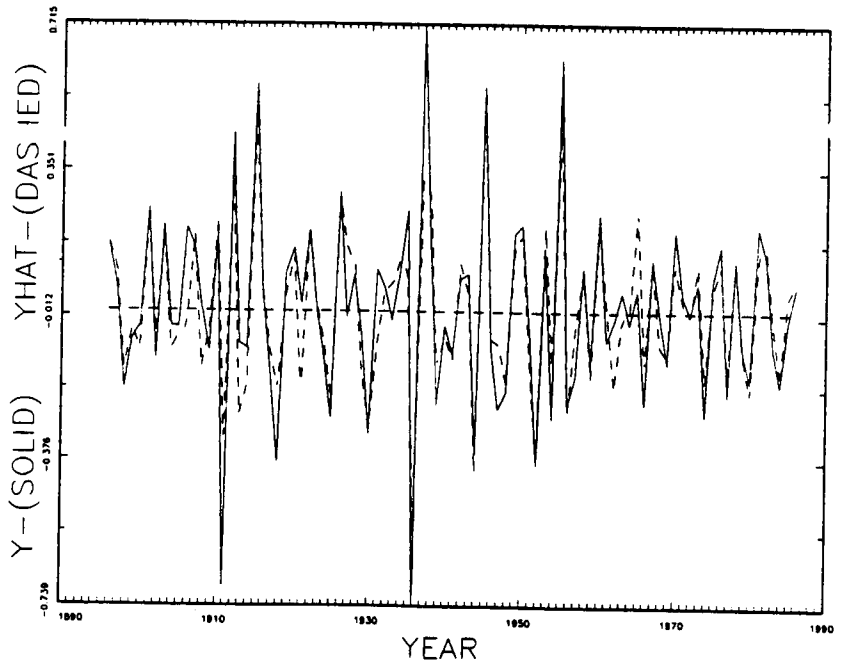
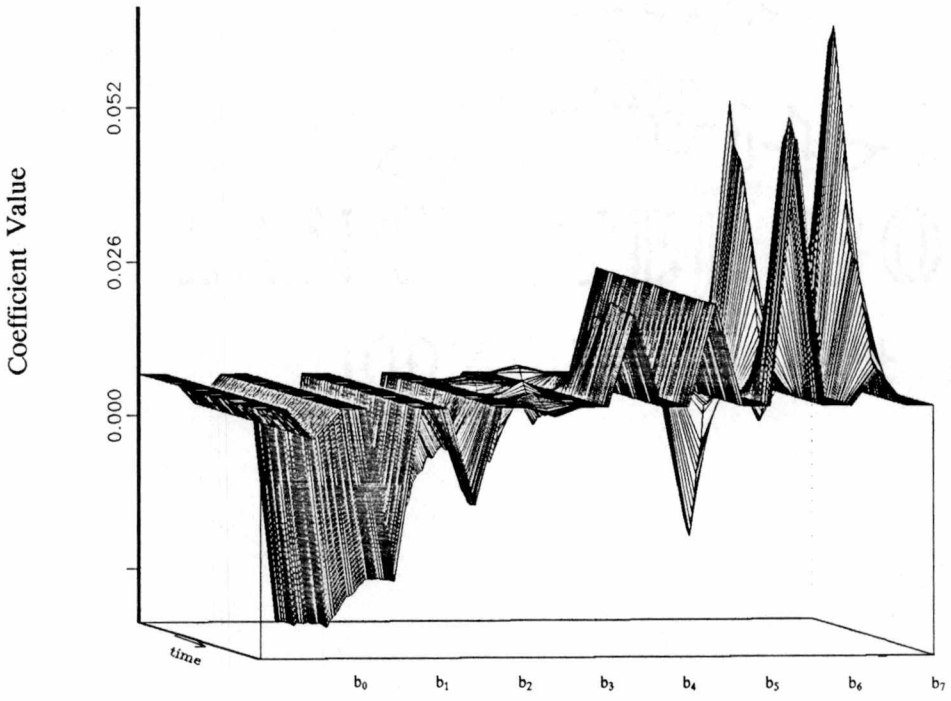


Figure A8. Graph of predicted and actual standardized growth, Emory River white oak, cluster 3.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = August temperature
b_3 = past February temperature
b_4 = past April temperature
b_5 = May rain
b_6 = June rain
b_7 = past August rain

Figure A9. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 3.

Table A3. Climate parameter estimates for Emory River white oak, cluster 3.

YEAR	June temp. b_1	August temp. b_2	Past February temp. b_3	Past April temp. b_4	May rain b_5	June rain b_6	Past August rain b_7
1897	-0.035*	-0.020	0.002	0.008	0.025*	-0.005	-0.002
1898	-0.035*	-0.020	0.002	0.008	0.025*	-0.006	-0.001
1899	-0.035*	-0.020	0.002	0.007	0.025*	-0.010	-0.000
1900	-0.035*	-0.020	0.003	0.006	0.025*	-0.016	0.002
1901	-0.035*	-0.020	0.003	0.005	0.025*	-0.018	0.003
1902	-0.035*	-0.020	0.003	0.005	0.025*	-0.018	0.005
1903	-0.034*	-0.020	0.003	0.004	0.025*	-0.019	0.009
1904	-0.034*	-0.020	0.002	0.003	0.025*	-0.020	0.014
1905	-0.034*	-0.020	0.002	0.003	0.025*	-0.020	0.017
1906	-0.034*	-0.020	0.003	0.001	0.025*	-0.019	0.018
1907	-0.034*	-0.020	0.005	-0.001	0.025*	-0.016	0.019
1908	-0.035*	-0.021	0.006	-0.001	0.025*	-0.015	0.021
1909	-0.035*	-0.021	0.006	-0.001	0.025*	-0.013	0.022
1910	-0.035*	-0.021	0.007	-0.001	0.025*	-0.010	0.024
1911	-0.034*	-0.020	0.006	0.000	0.025*	-0.008	0.027
1912	-0.034*	-0.020	0.005	0.000	0.025*	-0.007	0.029
1913	-0.034*	-0.020	0.006	0.000	0.025*	-0.006	0.030
1914	-0.034*	-0.020	0.006	0.001	0.025*	-0.004	0.032
1915	-0.034*	-0.021	0.007	0.001	0.025*	0.001	0.037
1916	-0.034*	-0.021	0.008	0.001	0.025*	0.002	0.038
1917	-0.034*	-0.021	0.008	0.001	0.025*	0.003	0.038
1918	-0.034*	-0.020	0.008	0.001	0.025*	0.003	0.036
1919	-0.034*	-0.020	0.008	0.001	0.025*	0.003	0.035
1920	-0.033*	-0.018	0.008	0.002	0.025*	0.004	0.032
1921	-0.033*	-0.018	0.008	0.002	0.025*	0.008	0.027
1922	-0.033*	-0.016	0.008	0.003	0.025*	0.013	0.020
1923	-0.033*	-0.016	0.007	0.004	0.025*	0.017	0.015
1924	-0.033*	-0.015	0.007	0.004	0.025*	0.018	0.014
1925	-0.033*	-0.015	0.007	0.004	0.025*	0.019	0.012
1926	-0.033*	-0.015	0.007	0.004	0.025*	0.020	0.010
1927	-0.033*	-0.015	0.006	0.004	0.025*	0.022	0.013
1928	-0.033*	-0.015	0.005	0.003	0.025*	0.025	0.017
1929	-0.033*	-0.015	0.004	0.003	0.025*	0.030*	0.018
1930	-0.033*	-0.015	0.004	0.003	0.025*	0.032*	0.019
1931	-0.033*	-0.015	0.003	0.003	0.025*	0.035*	0.019
1932	-0.033*	-0.014	-0.000	0.003	0.025*	0.041*	0.019
1933	-0.033*	-0.014	-0.002	0.004	0.025*	0.045*	0.018
1934	-0.033*	-0.013	-0.004	0.004	0.025*	0.048*	0.018
1935	-0.033*	-0.013	-0.005	0.004	0.025*	0.052*	0.019
1936	-0.033*	-0.012	-0.006	0.005	0.025*	0.055*	0.022
1937	-0.032*	-0.010	-0.005	0.005	0.025*	0.051*	0.027
1938	-0.032*	-0.009	-0.005	0.006	0.025*	0.048*	0.032
1939	-0.031*	-0.009	-0.004	0.007	0.025*	0.048*	0.035*
1940	-0.031*	-0.008	-0.003	0.007	0.025*	0.047*	0.038*
1941	-0.031*	-0.008	-0.002	0.008	0.025*	0.047*	0.041*
1942	-0.030*	-0.007	-0.000	0.009	0.025*	0.046*	0.046*
1943	-0.030*	-0.007	0.001	0.009	0.025*	0.046*	0.048*
1944	-0.030*	-0.007	0.002	0.011	0.025*	0.046*	0.052*
1945	-0.029*	-0.007	0.003	0.012	0.025*	0.045*	0.055*
1946	-0.028*	-0.006	0.005	0.013	0.024*	0.043*	0.058*
1947	-0.028*	-0.005	0.006	0.014*	0.024*	0.041*	0.061*
1948	-0.028*	-0.005	0.006	0.015*	0.024*	0.039*	0.064*
1949	-0.027*	-0.004	0.007	0.016*	0.024*	0.037*	0.065*
1950	-0.027*	-0.004	0.007	0.017*	0.024*	0.035*	0.067*
1951	-0.027*	-0.004	0.007	0.017*	0.024*	0.033*	0.067*

Table A3. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7
1952	-0.027*	-0.004	0.007	0.018*	0.024*	0.031*	0.068*
1953	-0.027*	-0.004	0.008	0.019*	0.024*	0.027*	0.069*
1954	-0.026*	-0.004	0.008	0.020*	0.024*	0.025	0.067*
1955	-0.026*	-0.003	0.008	0.020*	0.024*	0.022	0.064*
1956	-0.026*	-0.003	0.008	0.020*	0.024*	0.019	0.062*
1957	-0.025*	-0.002	0.008*	0.020*	0.024*	0.017	0.058*
1958	-0.025*	-0.002	0.009*	0.020*	0.024*	0.016	0.056*
1959	-0.025*	-0.002	0.009*	0.020*	0.024*	0.015	0.054*
1960	-0.024*	-0.001	0.010*	0.020*	0.024*	0.014	0.052*
1961	-0.024*	-0.001	0.010*	0.020*	0.024*	0.014	0.049*
1962	-0.024*	-0.002	0.009*	0.021*	0.024*	0.015	0.041*
1963	-0.024*	-0.002	0.009*	0.022*	0.024*	0.016	0.036*
1964	-0.023*	-0.002	0.008	0.022*	0.024*	0.017	0.032*
1965	-0.023*	-0.002	0.008	0.023*	0.024*	0.021	0.033*
1966	-0.023*	-0.001	0.008	0.023*	0.024*	0.023	0.031*
1967	-0.023*	-0.001	0.008	0.024*	0.024*	0.025*	0.030*
1968	-0.023*	-0.002	0.008	0.024*	0.024*	0.027*	0.030*
1969	-0.023*	-0.002	0.008	0.024*	0.024*	0.030*	0.030*
1970	-0.023*	-0.003	0.008	0.024*	0.024*	0.033*	0.030*
1971	-0.023*	-0.004	0.008	0.023*	0.024*	0.038*	0.028*
1972	-0.023*	-0.005	0.008	0.023*	0.024*	0.041*	0.028*
1973	-0.023*	-0.005	0.008	0.023*	0.024*	0.045*	0.026*
1974	-0.023*	-0.007	0.007	0.023*	0.024*	0.049*	0.024
1975	-0.023*	-0.007	0.007	0.023*	0.024*	0.050*	0.022
1976	-0.023*	-0.008	0.007	0.023*	0.024*	0.052*	0.021
1977	-0.022*	-0.008	0.007	0.023*	0.024*	0.052*	0.020
1978	-0.022*	-0.008	0.006	0.023*	0.024*	0.053*	0.018
1979	-0.022*	-0.009	0.006	0.023*	0.024*	0.054*	0.017
1980	-0.022*	-0.009	0.006	0.023*	0.024*	0.055*	0.015
1981	-0.022*	-0.009	0.006	0.023*	0.024*	0.055*	0.014
1982	-0.022*	-0.010	0.006	0.023*	0.024*	0.054*	0.013
1983	-0.022*	-0.009	0.006	0.023*	0.024*	0.053*	0.013
1984	-0.022*	-0.009	0.005	0.022*	0.024*	0.052*	0.013
1985	-0.022*	-0.009	0.005	0.022*	0.024*	0.052*	0.013
1986	-0.022*	-0.009	0.005	0.022*	0.024*	0.052*	0.013

* Indicates coefficient is significant at $P \leq 0.05$.

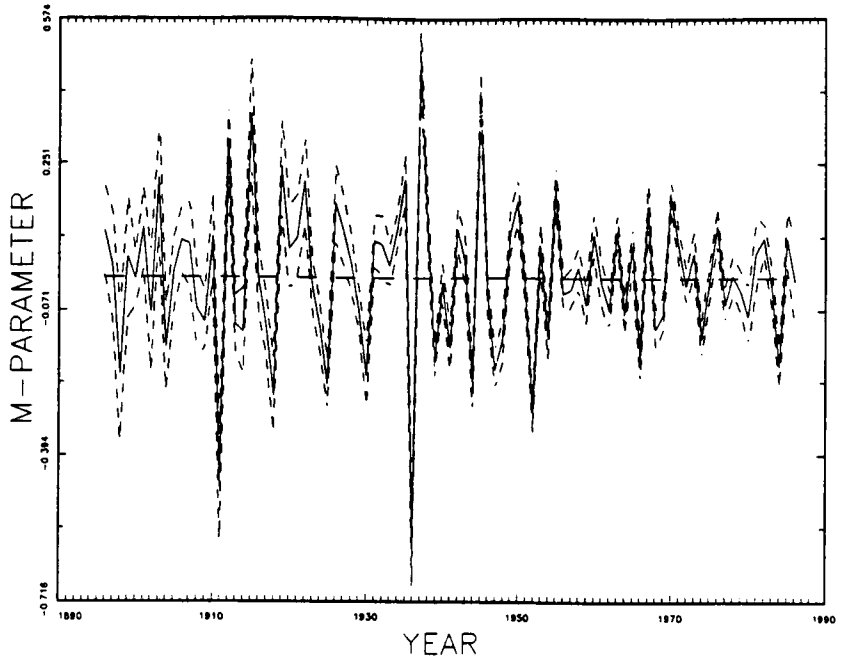


Figure A10. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 4.

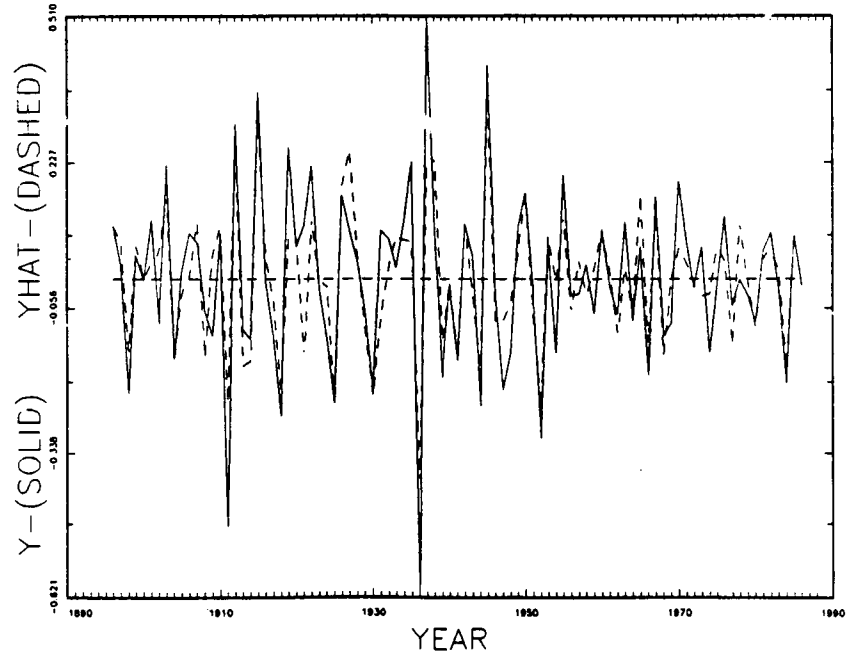
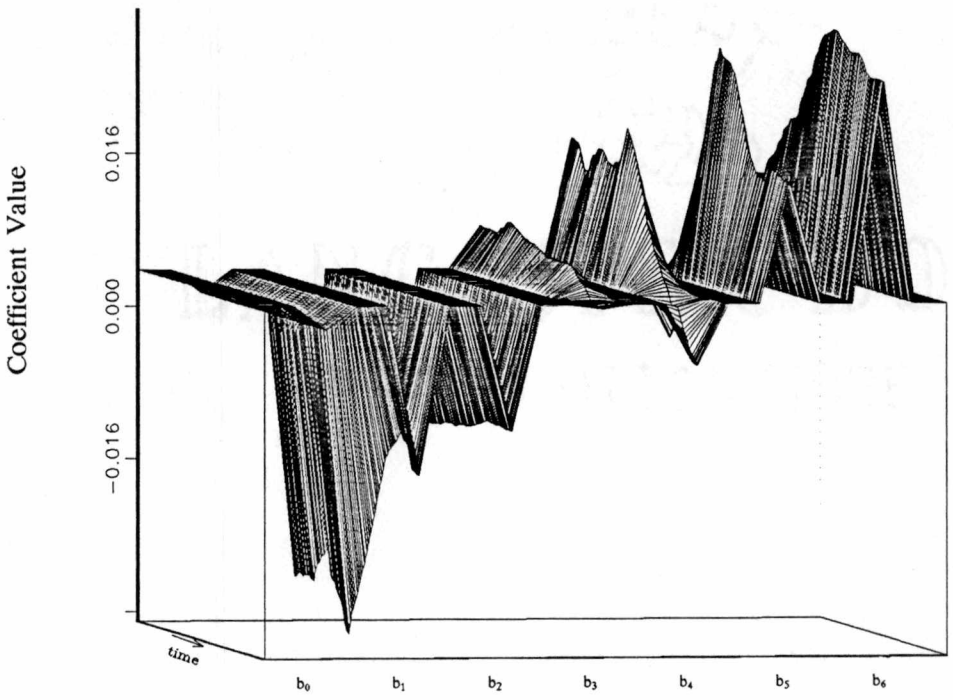


Figure A11. Graph of predicted and actual standardized growth, Emory River white oak, cluster 4.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = August temperature
b_3 = past May temperature
b_4 = May rain
b_5 = June rain
b_6 = past August rain

Figure A12. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 4.

Table A4. Climate parameter estimates for Emory River white oak, cluster 4.

YEAR	June temp. b_1	August temp. b_2	Past May temp. b_3	May rain b_4	June rain b_5	Past August rain b_6
1897	-0.028	-0.013	0.008	0.017	-0.003	0.014
1898	-0.028	-0.013	0.008	0.017	-0.003	0.014
1899	-0.028	-0.013	0.008	0.017	-0.003	0.014
1900	-0.028	-0.013	0.008	0.017	-0.003	0.014
1901	-0.028	-0.013	0.008	0.017	-0.003	0.014
1902	-0.028	-0.013	0.008	0.016	-0.002	0.014
1903	-0.028	-0.013	0.008	0.015	-0.001	0.015
1904	-0.028	-0.013	0.008	0.015	-0.001	0.015
1905	-0.028	-0.013	0.008	0.014	-0.001	0.016
1906	-0.028	-0.013	0.008	0.014	-0.000	0.016
1907	-0.028*	-0.013	0.008	0.014	0.000	0.016
1908	-0.028*	-0.013	0.008	0.014	0.001	0.016
1909	-0.028*	-0.013	0.008	0.015	0.001	0.016
1910	-0.028*	-0.012	0.008	0.016	0.003	0.017
1911	-0.027*	-0.012	0.009	0.016	0.004	0.017
1912	-0.026*	-0.012	0.009	0.016	0.005	0.018
1913	-0.026*	-0.012	0.009	0.016	0.005	0.018
1914	-0.026*	-0.012	0.009	0.017	0.006	0.018
1915	-0.026*	-0.012	0.009	0.017	0.008	0.019
1916	-0.025*	-0.012	0.009	0.017	0.009	0.019
1917	-0.025*	-0.012	0.009	0.017	0.009	0.019
1918	-0.025*	-0.012	0.010	0.017	0.010	0.019
1919	-0.025*	-0.012	0.009	0.017	0.012	0.020
1920	-0.025*	-0.011	0.009	0.017	0.013	0.020
1921	-0.026*	-0.011	0.009	0.016	0.014	0.020*
1922	-0.027*	-0.011	0.009	0.016	0.016	0.020*
1923	-0.027*	-0.011	0.009	0.016	0.017	0.020*
1924	-0.028*	-0.011	0.009	0.016	0.017	0.021*
1925	-0.028*	-0.011	0.009	0.016	0.018	0.021*
1926	-0.028*	-0.011	0.009	0.016	0.019*	0.021*
1927	-0.029*	-0.011	0.008	0.016	0.021*	0.022*
1928	-0.029*	-0.011	0.008	0.016	0.021*	0.023*
1929	-0.029*	-0.011	0.008	0.016	0.022*	0.023*
1930	-0.030*	-0.011	0.008	0.016	0.023*	0.024*
1931	-0.031*	-0.011	0.008	0.017	0.025*	0.024*
1932	-0.032*	-0.011	0.008	0.017*	0.026*	0.025*
1933	-0.032*	-0.011	0.008	0.018*	0.027*	0.025*
1934	-0.033*	-0.011	0.008	0.018*	0.027*	0.025*
1935	-0.033*	-0.011	0.008	0.019*	0.028*	0.026*
1936	-0.031*	-0.011	0.008	0.020*	0.028*	0.026*
1937	-0.030*	-0.011	0.008	0.020*	0.028*	0.027*
1938	-0.030*	-0.011	0.008	0.019*	0.027*	0.028*
1939	-0.029*	-0.011	0.008	0.019*	0.027*	0.028*
1940	-0.029*	-0.010	0.008	0.018*	0.027*	0.028*
1941	-0.028*	-0.010	0.007	0.018*	0.027*	0.029*
1942	-0.027*	-0.010	0.007	0.017*	0.027*	0.029*
1943	-0.027*	-0.010	0.007	0.017*	0.027*	0.030*
1944	-0.026*	-0.011	0.007	0.016	0.027*	0.030*
1945	-0.026*	-0.011	0.007	0.015	0.026*	0.030*
1946	-0.025*	-0.011*	0.007	0.015	0.026*	0.030*
1947	-0.024*	-0.010	0.007	0.014	0.026*	0.030*
1948	-0.024*	-0.010	0.007	0.013	0.025*	0.030*
1949	-0.023*	-0.010	0.007	0.012	0.024*	0.030*
1950	-0.022*	-0.010	0.007	0.011	0.023*	0.031*

Table A4. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1951	-0.021*	-0.010	0.007	0.010	0.023*	0.031*
1952	-0.021*	-0.010	0.007	0.010	0.022*	0.031*
1953	-0.020*	-0.010	0.007	0.010	0.021*	0.031*
1954	-0.019*	-0.010	0.007*	0.009	0.020*	0.031*
1955	-0.018*	-0.010	0.007*	0.008	0.019*	0.030*
1956	-0.017*	-0.010	0.007*	0.008	0.019*	0.030*
1957	-0.017*	-0.010	0.007*	0.007	0.018*	0.030*
1958	-0.016*	-0.010	0.007*	0.007	0.018*	0.030*
1959	-0.015*	-0.010	0.007*	0.007	0.017*	0.030*
1960	-0.014*	-0.010	0.007*	0.006	0.017*	0.029*
1961	-0.013	-0.010	0.007*	0.006	0.017*	0.029*
1962	-0.013	-0.010	0.007*	0.005	0.016*	0.029*
1963	-0.013	-0.010	0.007*	0.005	0.016*	0.029*
1964	-0.012	-0.010	0.007	0.005	0.016*	0.029*
1965	-0.012	-0.009	0.006	0.004	0.016*	0.029*
1966	-0.012	-0.009	0.006	0.004	0.016*	0.029*
1967	-0.012	-0.009	0.006	0.003	0.016*	0.029*
1968	-0.011	-0.009	0.006	0.003	0.016*	0.029*
1969	-0.011	-0.009	0.005	0.003	0.016*	0.029*
1970	-0.011	-0.009	0.005	0.003	0.016*	0.029*
1971	-0.010	-0.009	0.005	0.003	0.017*	0.028*
1972	-0.010	-0.009	0.005	0.003	0.017*	0.028*
1973	-0.010	-0.009	0.005	0.002	0.017*	0.028*
1974	-0.011	-0.009	0.004	0.002	0.017	0.027*
1975	-0.011	-0.009	0.004	0.001	0.017	0.027*
1976	-0.011	-0.009	0.004	0.001	0.017	0.027*
1977	-0.011	-0.009	0.004	0.000	0.017	0.027*
1978	-0.011	-0.009	0.004	-0.000	0.017	0.027*
1979	-0.012	-0.009	0.004	-0.000	0.017	0.027*
1980	-0.013	-0.009	0.004	-0.001	0.017	0.027*
1981	-0.014	-0.009	0.003	-0.002	0.016	0.027*
1982	-0.014	-0.009	0.003	-0.002	0.016	0.027*
1983	-0.014	-0.009	0.003	-0.002	0.016	0.027*
1984	-0.014	-0.009	0.003	-0.003	0.017	0.027*
1985	-0.014	-0.009	0.003	-0.003	0.017	0.027*
1986	-0.014	-0.009	0.003	-0.003	0.017	0.027*

* Indicates coefficient is significant at $P \leq 0.05$.

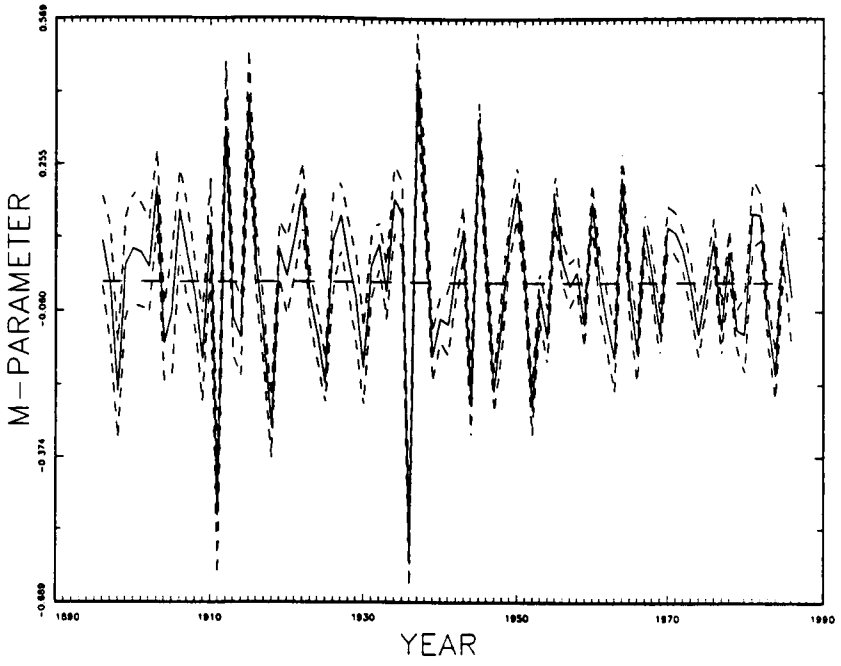


Figure A13. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 5.

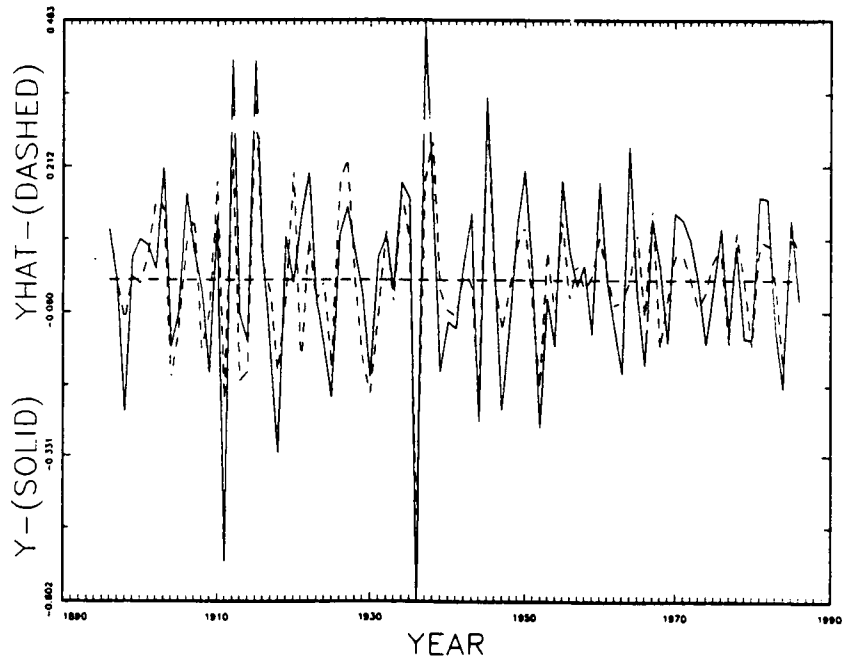
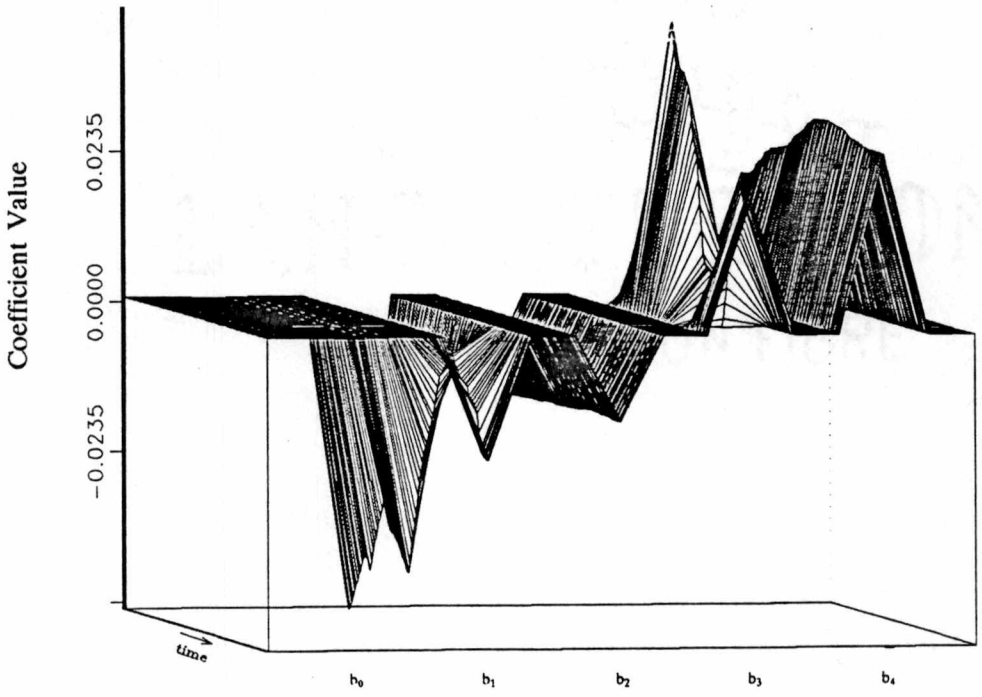


Figure A14. Graph of predicted and actual standardized growth, Emory River white oak, cluster 5.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = August temperature
b_3 = June rain
b_4 = past August rain

Figure A15. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 5.

Table A5. Climate parameter estimates for Emory River white oak, cluster 5.

YEAR	June temperature b_1	August temperature b_2	June rain b_3	Past August rain b_4
1897	-0.042*	-0.014	0.001	0.025*
1898	-0.041*	-0.014	0.001	0.025*
1899	-0.041*	-0.014	0.001	0.025*
1900	-0.040*	-0.014	0.000	0.025*
1901	-0.040*	-0.014	0.001	0.025*
1902	-0.040*	-0.014	0.001	0.025*
1903	-0.039*	-0.014	0.001	0.025*
1904	-0.039*	-0.014	0.001	0.025*
1905	-0.038*	-0.014	0.002	0.025*
1906	-0.038*	-0.014*	0.003	0.026*
1907	-0.037*	-0.014*	0.004	0.026*
1908	-0.037*	-0.014*	0.004	0.026*
1909	-0.037*	-0.014*	0.005	0.026*
1910	-0.037*	-0.014*	0.006	0.026*
1911	-0.036*	-0.013*	0.008	0.026*
1912	-0.035*	-0.013*	0.009	0.026*
1913	-0.034*	-0.013*	0.009	0.026*
1914	-0.034*	-0.013*	0.010	0.026*
1915	-0.032*	-0.013*	0.011	0.027*
1916	-0.032*	-0.013*	0.012	0.027*
1917	-0.031*	-0.013*	0.012	0.027*
1918	-0.031*	-0.013*	0.012	0.027*
1919	-0.030*	-0.013*	0.013	0.027*
1920	-0.030*	-0.013*	0.014	0.027*
1921	-0.031*	-0.013*	0.015	0.027*
1922	-0.031*	-0.013*	0.016	0.027*
1923	-0.032*	-0.013*	0.017	0.027*
1924	-0.032*	-0.013*	0.018	0.027*
1925	-0.032*	-0.013*	0.018	0.027*
1926	-0.032*	-0.013*	0.021	0.027*
1927	-0.032*	-0.013*	0.022*	0.027*
1928	-0.032*	-0.013*	0.023*	0.027*
1929	-0.033*	-0.013*	0.025*	0.027*
1930	-0.033*	-0.013*	0.026*	0.028*
1931	-0.033*	-0.013*	0.027*	0.028*
1932	-0.034*	-0.013*	0.028*	0.028*
1933	-0.034*	-0.013*	0.029*	0.028*
1934	-0.034*	-0.013*	0.030*	0.028*
1935	-0.035*	-0.013*	0.031*	0.028*
1936	-0.033*	-0.013*	0.031*	0.028*
1937	-0.031*	-0.013*	0.029*	0.028*
1938	-0.030*	-0.013*	0.029*	0.028*
1939	-0.029*	-0.013*	0.029*	0.028*
1940	-0.028*	-0.013*	0.028*	0.029*
1941	-0.026*	-0.013*	0.028*	0.029*
1942	-0.024*	-0.013*	0.028*	0.029*
1943	-0.024*	-0.013*	0.028*	0.029*
1944	-0.022*	-0.013*	0.027*	0.029*
1945	-0.021*	-0.013*	0.027*	0.029*
1946	-0.020*	-0.013*	0.026*	0.029*
1947	-0.019*	-0.013*	0.026*	0.029*
1948	-0.018*	-0.013*	0.024*	0.029*
1949	-0.017*	-0.012*	0.023*	0.029*
1950	-0.016*	-0.012*	0.022*	0.029*

Table A5. Continued.

YEAR	b_1	b_2	b_3	b_4
1951	-0.015*	-0.012*	0.022*	0.029*
1952	-0.014	-0.012*	0.021*	0.029*
1953	-0.013	-0.012*	0.019*	0.029*
1954	-0.012	-0.012*	0.018*	0.029*
1955	-0.011	-0.012*	0.017	0.029*
1956	-0.010	-0.012*	0.016	0.029*
1957	-0.010	-0.012*	0.016	0.029*
1958	-0.010	-0.012*	0.016	0.029*
1959	-0.009	-0.012*	0.015	0.029*
1960	-0.009	-0.012*	0.015	0.029*
1961	-0.009	-0.012*	0.014	0.029*
1962	-0.008	-0.012*	0.014	0.029*
1963	-0.007	-0.012*	0.012	0.029*
1964	-0.007	-0.012*	0.012	0.028*
1965	-0.008	-0.012*	0.012	0.028*
1966	-0.008	-0.012*	0.011	0.028*
1967	-0.008	-0.012*	0.011	0.028*
1968	-0.008	-0.012*	0.011	0.028*
1969	-0.008	-0.012*	0.012	0.028*
1970	-0.009	-0.012*	0.013	0.028*
1971	-0.009	-0.012*	0.013	0.028*
1972	-0.009	-0.012*	0.014	0.028*
1973	-0.009	-0.012*	0.015	0.028*
1974	-0.010	-0.012*	0.015	0.028*
1975	-0.010	-0.012*	0.015	0.028*
1976	-0.010	-0.012*	0.016	0.028*
1977	-0.010	-0.012*	0.016	0.028*
1978	-0.011	-0.012*	0.017	0.028*
1979	-0.011	-0.012*	0.017	0.028*
1980	-0.012	-0.012*	0.017	0.028*
1981	-0.014	-0.012*	0.016	0.028*
1982	-0.014	-0.012*	0.016	0.028*
1983	-0.014	-0.012*	0.017	0.028*
1984	-0.014 -	0.012*	0.017	0.028*
1985	-0.014	-0.012*	0.017	0.028*
1986	-0.014	-0.012*	0.017	0.028*

* Indicates coefficient is significant at $P \leq 0.05$.

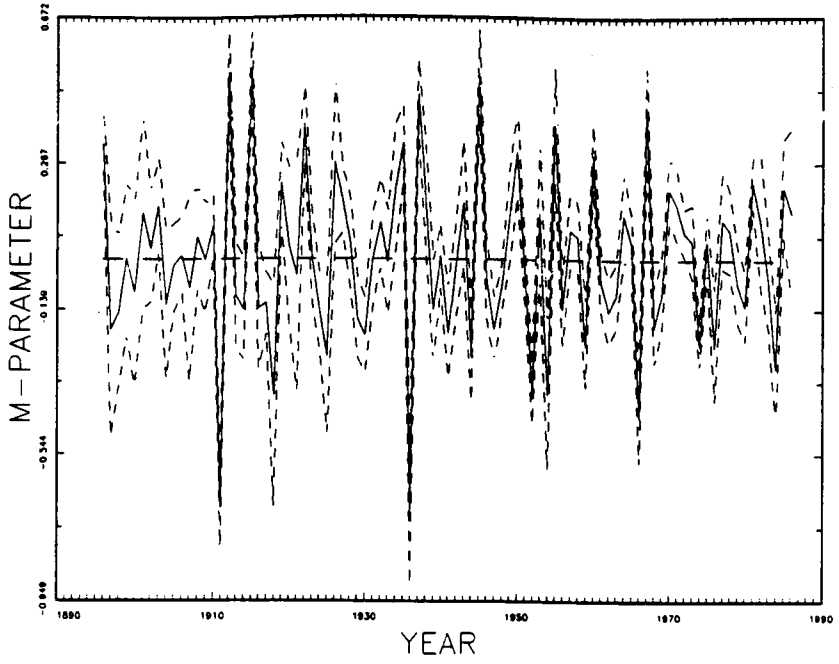


Figure A16. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 6.

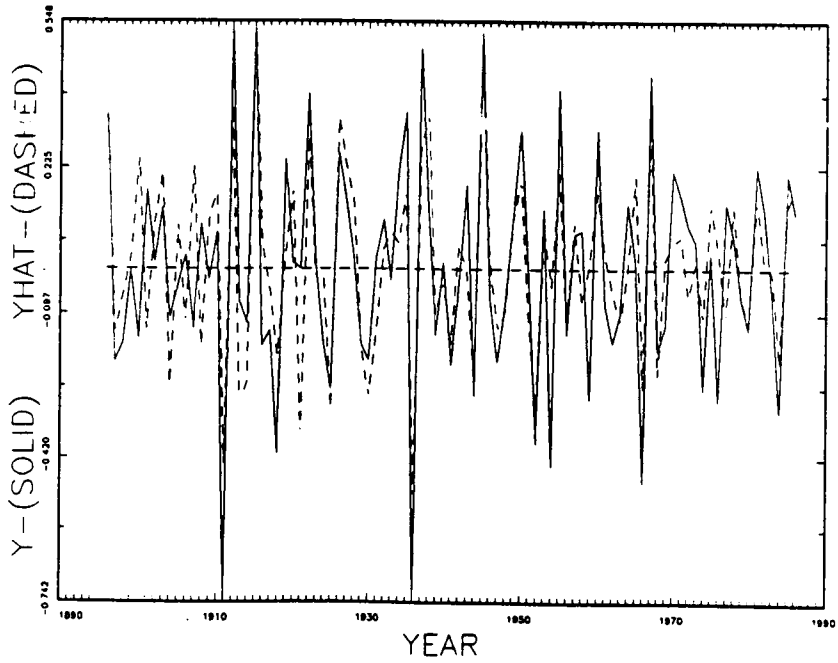
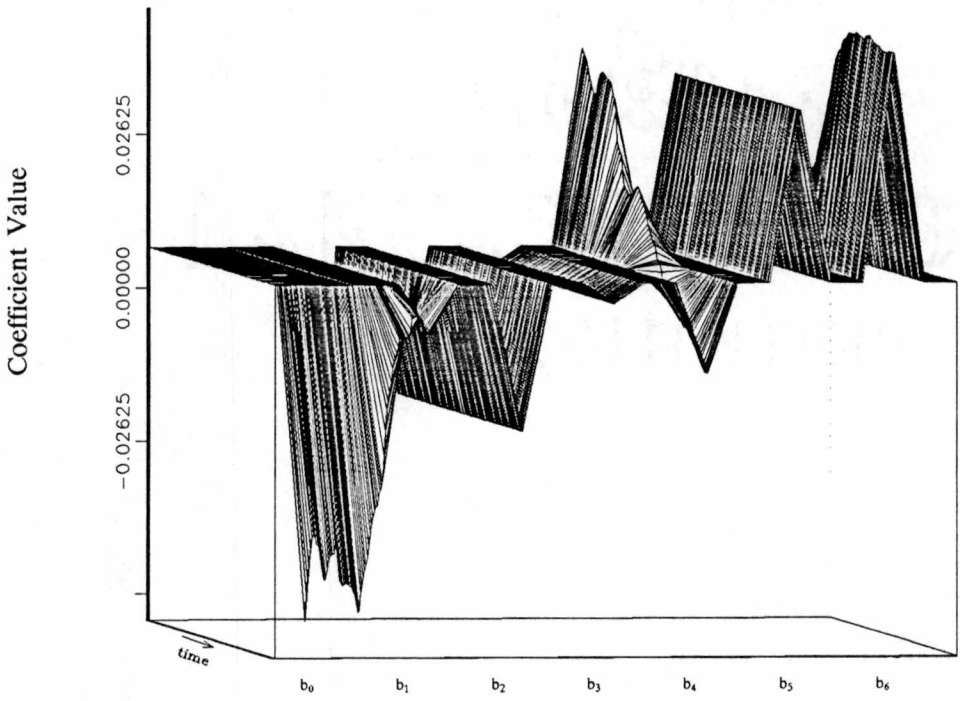


Figure A17. Graph of predicted and actual standardized growth, Emory River white oak, cluster 6.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = August temperature
b_3 = past March temperature
b_4 = May rain
b_5 = June rain
b_6 = past August rain

Figure A18. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 6.

Table A6. Climate parameter estimates for Emory River white oak, cluster 6.

YEAR	June temp. b_1	August temp. b_2	Past March temp. b_3	May rain b_4	June rain b_5	Past August rain b_6
1897	-0.028	-0.013	0.008	0.017	-0.003	0.014
1898	-0.028	-0.013	0.008	0.017	-0.003	0.014
1899	-0.028	-0.013	0.008	0.017	-0.003	0.014
1900	-0.028	-0.013	0.008	0.017	-0.003	0.014
1901	-0.028	-0.013	0.008	0.017	-0.003	0.014
1902	-0.028	-0.013	0.008	0.016	-0.002	0.014
1903	-0.028	-0.013	0.008	0.015	-0.001	0.015
1904	-0.028	-0.013	0.008	0.015	-0.001	0.015
1905	-0.028	-0.013	0.008	0.014	-0.001	0.016
1906	-0.028	-0.013	0.008	0.014	-0.000	0.016
1907	-0.028*	-0.013	0.008	0.014	0.000	0.016
1908	-0.028*	-0.013	0.008	0.014	0.001	0.016
1909	-0.028*	-0.013	0.008	0.015	0.001	0.016
1910	-0.028*	-0.012	0.008	0.016	0.003	0.017
1911	-0.027*	-0.012	0.009	0.016	0.004	0.017
1912	-0.026*	-0.012	0.009	0.016	0.005	0.018
1913	-0.026*	-0.012	0.009	0.016	0.005	0.018
1914	-0.026*	-0.012	0.009	0.017	0.006	0.018
1915	-0.026*	-0.012	0.009	0.017	0.008	0.019
1916	-0.025*	-0.012	0.009	0.017	0.009	0.019
1917	-0.025*	-0.012	0.009	0.017	0.009	0.019
1918	-0.025*	-0.012	0.010	0.017	0.010	0.019
1919	-0.025*	-0.012	0.009	0.017	0.012	0.020
1920	-0.025*	-0.011	0.009	0.017	0.013	0.020
1921	-0.026*	-0.011	0.009	0.016	0.014	0.020*
1922	-0.027*	-0.011	0.009	0.016	0.016	0.020*
1923	-0.027*	-0.011	0.009	0.016	0.017	0.020*
1924	-0.028*	-0.011	0.009	0.016	0.017	0.021*
1925	-0.028*	-0.011	0.009	0.016	0.018	0.021*
1926	-0.028*	-0.011	0.009	0.016	0.019*	0.021*
1927	-0.029*	-0.011	0.008	0.016	0.021*	0.022*
1928	-0.029*	-0.011	0.008	0.016	0.021*	0.023*
1929	-0.029*	-0.011	0.008	0.016	0.022*	0.023*
1930	-0.030*	-0.011	0.008	0.016	0.023*	0.024*
1931	-0.031*	-0.011	0.008	0.017	0.025*	0.024*
1932	-0.032*	-0.011	0.008	0.017*	0.026*	0.025*
1933	-0.032*	-0.011	0.008	0.018*	0.027*	0.025*
1934	-0.033*	-0.011	0.008	0.018*	0.027*	0.025*
1935	-0.033*	-0.011	0.008	0.019*	0.028*	0.026*
1936	-0.031*	-0.011	0.008	0.020*	0.028*	0.026*
1937	-0.030*	-0.011	0.008	0.020*	0.028*	0.027*
1938	-0.030*	-0.011	0.008	0.019*	0.027*	0.028*
1939	-0.029*	-0.011	0.008	0.019*	0.027*	0.028*
1940	-0.029*	-0.010	0.008	0.018*	0.027*	0.028*
1941	-0.028*	-0.010	0.007	0.018*	0.027*	0.029*
1942	-0.027*	-0.010	0.007	0.017*	0.027*	0.029*
1943	-0.027*	-0.010	0.007	0.017*	0.027*	0.030*
1944	-0.026*	-0.011	0.007	0.016	0.027*	0.030*
1945	-0.026*	-0.011	0.007	0.015	0.026*	0.030*
1946	-0.025*	-0.011*	0.007	0.015	0.026*	0.030*
1947	-0.024*	-0.010	0.007	0.014	0.026*	0.030*
1948	-0.024*	-0.010	0.007	0.013	0.025*	0.030*
1949	-0.023*	-0.010	0.007	0.012	0.024*	0.030*
1950	-0.022*	-0.010	0.007	0.011	0.023*	0.031*

Table A6. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1951	-0.021*	-0.010	0.007	0.010	0.023*	0.031*
1952	-0.021*	-0.010	0.007	0.010	0.022*	0.031*
1953	-0.020*	-0.010	0.007	0.010	0.021*	0.031*
1954	-0.019*	-0.010	0.007*	0.009	0.020*	0.031*
1955	-0.018*	-0.010	0.007*	0.008	0.019*	0.030*
1956	-0.017*	-0.010	0.007*	0.008	0.019*	0.030*
1957	-0.017*	-0.010	0.007*	0.007	0.018*	0.030*
1958	-0.016*	-0.010	0.007*	0.007	0.018*	0.030*
1959	-0.015*	-0.010	0.007*	0.007	0.017*	0.030*
1960	-0.014*	-0.010	0.007*	0.006	0.017*	0.029*
1961	-0.013	-0.010	0.007*	0.006	0.017*	0.029*
1962	-0.013	-0.010	0.007*	0.005	0.016*	0.029*
1963	-0.013	-0.010	0.007*	0.005	0.016*	0.029*
1964	-0.012	-0.010	0.007	0.005	0.016*	0.029*
1965	-0.012	-0.009	0.006	0.004	0.016*	0.029*
1966	-0.012	-0.009	0.006	0.004	0.016*	0.029*
1967	-0.012	-0.009	0.006	0.003	0.016*	0.029*
1968	-0.011	-0.009	0.006	0.003	0.016*	0.029*
1969	-0.011	-0.009	0.005	0.003	0.016*	0.029*
1970	-0.011	-0.009	0.005	0.003	0.016*	0.029*
1971	-0.010	-0.009	0.005	0.003	0.017*	0.028*
1972	-0.010	-0.009	0.005	0.003	0.017*	0.028*
1973	-0.010	-0.009	0.005	0.002	0.017*	0.028*
1974	-0.011	-0.009	0.004	0.002	0.017	0.027*
1975	-0.011	-0.009	0.004	0.001	0.017	0.027*
1976	-0.011	-0.009	0.004	0.001	0.017	0.027*
1977	-0.011	-0.009	0.004	0.000	0.017	0.027*
1978	-0.011	-0.009	0.004	-0.000	0.017	0.027*
1979	-0.012	-0.009	0.004	-0.000	0.017	0.027*
1980	-0.013	-0.009	0.004	-0.001	0.017	0.027*
1981	-0.014	-0.009	0.003	-0.002	0.016	0.027*
1982	-0.014	-0.009	0.003	-0.002	0.016	0.027*
1983	-0.014	-0.009	0.003	-0.002	0.016	0.027*
1984	-0.014	-0.009	0.003	-0.003	0.017	0.027*
1985	-0.014	-0.009	0.003	-0.003	0.017	0.027*
1986	-0.014	-0.009	0.003	-0.003	0.017	0.027*

* Indicates coefficient is significant at $P \leq 0.05$.

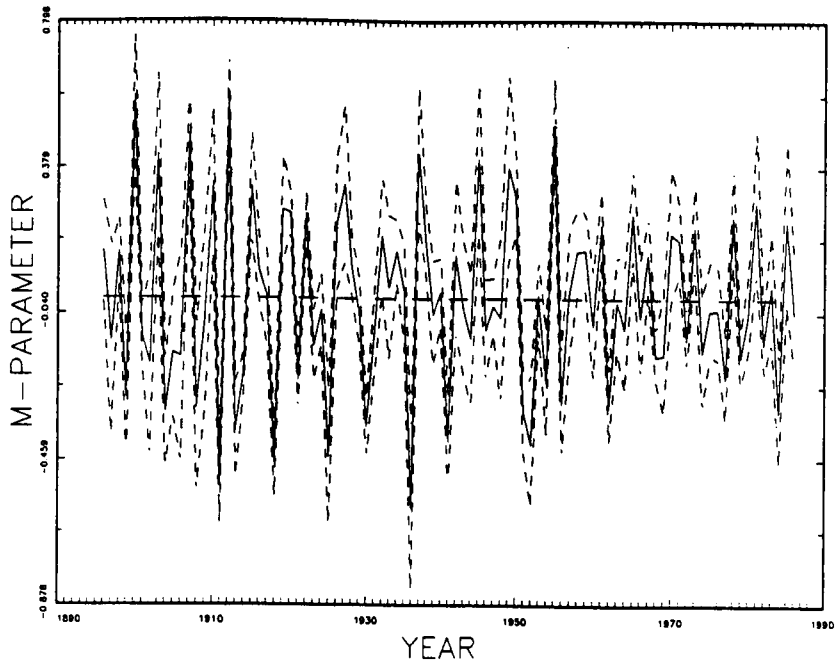


Figure A19. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 7.

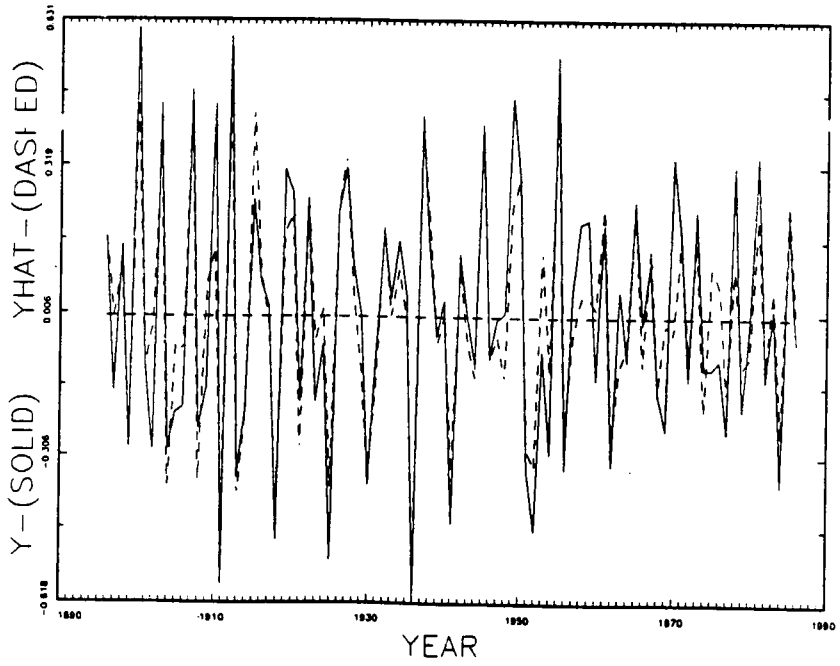
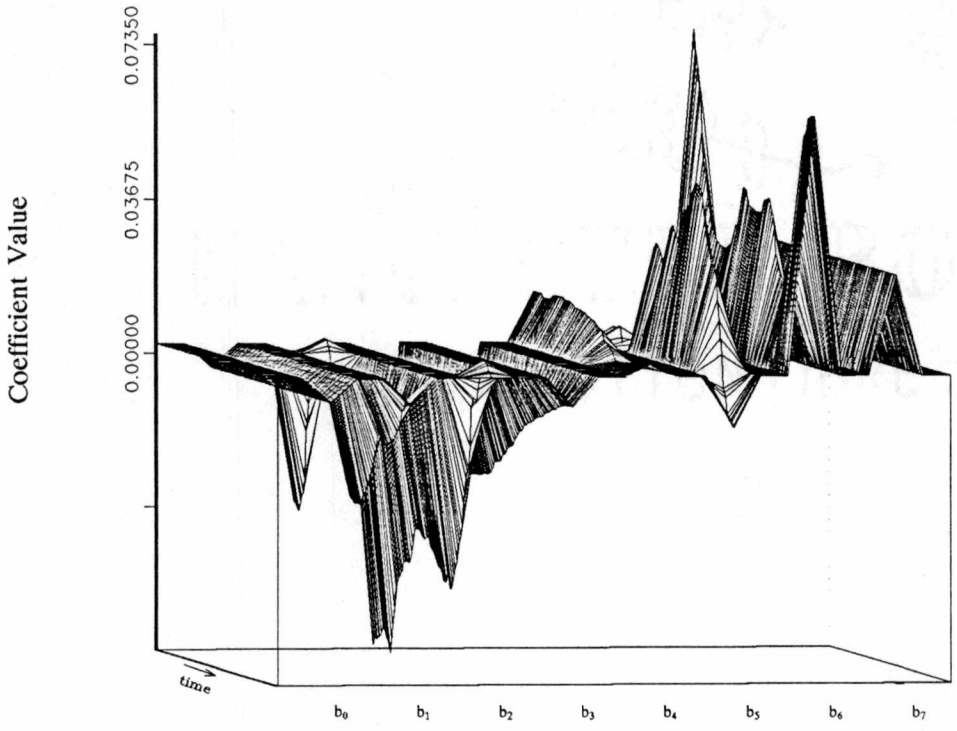


Figure A20. Graph of predicted and actual standardized growth, Emory River white oak, cluster 7.



Where:

b_0 = the intercept (non-varying)
b_1 = April temperature
b_2 = June temperature
b_3 = August temperature
b_4 = past December temperature
b_5 = May rain
b_6 = June rain
b_7 = past August rain

Figure A21. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 7.

Table A7. Climate parameter estimates for Emory River white oak, cluster 7.

YEAR	April temp. b_1	June temp. b_2	August temp. b_3	Past December temp. b_4	May rain b_5	June rain b_6	Past August rain b_7
1897	-0.014*	-0.055	-0.040*	0.015*	0.005	0.053*	0.027*
1898	-0.014*	-0.056	-0.040*	0.015*	0.005	0.053*	0.027*
1899	-0.014*	-0.057*	-0.041*	0.015*	0.006	0.053*	0.027*
1900	-0.014*	-0.057*	-0.041*	0.015*	0.006	0.051*	0.027*
1901	-0.014*	-0.057*	-0.041*	0.015*	0.006	0.051*	0.027*
1902	-0.014*	-0.059*	-0.041*	0.014*	0.007	0.048*	0.027*
1903	-0.014*	-0.057*	-0.042*	0.014*	0.007	0.046*	0.027*
1904	-0.014*	-0.058*	-0.042*	0.014*	0.007	0.045*	0.027*
1905	-0.014*	-0.059*	-0.042*	0.014*	0.007	0.045*	0.027*
1906	-0.014*	-0.061*	-0.042*	0.014*	0.009	0.042*	0.027*
1907	-0.014*	-0.061*	-0.042*	0.014*	0.009	0.042*	0.027*
1908	-0.014*	-0.062*	-0.042*	0.014*	0.010	0.041*	0.027*
1909	-0.014*	-0.062*	-0.042*	0.014*	0.011	0.039*	0.027*
1910	-0.014*	-0.059*	-0.042*	0.014*	0.012	0.038*	0.027*
1911	-0.014*	-0.056*	-0.042*	0.014*	0.012	0.038*	0.027*
1912	-0.014*	-0.052*	-0.042*	0.014*	0.012	0.038*	0.027*
1913	-0.014*	-0.046*	-0.041*	0.014*	0.012	0.037*	0.027*
1914	-0.014*	-0.045*	-0.041*	0.014*	0.012	0.037*	0.027*
1915	-0.014*	-0.042*	-0.041*	0.014*	0.012	0.037*	0.027*
1916	-0.014*	-0.042*	-0.041*	0.014*	0.012	0.037*	0.027*
1917	-0.014*	-0.040*	-0.041*	0.014*	0.012	0.036*	0.027*
1918	-0.014*	-0.038*	-0.041*	0.014*	0.012	0.036*	0.027*
1919	-0.014*	-0.035*	-0.040*	0.014*	0.013	0.036*	0.027*
1920	-0.014*	-0.034*	-0.040*	0.014*	0.013	0.036*	0.027*
1921	-0.014*	-0.034*	-0.040*	0.014*	0.013	0.036*	0.027*
1922	-0.014*	-0.034*	-0.040*	0.014*	0.013	0.036*	0.027*
1923	-0.014*	-0.034*	-0.040*	0.014*	0.014	0.036*	0.027*
1924	-0.014*	-0.034*	-0.040*	0.014*	0.014	0.036*	0.027*
1925	-0.014*	-0.033*	-0.038*	0.014*	0.016	0.036*	0.027*
1926	-0.014*	-0.032	-0.037*	0.014*	0.018	0.036*	0.027*
1927	-0.014*	-0.032	-0.036*	0.013*	0.020	0.036*	0.027*
1928	-0.014*	-0.031	-0.035*	0.013*	0.020	0.036*	0.027*
1929	-0.014*	-0.032	-0.035*	0.013*	0.020	0.036*	0.027*
1930	-0.014*	-0.032	-0.035*	0.013*	0.020	0.036*	0.027*
1931	-0.014*	-0.033	-0.035*	0.013*	0.020	0.036*	0.027*
1932	-0.014*	-0.034	-0.034*	0.013*	0.020	0.037*	0.027*
1933	-0.014*	-0.036*	-0.032*	0.013*	0.019	0.037*	0.027*
1934	-0.014*	-0.037*	-0.032*	0.013*	0.020	0.037*	0.027*
1935	-0.014*	-0.037*	-0.032*	0.013*	0.020	0.037*	0.027*
1936	-0.014*	-0.039*	-0.030*	0.012*	0.021	0.037*	0.027*
1937	-0.014*	-0.040*	-0.029*	0.012*	0.021	0.036*	0.027*
1938	-0.014*	-0.041*	-0.029*	0.012*	0.021	0.036*	0.027*
1939	-0.014*	-0.043*	-0.029*	0.012*	0.022	0.036*	0.027*
1940	-0.014*	-0.044*	-0.028*	0.012*	0.022	0.036*	0.027*
1941	-0.014*	-0.044*	-0.028*	0.012*	0.021	0.036*	0.027*
1942	-0.014*	-0.044*	-0.026*	0.011*	0.021	0.036*	0.027*
1943	-0.014*	-0.045*	-0.025*	0.011*	0.020	0.035*	0.027*
1944	-0.014*	-0.047*	-0.024*	0.011*	0.020	0.035*	0.027*
1945	-0.014*	-0.048*	-0.023*	0.011*	0.019	0.035*	0.027*
1946	-0.014*	-0.049*	-0.023*	0.010*	0.019	0.035*	0.027*
1947	-0.014*	-0.049*	-0.023*	0.010*	0.019	0.035*	0.027*
1948	-0.014*	-0.050*	-0.022*	0.010*	0.019	0.035*	0.027*
1949	-0.014*	-0.053*	-0.022*	0.009*	0.019	0.035*	0.027*
1950	-0.014*	-0.053*	-0.022*	0.009*	0.019	0.035*	0.027*

Table A7. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7
1951	-0.014*	-0.053*	-0.022*	0.009*	0.019	0.035*	0.027*
1952	-0.014*	-0.050*	-0.021*	0.008	0.018	0.035*	0.027*
1953	-0.014*	-0.051*	-0.021*	0.008	0.018	0.035*	0.027*
1954	-0.014*	-0.053*	-0.021*	0.008	0.018	0.035*	0.027*
1955	-0.014*	-0.053*	-0.021*	0.008	0.018	0.035*	0.027*
1956	-0.014*	-0.051*	-0.020	0.007	0.018	0.034*	0.027*
1957	-0.014*	-0.049*	-0.020	0.007	0.018	0.034*	0.027*
1958	-0.014*	-0.047*	-0.019	0.007	0.018	0.034*	0.027*
1959	-0.014*	-0.045*	-0.019	0.007	0.018	0.034*	0.027*
1960	-0.014*	-0.040*	-0.019	0.007	0.017	0.034*	0.027*
1961	-0.014*	-0.039*	-0.019	0.007	0.017	0.034*	0.027*
1962	-0.014*	-0.037*	-0.019	0.006	0.017	0.034*	0.027*
1963	-0.014*	-0.033	-0.018	0.007	0.016	0.034*	0.027*
1964	-0.014*	-0.025	-0.018	0.007	0.014	0.034*	0.027*
1965	-0.014*	-0.022	-0.017	0.007	0.014	0.035*	0.027*
1966	-0.014*	-0.017	-0.017	0.007	0.013	0.035*	0.027*
1967	-0.014*	-0.014	-0.016	0.007	0.012	0.035*	0.027*
1968	-0.014*	-0.014	-0.016	0.007	0.012	0.036*	0.027*
1969	-0.014*	-0.007	-0.016	0.007	0.011	0.037*	0.027*
1970	-0.014*	0.004	-0.015	0.007	0.010	0.038*	0.027*
1971	-0.014*	0.006	-0.015	0.007	0.010	0.039*	0.027*
1972	-0.014*	0.007	-0.015	0.007	0.010	0.039*	0.027*
1973	-0.014*	0.006	-0.015	0.007	0.009	0.039*	0.027*
1974	-0.014*	0.008	-0.015	0.007	0.008	0.041*	0.027*
1975	-0.014*	0.012	-0.014	0.007	0.006	0.041*	0.027*
1976	-0.014*	0.015	-0.014	0.007	0.005	0.042*	0.027*
1977	-0.014*	0.018	-0.014	0.007	0.004	0.043*	0.027*
1978	-0.014*	0.022	-0.013	0.008	0.002	0.044*	0.027*
1979	-0.014*	0.023	-0.013	0.008	0.002	0.045*	0.027*
1980	-0.014*	0.023	-0.013	0.008	0.002	0.045*	0.027*
1981	-0.014*	0.025	-0.013	0.008	0.000	0.046*	0.027*
1982	-0.014*	0.024	-0.013	0.008	-0.000	0.046*	0.027*
1983	-0.014*	0.022	-0.013	0.008	-0.000	0.046*	0.027*
1984	-0.014*	0.021	-0.013	0.008	-0.001	0.046*	0.027*
1985	-0.014*	0.020	-0.013	0.008	-0.001	0.046*	0.027*
1986	-0.014*	0.020	-0.013	0.008	-0.001	0.046*	0.027*

* Indicates coefficient is significant at $P \leq 0.05$.

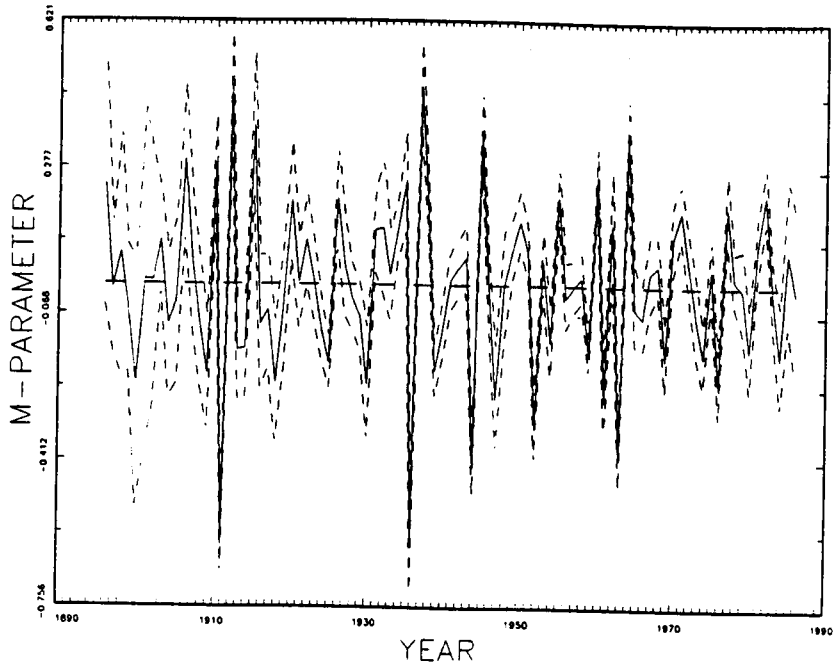


Figure A22. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 8.

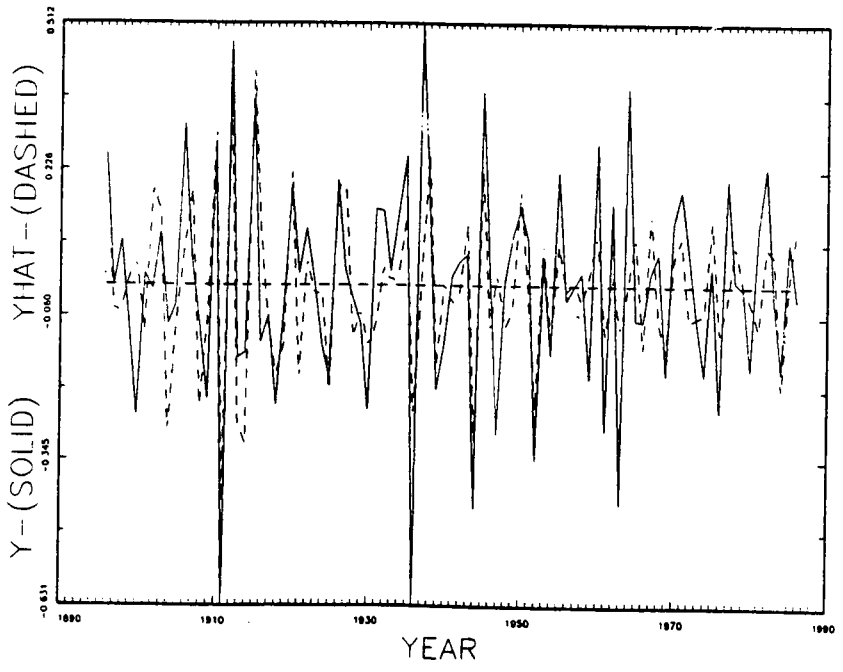
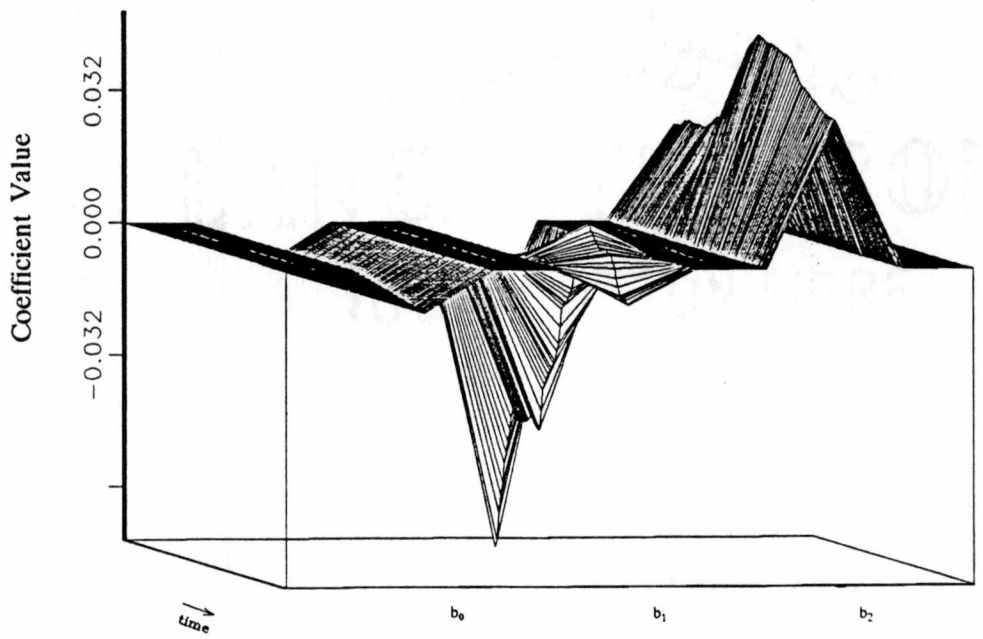


Figure A23. Graph of predicted and actual standardized growth, Emory River white oak, cluster 8.



Where:

b_0 = the intercept (non-varying)
b_1 = April temperature
b_2 = May temperature

Figure A24. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 8.

Table A8. Climate parameter estimates by year for Emory River white oak, cluster 8.

YEAR	June temperature b_1	Past August rain b_2
1897	-0.052	0.029
1898	-0.052	0.029
1899	-0.052	0.029
1900	-0.053	0.029
1901	-0.054*	0.030
1902	-0.055*	0.030
1903	-0.055*	0.030
1904	-0.057*	0.030
1905	-0.059*	0.030
1906	-0.060*	0.030
1907	-0.062*	0.030
1908	-0.063*	0.030
1909	-0.065*	0.030
1910	-0.065*	0.030
1911	-0.065*	0.030
1912	-0.062*	0.030
1913	-0.060*	0.030
1914	-0.058*	0.030
1915	-0.055*	0.030
1916	-0.053*	0.030*
1917	-0.051*	0.031*
1918	-0.049*	0.031*
1919	-0.047*	0.031*
1920	-0.045*	0.031*
1921	-0.045*	0.031*
1922	-0.045*	0.032*
1923	-0.044*	0.032*
1924	-0.044*	0.032*
1925	-0.044*	0.032*
1926	-0.043*	0.033*
1927	-0.042*	0.034*
1928	-0.041*	0.034*
1929	-0.041*	0.035*
1930	-0.040*	0.037*
1931	-0.039*	0.038*
1932	-0.038*	0.040*
1933	-0.037*	0.041*
1934	-0.037*	0.042*
1935	-0.036*	0.043*
1936	-0.034*	0.044*
1937	-0.031*	0.045*
1938	-0.031*	0.046*
1939	-0.030*	0.046*
1940	-0.029*	0.046*
1941	-0.028*	0.047*
1942	-0.027*	0.047*
1943	-0.026*	0.048*
1944	-0.026*	0.048*
1945	-0.024*	0.048*
1946	-0.023*	0.048*
1947	-0.020*	0.048*
1948	-0.017	0.047*
1949	-0.016	0.047*

Table A8. Continued.

YEAR	b_1	b_2
1950	-0.015	0.047*
1951	-0.015	0.047*
1952	-0.014	0.047*
1953	-0.013	0.047*
1954	-0.012	0.047*
1955	-0.011	0.047*
1956	-0.010	0.047*
1957	-0.009	0.047*
1958	-0.008	0.046*
1959	-0.008	0.046*
1960	-0.007	0.046*
1961	-0.006	0.046*
1962	-0.005	0.045*
1963	-0.004	0.045*
1964	-0.004	0.044*
1965	-0.004	0.043*
1966	-0.004	0.043*
1967	-0.003	0.042*
1968	-0.003	0.042*
1969	-0.003	0.042*
1970	-0.003	0.042*
1971	-0.003	0.042*
1972	-0.003	0.041*
1973	-0.002	0.041*
1974	-0.002	0.041*
1975	-0.002	0.040*
1976	-0.002	0.040*
1977	-0.003	0.040*
1978	-0.003	0.040*
1979	-0.004	0.039*
1980	-0.004	0.039*
1981	-0.005	0.039*
1982	-0.005	0.039*
1983	-0.005	0.039*
1984	-0.005	0.039*
1985	-0.005	0.039*
1986	-0.005	0.039*

* Indicates coefficient is significant at $P \leq 0.05$.

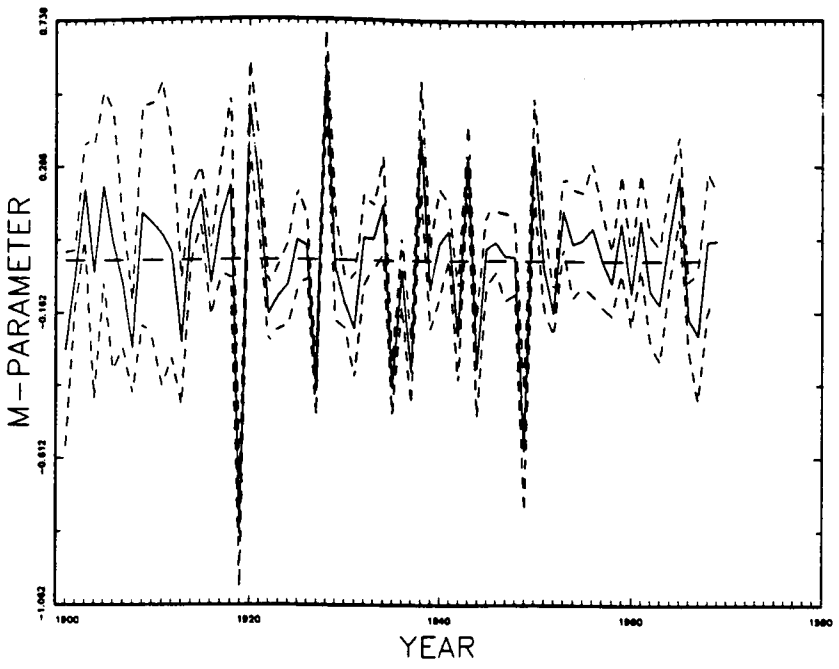


Figure A25. Graph of M-parameter and associated 95% confidence interval over time, Emory River white oak, cluster 9.

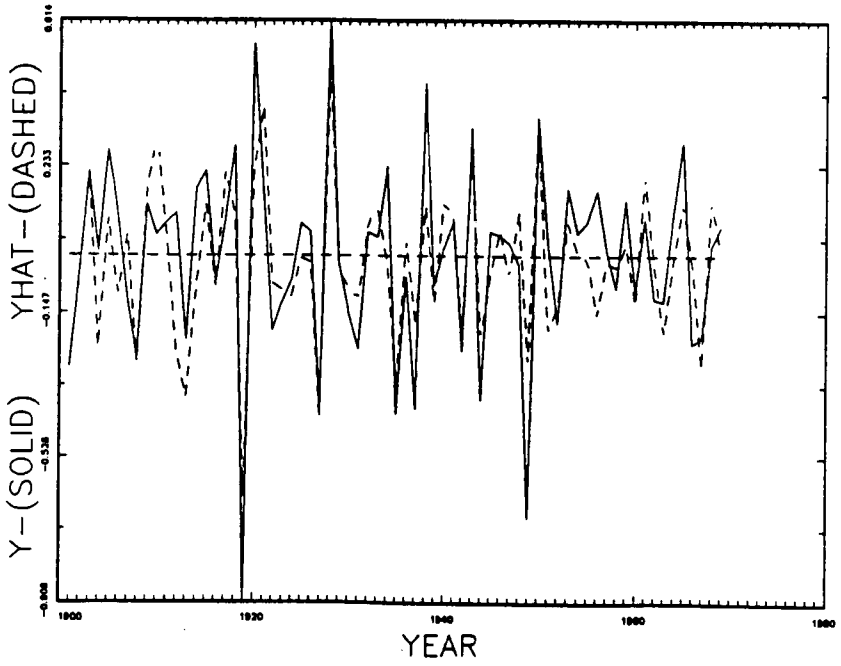
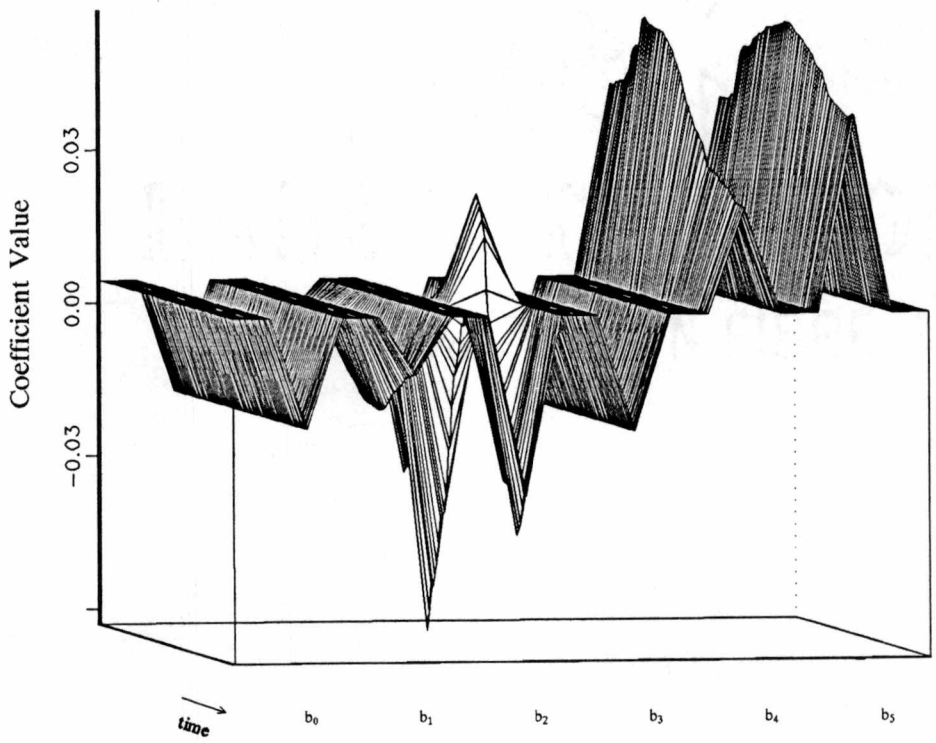


Figure A26. Graph of predicted and actual standardized growth, Emory River white oak, cluster 9.



Where:

b_0 = the intercept (non-varying)
b_1 = February temperature
b_2 = June temperature
b_3 = August temperature
b_4 = June rain
b_5 = past August rain

Figure A27. Three dimensional graph of changes in parameter coefficients over time, Emory River white oak, cluster 9.

Table A9. Climate parameter estimates for Emory River white oak, cluster 9.

YEAR	February temp. b_1	June temp. b_2	August temp. b_3	June rain b_4	Past August rain b_5
1918	-0.003	-0.024	-0.019*	0.038	0.050*
1919	-0.003	-0.024	-0.019*	0.038	0.050*
1920	-0.003	-0.024	-0.019*	0.038	0.050*
1921	-0.003	-0.026	-0.019*	0.040	0.050*
1922	-0.003	-0.027	-0.019*	0.040	0.050*
1923	-0.002	-0.028	-0.019*	0.041	0.050*
1924	-0.002	-0.028	-0.019*	0.041	0.050*
1925	-0.002	-0.029	-0.019*	0.041	0.050*
1926	-0.002	-0.029	-0.019*	0.042	0.050*
1927	-0.002	-0.030	-0.019*	0.044	0.050*
1928	-0.001	-0.032	-0.019*	0.045*	0.050*
1929	-0.000	-0.033*	-0.019*	0.047*	0.050*
1930	-0.000	-0.033*	-0.019*	0.049*	0.050*
1931	-0.000	-0.033*	-0.019*	0.049*	0.050*
1932	-0.000	-0.033*	-0.019*	0.049*	0.050*
1933	-0.000	-0.034*	-0.019*	0.049*	0.050*
1934	-0.000	-0.035*	-0.019*	0.051*	0.050*
1935	-0.000	-0.036*	-0.019*	0.054*	0.051*
1936	-0.001	-0.035*	-0.019*	0.054*	0.051*
1937	-0.001	-0.034*	-0.019*	0.053*	0.051*
1938	-0.002	-0.034*	-0.019*	0.052*	0.051*
1939	-0.002	-0.034*	-0.019*	0.052*	0.051*
1940	-0.002	-0.033*	-0.019*	0.052*	0.051*
1941	-0.003	-0.032*	-0.019*	0.052*	0.051*
1942	-0.003	-0.030*	-0.019*	0.052*	0.051*
1943	-0.004	-0.029*	-0.019*	0.052*	0.051*
1944	-0.004	-0.029*	-0.019*	0.052*	0.051*
1945	-0.004	-0.028*	-0.019*	0.051*	0.051*
1946	-0.005	-0.026*	-0.019*	0.050*	0.051*
1947	-0.006	-0.025*	-0.019*	0.050*	0.051*
1948	-0.007	-0.023*	-0.019*	0.048*	0.051*
1949	-0.007	-0.021*	-0.019*	0.047*	0.051*
1950	-0.008	-0.021*	-0.019*	0.047*	0.051*
1951	-0.009	-0.019*	-0.019*	0.045*	0.051*
1952	-0.009	-0.018	-0.019*	0.044*	0.051*
1953	-0.009*	-0.018	-0.019*	0.043*	0.051*
1954	-0.010*	-0.017	-0.019*	0.042*	0.051*
1955	-0.010*	-0.015	-0.019*	0.040*	0.051*
1956	-0.011*	-0.015	-0.019*	0.039*	0.051*
1957	-0.012*	-0.014	-0.019*	0.037*	0.051*
1958	-0.012*	-0.014	-0.019*	0.037*	0.051*
1959	-0.013*	-0.013	-0.019*	0.035*	0.051*
1960	-0.013*	-0.013	-0.019*	0.034*	0.051*
1961	-0.013*	-0.012	-0.019*	0.033*	0.051*
1962	-0.013*	-0.013	-0.019*	0.032*	0.051*
1963	-0.014*	-0.013	-0.019*	0.032*	0.051*
1964	-0.014*	-0.013	-0.019*	0.031*	0.050*
1965	-0.014*	-0.014	-0.019*	0.031*	0.050*
1966	-0.014*	-0.015	-0.019*	0.029*	0.050*
1967	-0.014*	-0.016	-0.019*	0.028	0.050*
1968	-0.014*	-0.017	-0.019*	0.027	0.050*
1969	-0.014*	-0.017	-0.019*	0.027	0.050*
1970	-0.013*	-0.017	-0.019*	0.027	0.050*
1971	-0.013*	-0.018	-0.019*	0.027	0.050*

Table A9. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5
1972	-0.012*	-0.019	-0.019*	0.026	0.050*
1973	-0.012	-0.021	-0.019*	0.025	0.050*
1974	-0.011	-0.021	-0.019*	0.025	0.050*
1975	-0.011	-0.021	-0.019*	0.025	0.050*
1976	-0.010	-0.022	-0.019*	0.025	0.050*
1977	-0.010	-0.022	-0.019*	0.025	0.050*
1978	-0.010	-0.022	-0.019*	0.024	0.050*
1979	-0.009	-0.022	-0.019*	0.024	0.050*
1980	-0.009	-0.023	-0.019*	0.023	0.050*
1981	-0.009	-0.023	-0.019*	0.022	0.050*
1982	-0.009	-0.023	-0.019*	0.022	0.050*
1983	-0.009	-0.023	-0.019*	0.022	0.050*
1984	-0.008	-0.023	-0.019*	0.022	0.050*
1985	-0.008	-0.023	-0.019*	0.022	0.050*
1986	-0.008	-0.023	-0.019*	0.022	0.050*

* Indicates coefficient is significant at $P \leq 0.05$.

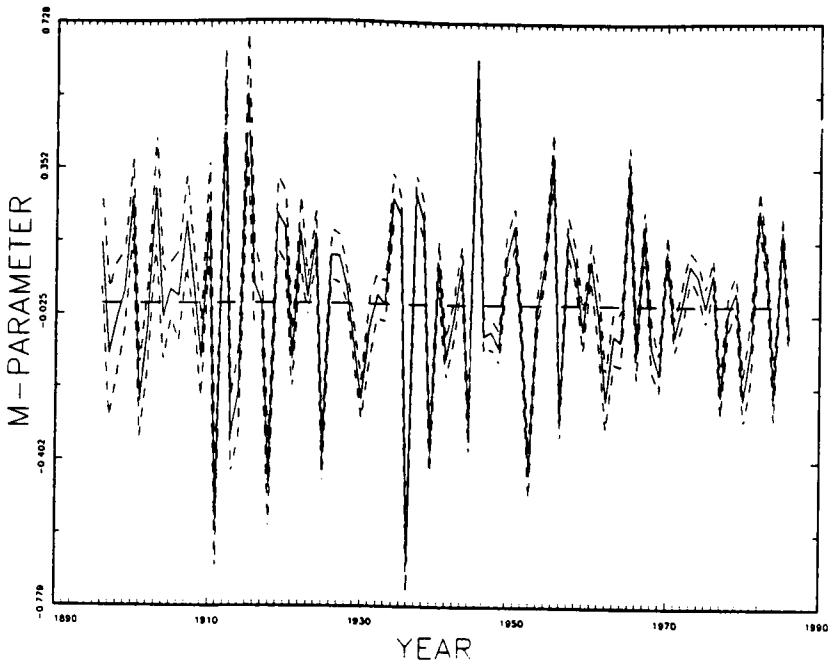


Figure A28. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 1.

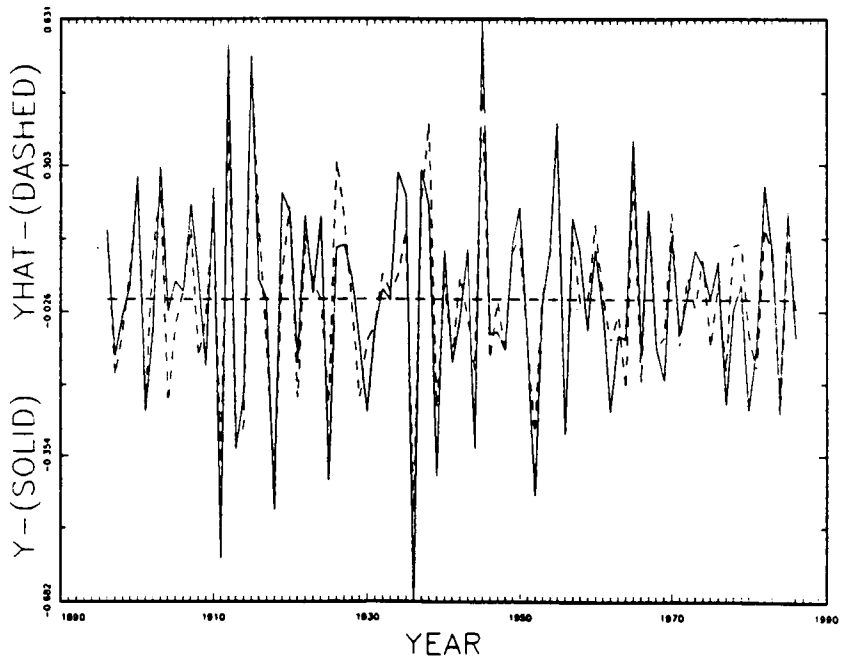
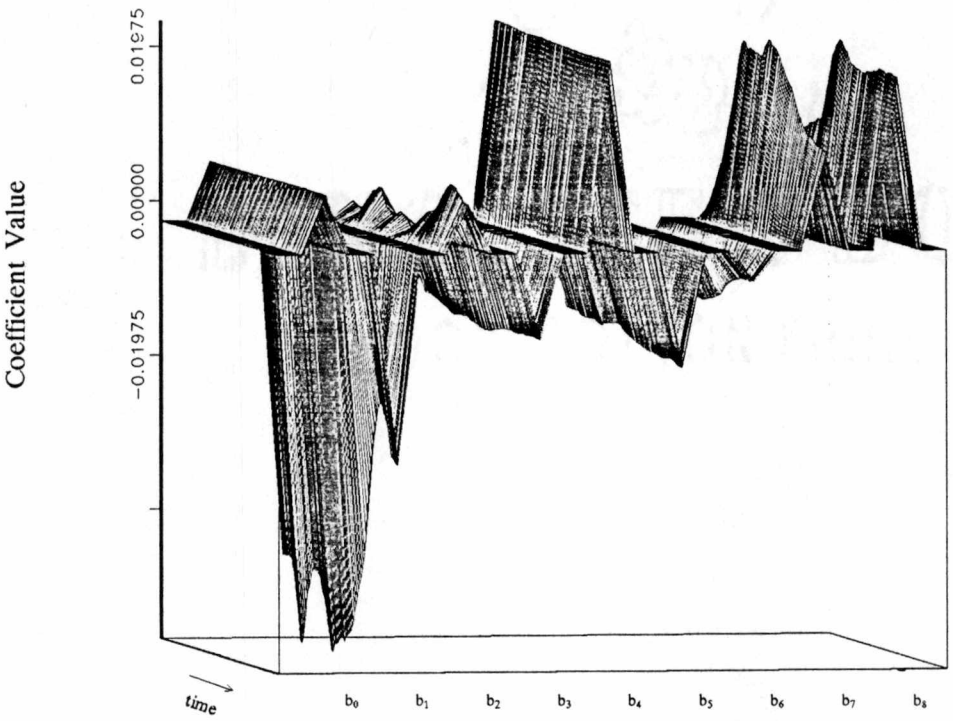


Figure A29. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = past May temperature
b_3 = April rain
b_4 = June rain
b_5 = October rain
b_6 = past March rain
b_7 = past August rain
b_8 = past December rain

Figure A30. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 1.

Table A10. Climate parameter estimates for LBL white oak, cluster 1.

YEAR	June temp. b_1	Past May temp. b_2	April rain b_3	June rain b_4	October rain b_5	Past March rain b_6	Past August rain b_7	Past December rain b_8
1897	-0.045	-0.000	-0.012	0.023*	-0.014	-0.008	-0.003	0.006
1898	-0.045	-0.001	-0.012	0.023*	-0.014	-0.008	-0.003	0.006
1899	-0.045	-0.001	-0.012	0.023*	-0.014	-0.008	-0.003	0.006
1900	-0.045	-0.001	-0.012	0.023*	-0.014	-0.008	-0.003	0.006
1901	-0.045	-0.001	-0.012	0.023*	-0.014	-0.008	-0.003	0.006
1902	-0.045	-0.001	-0.012	0.023*	-0.014	-0.008	-0.002	0.006
1903	-0.045*	-0.001	-0.012	0.023*	-0.014	-0.009	-0.001	0.006
1904	-0.047*	-0.001	-0.012	0.023*	-0.014	-0.009	0.000	0.007
1905	-0.047*	-0.001	-0.012	0.023*	-0.014	-0.009	0.001	0.007
1906	-0.049*	-0.001	-0.012	0.023*	-0.014	-0.009	0.002	0.007
1907	-0.050*	-0.001	-0.012	0.023*	-0.014	-0.009	0.003	0.007
1908	-0.052*	-0.000	-0.012	0.022*	-0.014	-0.009	0.004	0.008
1909	-0.054*	0.000	-0.013	0.022*	-0.014	-0.009	0.005	0.008
1910	-0.056*	0.001	-0.013	0.022*	-0.014	-0.009	0.007	0.009
1911	-0.056*	0.002	-0.013	0.022*	-0.015	-0.009	0.008	0.010
1912	-0.055*	0.002	-0.013	0.022*	-0.015	-0.010	0.009	0.010
1913	-0.054*	0.002	-0.013	0.022*	-0.014	-0.010	0.010	0.009
1914	-0.052*	0.002	-0.013	0.022*	-0.014	-0.010	0.011	0.010
1915	-0.050*	0.002	-0.013	0.022*	-0.014	-0.011	0.013	0.010
1916	-0.049*	0.002	-0.013	0.022*	-0.014	-0.011	0.014	0.010
1917	-0.049*	0.002	-0.013	0.022*	-0.014	-0.012	0.015	0.010
1918	-0.047*	0.002	-0.014	0.022*	-0.014	-0.012	0.016	0.010
1919	-0.047*	0.002	-0.014	0.022*	-0.015	-0.012	0.018	0.010
1920	-0.046*	0.001	-0.014	0.022*	-0.015	-0.012	0.019	0.011
1921	-0.046*	0.001	-0.014	0.022*	-0.015	-0.012	0.020	0.011
1922	-0.046*	0.000	-0.013	0.022*	-0.015	-0.011	0.021	0.011
1923	-0.046*	0.000	-0.013	0.022*	-0.015	-0.011	0.021	0.011
1924	-0.047*	0.000	-0.013	0.022*	-0.015	-0.011	0.021	0.011
1925	-0.047*	-0.000	-0.013	0.022*	-0.015	-0.011	0.021	0.011
1926	-0.048*	-0.000	-0.013	0.022*	-0.015	-0.011	0.020	0.011
1927	-0.049*	-0.000	-0.013	0.022*	-0.014	-0.011	0.020	0.011
1928	-0.049*	-0.000	-0.013	0.022*	-0.014	-0.011	0.020	0.012
1929	-0.050*	-0.000	-0.013	0.022*	-0.014	-0.011	0.020	0.012
1930	-0.050*	-0.000	-0.013	0.022*	-0.014	-0.011	0.020	0.013
1931	-0.052*	-0.000	-0.014	0.022*	-0.014	-0.011	0.020	0.014
1932	-0.053*	0.000	-0.014	0.022*	-0.014	-0.011	0.020	0.015*
1933	-0.054*	0.000	-0.014	0.022*	-0.014	-0.011	0.020	0.016*
1934	-0.056*	0.000	-0.014	0.022*	-0.014	-0.010	0.020	0.017*
1935	-0.056*	0.000	-0.014	0.022*	-0.014	-0.010	0.020	0.018*
1936	-0.055*	-0.000	-0.014	0.022*	-0.014	-0.010	0.020	0.019*
1937	-0.055*	-0.000	-0.014	0.022*	-0.014	-0.010	0.020	0.020*
1938	-0.055*	-0.000	-0.014	0.022*	-0.014	-0.010	0.020	0.020*
1939	-0.055*	-0.001	-0.014	0.022*	-0.015	-0.010	0.021	0.021*
1940	-0.054*	-0.001	-0.014	0.022*	-0.015	-0.010	0.021	0.021*
1941	-0.054*	-0.001	-0.014	0.022*	-0.015	-0.010	0.022*	0.022*
1942	-0.054*	-0.002	-0.014	0.022*	-0.015	-0.010	0.022*	0.022*
1943	-0.054*	-0.002	-0.014	0.022*	-0.015	-0.010	0.022*	0.022*
1944	-0.054*	-0.001	-0.014	0.022*	-0.015	-0.011	0.022*	0.022*
1945	-0.054*	-0.001	-0.014	0.022*	-0.015	-0.011	0.022*	0.021*
1946	-0.053*	-0.001	-0.014	0.022*	-0.015	-0.011	0.022*	0.021*
1947	-0.053*	-0.001	-0.014	0.022*	-0.016	-0.011	0.021*	0.021*
1948	-0.053*	-0.000	-0.014	0.022*	-0.016	-0.011	0.021*	0.021*
1949	-0.053*	-0.000	-0.014	0.022*	-0.016	-0.010	0.021*	0.020*
1950	-0.052*	0.000	-0.014	0.022*	-0.016	-0.010	0.021*	0.020*

Table A10. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
1951	-0.052*	0.001	-0.014	0.022*	-0.016	-0.010	0.021*	0.019*
1952	-0.050*	0.001	-0.014	0.022*	-0.016	-0.010	0.020*	0.019*
1953	-0.049*	0.001	-0.014	0.022*	-0.016*	-0.010	0.019	0.019*
1954	-0.048*	0.001	-0.014	0.022*	-0.016*	-0.010	0.019	0.019*
1955	-0.047*	0.001	-0.014	0.022*	-0.016*	-0.010	0.018	0.019*
1956	-0.046*	0.001	-0.014	0.022*	-0.016*	-0.010	0.018	0.019*
1957	-0.046*	0.001	-0.014	0.022*	-0.016*	-0.010	0.018	0.019*
1958	-0.045*	0.002	-0.014	0.022*	-0.016*	-0.010	0.017	0.019*
1959	-0.043*	0.002	-0.014	0.022*	-0.016*	-0.009	0.017	0.019*
1960	-0.042*	0.002	-0.014	0.022*	-0.016*	-0.009	0.017	0.019*
1961	-0.040*	0.002	-0.014	0.022*	-0.016*	-0.009	0.016	0.019*
1962	-0.037*	0.002	-0.014	0.022*	-0.016*	-0.009	0.016	0.019*
1963	-0.035*	0.003	-0.014	0.022*	-0.016*	-0.008	0.015	0.019*
1964	-0.033*	0.003	-0.014	0.022*	-0.017*	-0.008	0.015	0.019*
1965	-0.031*	0.004	-0.014	0.022*	-0.017*	-0.008	0.014	0.019*
1966	-0.029*	0.004	-0.014	0.022*	-0.017*	-0.008	0.014	0.019*
1967	-0.028*	0.004	-0.014	0.022*	-0.017*	-0.007	0.013	0.019*
1968	-0.026*	0.005	-0.014	0.022*	-0.017*	-0.007	0.013	0.019*
1969	-0.025*	0.005	-0.014	0.022*	-0.017*	-0.007	0.012	0.019*
1970	-0.024*	0.005	-0.014	0.022*	-0.017*	-0.007	0.012	0.019*
1971	-0.023*	0.005	-0.014	0.022*	-0.017*	-0.007	0.012	0.020*
1972	-0.022*	0.005	-0.014	0.022*	-0.017*	-0.007	0.011	0.020*
1973	-0.022*	0.005	-0.014	0.022*	-0.017	-0.007	0.011	0.020*
1974	-0.023*	0.005	-0.014	0.022*	-0.017	-0.007	0.011	0.020*
1975	-0.023*	0.005	-0.014	0.022*	-0.017	-0.007	0.011	0.020*
1976	-0.024*	0.005	-0.014	0.022*	-0.017	-0.006	0.011	0.020*
1977	-0.025*	0.005	-0.014	0.022*	-0.017	-0.006	0.011	0.020*
1978	-0.025*	0.005	-0.014	0.022*	-0.017	-0.006	0.011	0.019*
1979	-0.026*	0.005	-0.014	0.022*	-0.017	-0.006	0.011	0.020*
1980	-0.027*	0.004	-0.014	0.022*	-0.017	-0.007	0.010	0.020*
1981	-0.029*	0.004	-0.014	0.022*	-0.017	-0.007	0.010	0.020*
1982	-0.029*	0.004	-0.014	0.022*	-0.017	-0.007	0.010	0.020*
1983	-0.029*	0.004	-0.014	0.022*	-0.017	-0.007	0.010	0.020
1984	-0.030*	0.004	-0.014	0.022*	-0.017	-0.006	0.010	0.019
1985	-0.030*	0.004	-0.014	0.022*	-0.017	-0.006	0.010	0.019
1986	-0.030*	0.004	-0.014	0.022*	-0.017	-0.006	0.010	0.019

* Indicates coefficient is significant at $P \leq 0.05$.

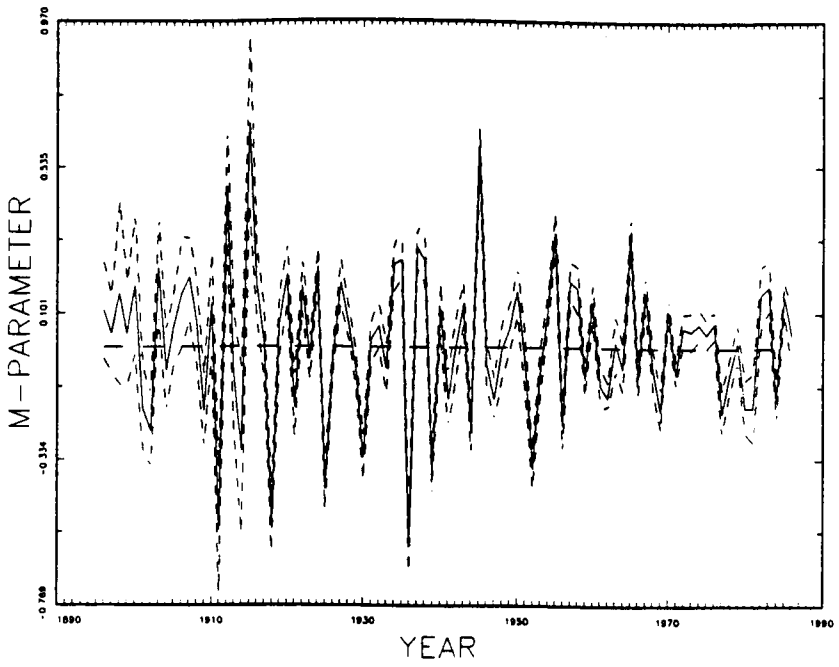


Figure A31. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 2.

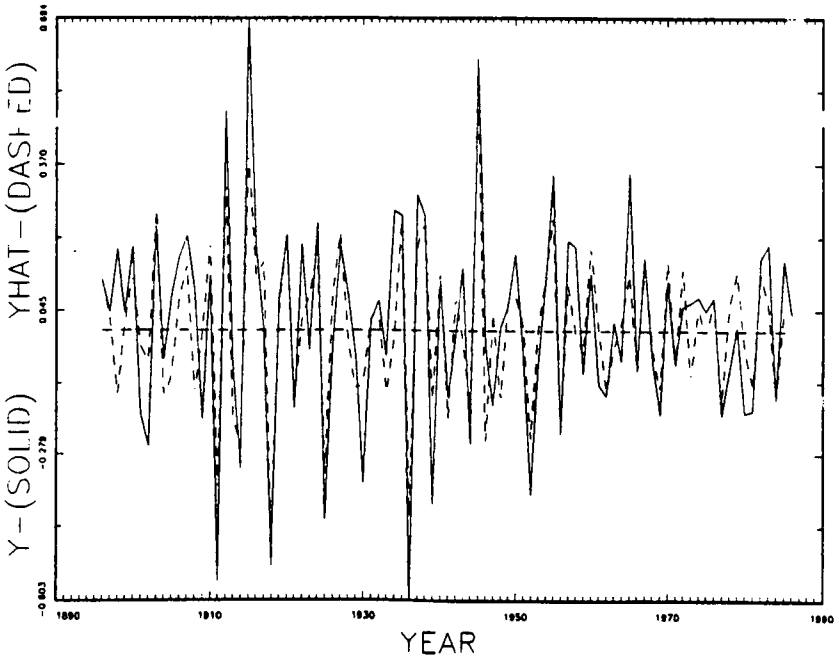
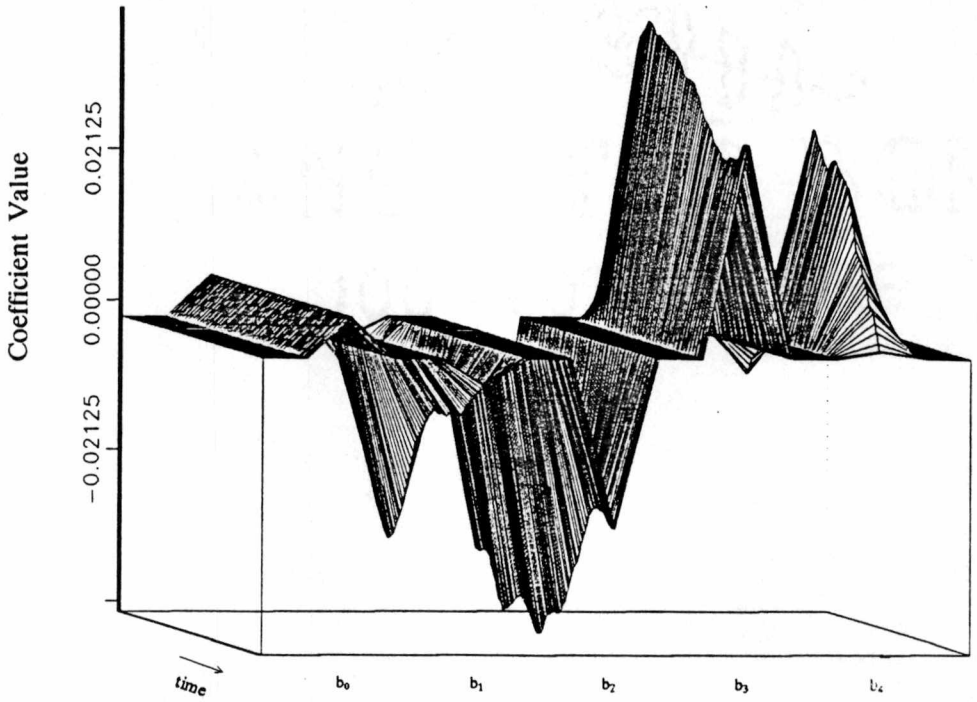


Figure A32. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = past August rain
b_4 = past December rain

Figure A33. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 2.

Table A11. Climate parameter estimates for LBL white oak, cluster 2.

YEAR	May temperature b_1	June temperature b_2	Past August rain b_3	Past December rain b_4
1897	-0.006	-0.035	-0.002	-0.008
1898	-0.008	-0.035	-0.003	-0.009
1899	-0.009	-0.035	-0.003	-0.009
1900	-0.010	-0.035	-0.003	-0.009
1901	-0.011	-0.035	-0.003	-0.010
1902	-0.010	-0.035	-0.002	-0.010
1903	-0.009	-0.035	0.000	-0.009
1904	-0.009	-0.035	0.002	-0.008
1905	-0.009	-0.036	0.003	-0.008
1906	-0.009	-0.037*	0.006	-0.007
1907	-0.008	-0.037*	0.008	-0.007
1908	-0.009	-0.038*	0.009	-0.006
1909	-0.010	-0.039*	0.011	-0.005
1910	-0.012	-0.040*	0.013	-0.003
1911	-0.014	-0.041*	0.018	-0.001
1912	-0.016	-0.041*	0.021	0.000
1913	-0.017	-0.042*	0.024	0.002
1914	-0.021	-0.043*	0.031	0.004
1915	-0.025*	-0.042*	0.037*	0.005
1916	-0.025*	-0.042*	0.038*	0.005
1917	-0.027*	-0.042*	0.038*	0.005
1918	-0.027*	-0.042*	0.039*	0.004
1919	-0.028*	-0.041*	0.039*	0.004
1920	-0.029*	-0.041*	0.040*	0.003
1921	-0.029*	-0.041*	0.040*	0.002
1922	-0.030*	-0.040*	0.041*	0.002
1923	-0.031*	-0.040*	0.041*	0.003
1924	-0.031*	-0.040*	0.041*	0.003
1925	-0.032*	-0.040*	0.040*	0.004
1926	-0.031*	-0.040*	0.040*	0.004
1927	-0.031*	-0.041*	0.039*	0.003
1928	-0.031*	-0.041*	0.039*	0.004
1929	-0.031*	-0.041*	0.039*	0.005
1930	-0.030*	-0.042*	0.039*	0.008
1931	-0.029*	-0.042*	0.039*	0.010
1932	-0.028*	-0.042*	0.039*	0.012
1933	-0.028*	-0.043*	0.038*	0.015
1934	-0.027*	-0.044*	0.038*	0.017
1935	-0.026*	-0.044*	0.038*	0.019
1936	-0.025*	-0.044*	0.038*	0.022*
1937	-0.024*	-0.044*	0.038*	0.022*
1938	-0.022*	-0.044*	0.038*	0.023*
1939	-0.021*	-0.044*	0.037*	0.024*
1940	-0.020*	-0.043*	0.037*	0.025*
1941	-0.019*	-0.042*	0.037*	0.026*
1942	-0.017*	-0.041*	0.036*	0.027*
1943	-0.017*	-0.041*	0.036*	0.027*
1944	-0.017*	-0.041*	0.035*	0.026*
1945	-0.016*	-0.041*	0.035*	0.025*
1946	-0.015	-0.041*	0.034*	0.025*
1947	-0.015	-0.040*	0.034*	0.024*
1948	-0.014	-0.041*	0.034*	0.023*
1949	-0.014	-0.041*	0.034*	0.023*
1950	-0.013	-0.040*	0.034*	0.022*

Table A11. Continued.

YEAR	b_1	b_2	b_3	b_4
1951	-0.013	-0.040*	0.034*	0.022*
1952	-0.013	-0.040*	0.033*	0.022*
1953	-0.012	-0.039*	0.033*	0.023*
1954	-0.012	-0.039*	0.032*	0.023*
1955	-0.012	-0.038*	0.032*	0.023*
1956	-0.012	-0.037*	0.031*	0.023*
1957	-0.012*	-0.036*	0.030*	0.023*
1958	-0.012*	-0.035*	0.029*	0.022*
1959	-0.012*	-0.034*	0.029*	0.022*
1960	-0.012*	-0.033*	0.029*	0.022*
1961	-0.012*	-0.033*	0.028*	0.021*
1962	-0.012*	-0.032*	0.028*	0.021*
1963	-0.012*	-0.031*	0.027*	0.021*
1964	-0.011	-0.030*	0.026*	0.020*
1965	-0.011	-0.029*	0.026*	0.019*
1966	-0.011	-0.029*	0.026*	0.017*
1967	-0.011	-0.028*	0.026*	0.016*
1968	-0.011	-0.027*	0.025*	0.014
1969	-0.011	-0.025*	0.025*	0.012
1970	-0.011	-0.025*	0.025*	0.011
1971	-0.011	-0.025*	0.025*	0.011
1972	-0.011	-0.024*	0.025*	0.010
1973	-0.010	-0.024*	0.025*	0.009
1974	-0.010	-0.024*	0.025*	0.008
1975	-0.010	-0.024*	0.025*	0.007
1976	-0.009	-0.024*	0.025*	0.007
1977	-0.008	-0.024*	0.025*	0.005
1978	-0.008	-0.024*	0.025*	0.004
1979	-0.008	-0.025*	0.025*	0.004
1980	-0.008	-0.025*	0.026*	0.004
1981	-0.007	-0.026*	0.027	0.002
1982	-0.007	-0.026*	0.027	0.001
1983	-0.007	-0.026*	0.027	-0.000
1984	-0.006	-0.026*	0.028	-0.001
1985	-0.006	-0.026*	0.028	-0.001
1986	-0.006	-0.026*	0.028	-0.001

* Indicates coefficient is significant at $P \leq 0.05$.

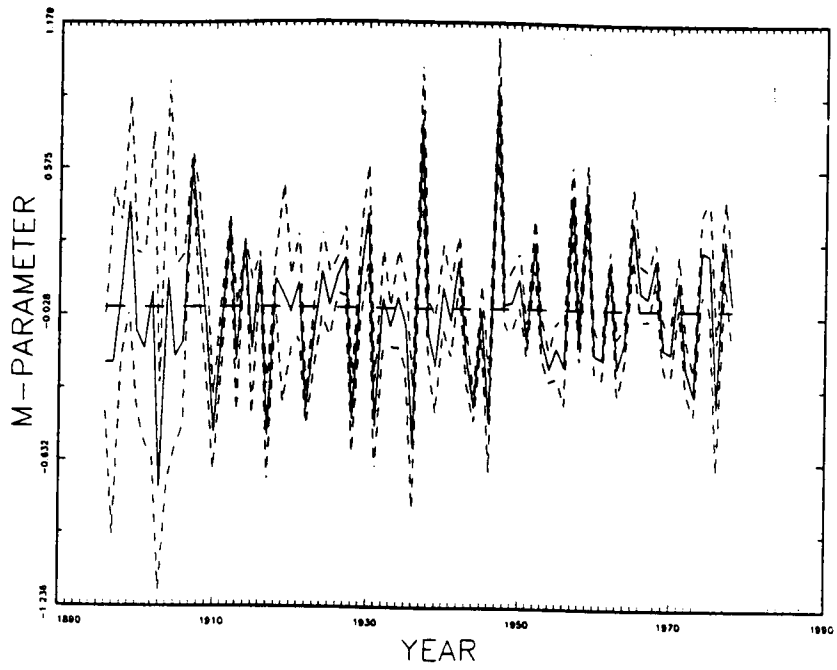


Figure A34. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 3.

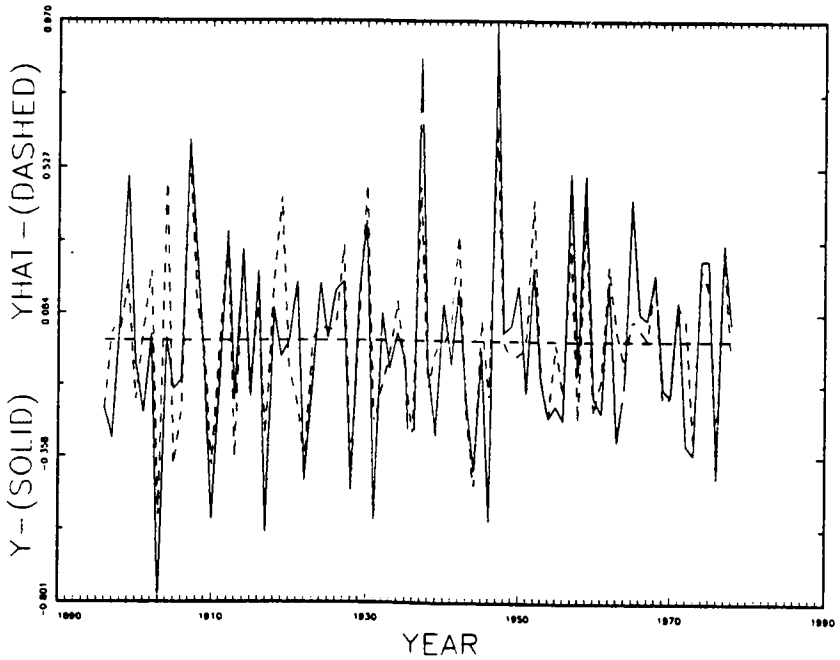
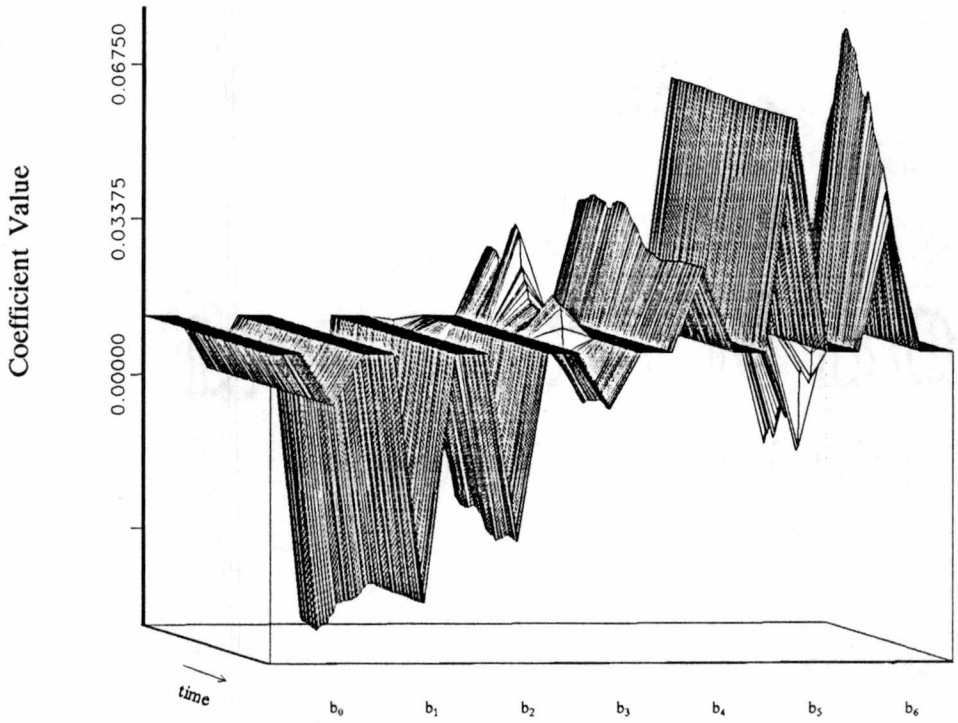


Figure A35. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 3.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = past June temperature
b_3 = past August temperature
b_4 = June rain
b_5 = past August rain
b_6 = past October rain

Figure A36. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 3.

Table A12. Climate parameter estimates for LBL white oak, cluster 3.

YEAR	June temp. b_1	Past June temp. b_2	Past August temp. b_3	June rain b_4	Past August rain b_5	Past October rain b_6
1904	-0.053*	0.012	0.027	0.037	0.064*	-0.016
1905	-0.054*	0.009	0.028	0.038	0.064*	-0.013
1906	-0.054*	0.009	0.028	0.038	0.064*	-0.013
1907	-0.054*	0.008	0.028	0.038	0.064*	-0.012
1908	-0.054*	0.008	0.028	0.038	0.064*	-0.012
1909	-0.054*	0.008	0.028	0.038	0.064*	-0.012
1910	-0.055*	0.009	0.027	0.039	0.064*	-0.014
1911	-0.055*	0.008	0.027	0.039	0.064*	-0.013
1912	-0.055*	0.008	0.025	0.039*	0.064*	-0.010
1913	-0.055*	0.009	0.025	0.039*	0.064*	-0.007
1914	-0.055*	0.010	0.024	0.040*	0.064*	-0.006
1915	-0.055*	0.010	0.024	0.040*	0.064*	-0.006
1916	-0.055*	0.009	0.026	0.039*	0.064*	-0.007
1917	-0.054*	0.008	0.028*	0.039*	0.064*	-0.008
1918	-0.054*	0.007	0.029*	0.039*	0.064*	-0.009
1919	-0.054*	0.007	0.030*	0.039*	0.064*	-0.008
1920	-0.054*	0.007	0.030*	0.039*	0.064*	-0.008
1921	-0.053*	0.007	0.033*	0.039*	0.064*	-0.005
1922	-0.053*	0.007	0.033*	0.039*	0.064*	-0.005
1923	-0.051*	-0.001	0.034*	0.038*	0.064*	-0.010
1924	-0.051*	-0.001	0.034*	0.038*	0.064*	-0.011
1925	-0.051*	-0.002	0.033*	0.038*	0.064*	-0.015
1926	-0.051*	-0.003	0.033*	0.038*	0.064*	-0.014
1927	-0.048*	-0.009	0.026	0.039*	0.064*	0.002
1928	-0.048*	-0.010	0.025	0.039*	0.064*	0.004
1929	-0.048*	-0.011	0.023	0.040*	0.064*	0.006
1930	-0.048*	-0.011	0.023	0.040*	0.064*	0.006
1931	-0.047*	-0.011	0.021	0.040*	0.064*	0.005
1932	-0.047*	-0.011	0.019	0.040*	0.064*	0.002
1933	-0.047*	-0.011	0.018	0.040*	0.064*	0.001
1934	-0.047*	-0.011	0.018	0.040*	0.064*	0.002
1935	-0.047*	-0.011	0.018	0.039*	0.064*	0.007
1936	-0.047*	-0.011	0.018	0.039*	0.064*	0.013
1937	-0.046*	-0.012	0.017	0.038*	0.064*	0.022
1938	-0.046*	-0.012	0.017	0.037*	0.063*	0.034
1939	-0.046*	-0.013	0.016	0.037*	0.063*	0.038
1940	-0.045*	-0.015	0.016	0.036*	0.063*	0.042
1941	-0.045*	-0.015	0.016	0.036*	0.063*	0.043
1942	-0.045*	-0.017	0.016	0.035*	0.063*	0.047
1943	-0.044*	-0.019	0.016	0.035*	0.063*	0.051
1944	-0.044*	-0.021	0.018	0.034*	0.063*	0.055*
1945	-0.043*	-0.023	0.020	0.033*	0.063*	0.058*
1946	-0.043*	-0.023*	0.021	0.033*	0.063*	0.059*
1947	-0.042*	-0.024*	0.021	0.032*	0.063*	0.061*
1948	-0.042*	-0.024*	0.021	0.032*	0.063*	0.062*
1949	-0.041*	-0.024*	0.021	0.031*	0.063*	0.063*
1950	-0.041*	-0.024*	0.021	0.031*	0.063*	0.066*
1951	-0.041*	-0.024*	0.020	0.031*	0.063*	0.069*
1952	-0.041*	-0.025*	0.020	0.031*	0.063*	0.070*
1953	-0.041*	-0.024*	0.019	0.031*	0.063*	0.072*
1954	-0.041*	-0.024*	0.015	0.031*	0.063*	0.076*
1955	-0.041*	-0.024*	0.009	0.030*	0.063*	0.079*
1956	-0.042*	-0.024*	0.008	0.030*	0.063*	0.079*
1957	-0.042*	-0.024*	0.007	0.030*	0.063*	0.080*

Table A12. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1958	-0.042*	-0.024*	0.005	0.030*	0.063*	0.080*
1959	-0.042*	-0.024*	0.005	0.030*	0.063*	0.079*
1960	-0.042*	-0.024*	0.004	0.030*	0.063*	0.077*
1961	-0.042*	-0.025*	0.004	0.030*	0.063*	0.077*
1962	-0.042*	-0.025*	0.004	0.030*	0.063*	0.076*
1963	-0.042*	-0.026*	0.003	0.030*	0.063*	0.075*
1964	-0.042*	-0.027*	0.002	0.030*	0.063*	0.074*
1965	-0.042*	-0.028*	0.001	0.030*	0.063*	0.071*
1966	-0.042*	-0.028*	0.001	0.030*	0.063*	0.070*
1967	-0.042*	-0.029*	0.000	0.031*	0.063*	0.068*
1968	-0.042*	-0.029*	-0.000	0.031*	0.063*	0.067*
1969	-0.042*	-0.029*	0.000	0.031*	0.063*	0.066*
1970	-0.042*	-0.029*	0.000	0.031*	0.063*	0.066*
1971	-0.042*	-0.030*	0.001	0.031*	0.063*	0.068*
1972	-0.042*	-0.030*	0.001	0.031*	0.063*	0.067*
1973	-0.042*	-0.029*	0.001	0.031*	0.063*	0.063*
1974	-0.042*	-0.029*	0.001	0.031*	0.063*	0.061*
1975	-0.042*	-0.029*	0.001	0.031*	0.063*	0.059*
1976	-0.042*	-0.029*	0.001	0.031*	0.063*	0.058*
1977	-0.042*	-0.029*	0.001	0.031*	0.063*	0.057*
1978	-0.042*	-0.028*	0.002	0.031*	0.063*	0.055*
1979	-0.042*	-0.028*	0.002	0.031*	0.063*	0.053*
1980	-0.042*	-0.028*	0.002	0.031*	0.063*	0.053*
1981	-0.042*	-0.028*	0.001	0.031*	0.063*	0.052*
1982	-0.042*	-0.028*	0.001	0.031*	0.063*	0.050*
1983	-0.042*	-0.028	0.001	0.031*	0.063*	0.047*
1984	-0.042*	-0.028	0.000	0.031*	0.063*	0.043
1985	-0.042*	-0.029	0.000	0.031*	0.063*	0.041
1986	-0.042*	-0.029	0.000	0.031*	0.063*	0.041

* Indicates coefficient is significant at $P \leq 0.05$.

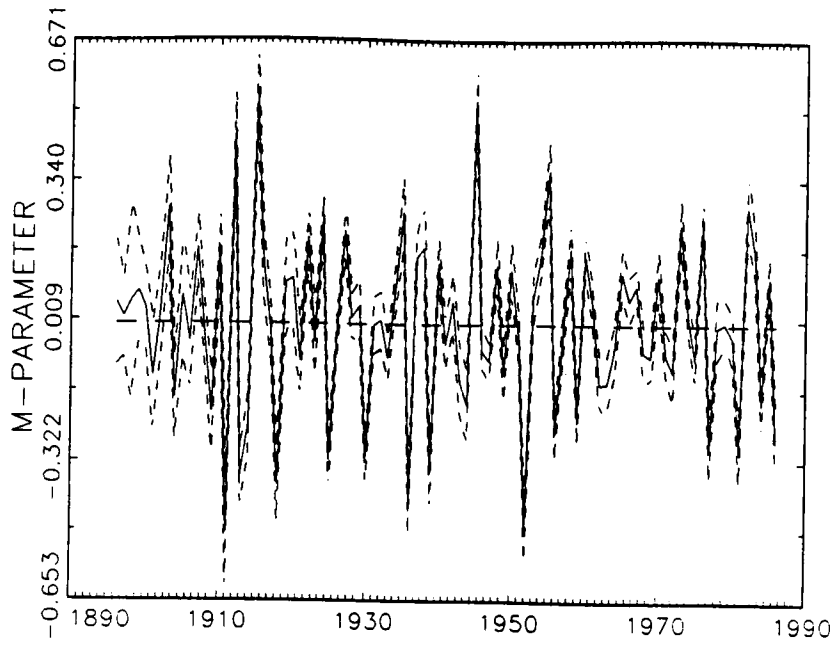


Figure A37. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 4.

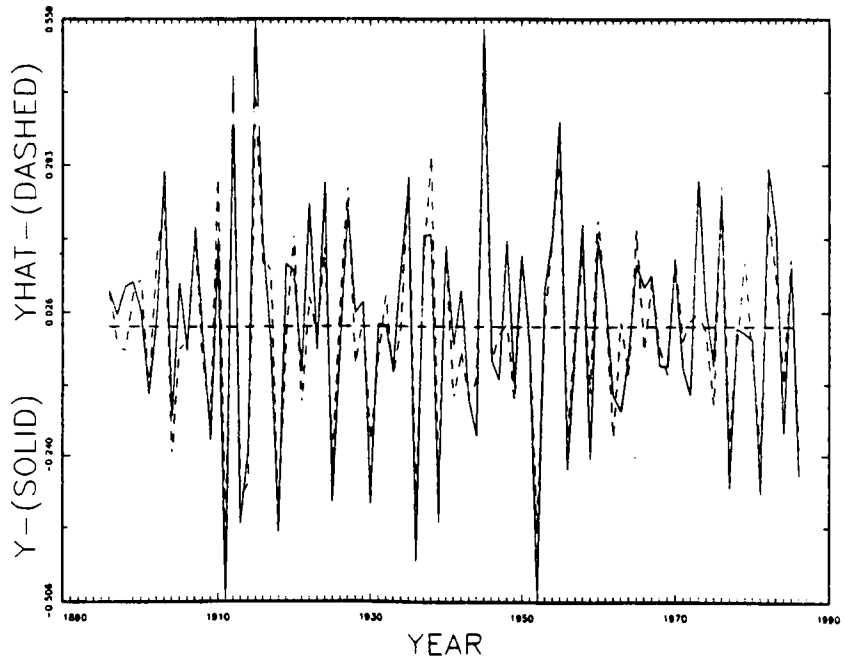
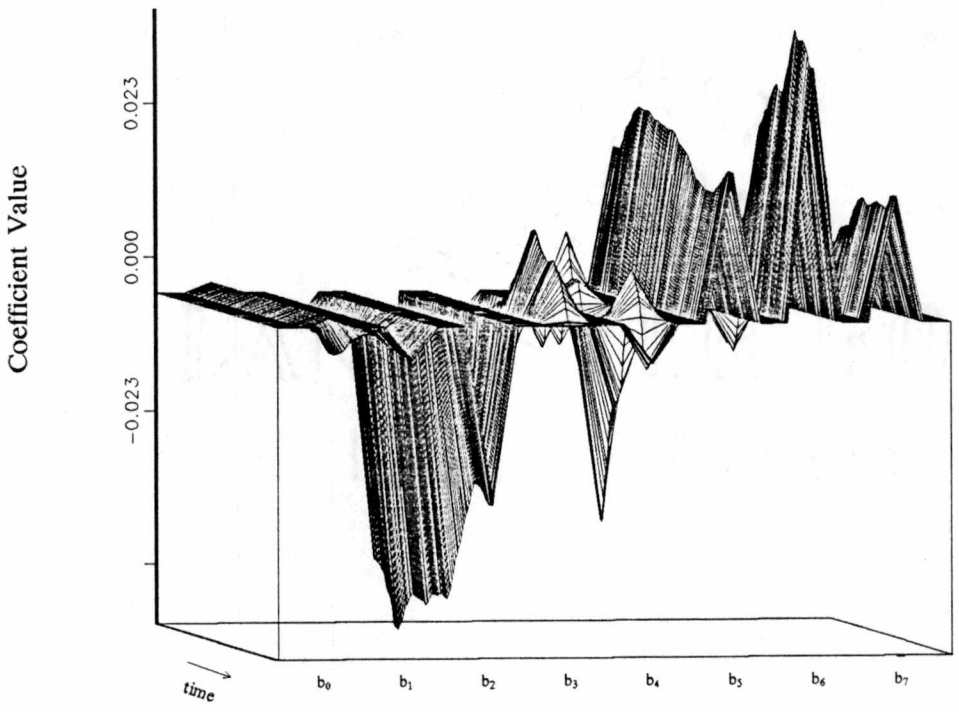


Figure A38. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 4.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = past April temperature
b_4 = past July temperature
b_5 = past August rain
b_6 = past October rain
b_7 = past December rain

Figure A39. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 4.

Table A13. Climate parameter estimates for LBL white oak, cluster 4.

YEAR	May temp. b_1	June temp. b_2	Past April temp. b_3	Past July temp. b_4	Past August rain b_5	Past October rain b_6	Past December rain b_7
1897	-0.010	-0.045*	-0.010	-0.000	0.016	-0.004	-0.006
1898	-0.010	-0.046*	-0.014	-0.008	0.016	-0.003	-0.006
1899	-0.010	-0.046*	-0.014	-0.010	0.016	-0.003	-0.006
1900	-0.010	-0.046*	-0.015	-0.011	0.016	-0.004	-0.006
1901	-0.010	-0.046*	-0.015	-0.013	0.016	-0.004	-0.005
1902	-0.010	-0.047*	-0.015	-0.014	0.016	-0.005	-0.005
1903	-0.010	-0.047*	-0.016	-0.013	0.017	-0.006	-0.004
1904	-0.010	-0.048*	-0.017	-0.012	0.017	-0.006	-0.004
1905	-0.010	-0.049*	-0.018	-0.009	0.019	-0.007	-0.003
1906	-0.010	-0.050*	-0.019*	-0.007	0.019	-0.008	-0.002
1907	-0.010	-0.050*	-0.019*	-0.006	0.020	-0.008	-0.002
1908	-0.010	-0.050*	-0.019*	-0.006	0.020	-0.008	-0.002
1909	-0.010	-0.051*	-0.018	-0.007	0.020	-0.008	-0.001
1910	-0.010	-0.052*	-0.018	-0.008	0.021	-0.008	-0.001
1911	-0.010	-0.054*	-0.018	-0.010	0.022	-0.007	-0.000
1912	-0.010	-0.055*	-0.018	-0.011	0.022	-0.007	0.000
1913	-0.010	-0.055*	-0.017	-0.011	0.022	-0.007	0.000
1914	-0.010	-0.055*	-0.017	-0.012	0.023	-0.007	0.000
1915	-0.011	-0.054*	-0.016	-0.012	0.023	-0.008	0.000
1916	-0.011	-0.054*	-0.016	-0.012	0.023*	-0.008	-0.000
1917	-0.011	-0.054*	-0.017	-0.011	0.023*	-0.009	-0.000
1918	-0.011*	-0.053*	-0.018	-0.009	0.023*	-0.009	-0.001
1919	-0.012*	-0.052*	-0.019*	-0.005	0.023*	-0.011	-0.002
1920	-0.012*	-0.051*	-0.020*	0.001	0.023*	-0.012	-0.003
1921	-0.012*	-0.051*	-0.020*	0.005	0.023*	-0.012	-0.004
1922	-0.013*	-0.050*	-0.021*	0.003	0.023*	-0.012	-0.004
1923	-0.013*	-0.050*	-0.022*	0.001	0.023*	-0.012	-0.004
1924	-0.013*	-0.049*	-0.022*	-0.000	0.023*	-0.013	-0.005
1925	-0.013*	-0.049*	-0.022*	-0.002	0.022*	-0.013	-0.005
1926	-0.013*	-0.049*	-0.021*	-0.002	0.022*	-0.012	-0.005
1927	-0.013*	-0.049*	-0.020*	-0.002	0.022*	-0.011	-0.005
1928	-0.013*	-0.049*	-0.021*	-0.002	0.022*	-0.010	-0.005
1929	-0.013*	-0.049*	-0.021*	-0.002	0.022*	-0.008	-0.004
1930	-0.013*	-0.049*	-0.020*	-0.002	0.022*	-0.007	-0.004
1931	-0.013*	-0.049*	-0.019*	-0.003	0.021*	-0.006	-0.003
1932	-0.012*	-0.050*	-0.018*	-0.005	0.021*	-0.005	-0.002
1933	-0.012*	-0.050*	-0.017*	-0.006	0.021*	-0.005	-0.002
1934	-0.012*	-0.050*	-0.016*	-0.007	0.021*	-0.003	-0.001
1935	-0.012*	-0.050*	-0.015	-0.008	0.021*	0.001	0.000
1936	-0.011*	-0.050*	-0.013	-0.009	0.021*	0.003	0.001
1937	-0.011*	-0.049*	-0.012	-0.011	0.021*	0.006	0.002
1938	-0.011*	-0.049*	-0.009	-0.018	0.021*	0.011	0.003
1939	-0.010*	-0.048*	-0.007	-0.021	0.021*	0.014	0.004
1940	-0.010*	-0.048*	-0.006	-0.023	0.021*	0.015	0.004
1941	-0.010*	-0.048*	-0.005	-0.023	0.021*	0.016	0.004
1942	-0.010*	-0.048*	-0.004	-0.026	0.021*	0.017	0.005
1943	-0.010*	-0.048*	-0.003	-0.030*	0.020*	0.019	0.005
1944	-0.009*	-0.048*	-0.002	-0.034*	0.020*	0.020	0.006
1945	-0.009*	-0.048*	-0.002	-0.036*	0.019*	0.021	0.006
1946	-0.009*	-0.048*	-0.001	-0.037*	0.019*	0.022*	0.006
1947	-0.009	-0.048*	-0.001	-0.037*	0.019*	0.022*	0.007
1948	-0.009	-0.048*	0.000	-0.034*	0.019*	0.023*	0.007
1949	-0.009	-0.048*	0.002	-0.031*	0.018*	0.024*	0.007
1950	-0.009	-0.048*	0.003	-0.029*	0.018*	0.024*	0.007
1951	-0.009	-0.048*	0.003	-0.028*	0.018*	0.025*	0.007

Table A13. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7
1952	-0.008	-0.048*	0.004	-0.025*	0.018*	0.025*	0.008
1953	-0.008	-0.047*	0.006	-0.023	0.017*	0.026*	0.008
1954	-0.008	-0.047*	0.006	-0.021	0.017*	0.027*	0.009
1955	-0.008	-0.045*	0.007	-0.019	0.016*	0.027*	0.010
1956	-0.008	-0.044*	0.007	-0.019	0.016*	0.028*	0.010
1957	-0.008	-0.043*	0.007	-0.019	0.015*	0.028*	0.011*
1958	-0.008	-0.042*	0.007	-0.019	0.015	0.029*	0.011*
1959	-0.008	-0.041*	0.006	-0.018	0.015	0.028*	0.011*
1960	-0.008	-0.040*	0.006	-0.018	0.014	0.028*	0.011*
1961	-0.008	-0.039*	0.005	-0.017	0.014	0.028*	0.012*
1962	-0.008	-0.038*	0.005	-0.016	0.014	0.028*	0.012*
1963	-0.008	-0.037*	0.004	-0.013	0.014	0.028*	0.011*
1964	-0.009*	-0.036*	0.004	-0.010	0.014	0.029*	0.011*
1965	-0.009*	-0.035*	0.004	-0.007	0.013	0.030*	0.011*
1966	-0.009*	-0.034*	0.003	-0.004	0.013	0.031*	0.011*
1967	-0.009*	-0.034*	0.003	-0.002	0.013	0.032*	0.011*
1968	-0.009*	-0.033*	0.003	-0.001	0.013	0.033*	0.011*
1969	-0.009*	-0.032*	0.003	0.000	0.013	0.034*	0.011*
1970	-0.009*	-0.031*	0.003	0.002	0.013	0.035*	0.012*
1971	-0.009*	-0.030*	0.004	0.002	0.013	0.036*	0.012*
1972	-0.010*	-0.029*	0.003	0.001	0.014	0.037*	0.012*
1973	-0.010*	-0.030*	0.002	0.000	0.014	0.036*	0.011*
1974	-0.010*	-0.030*	0.002	-0.001	0.014	0.036*	0.011*
1975	-0.010*	-0.030*	0.002	-0.002	0.015	0.036*	0.011*
1976	-0.010*	-0.030*	0.001	-0.002	0.015	0.036*	0.011*
1977	-0.010	-0.030*	0.000	-0.005	0.015	0.036*	0.011
1978	-0.010	-0.030*	-0.001	-0.007	0.016	0.036*	0.011
1979	-0.010	-0.031*	-0.001	-0.010	0.016	0.036*	0.011
1980	-0.010	-0.031*	-0.002	-0.012	0.016	0.035*	0.012
1981	-0.010	-0.032*	-0.003	-0.012	0.017	0.034*	0.012
1982	-0.010	-0.032*	-0.005	-0.012	0.017	0.033*	0.013
1983	-0.010	-0.032*	-0.005	-0.012	0.017	0.033*	0.013
1984	-0.010	-0.032*	-0.005	-0.011	0.017	0.032*	0.013
1985	-0.010	-0.032*	-0.005	-0.011	0.017	0.033*	0.013
1986	-0.010	-0.032*	-0.005	-0.011	0.017	0.033*	0.013

* Indicates coefficient is significant at $P \leq 0.05$.

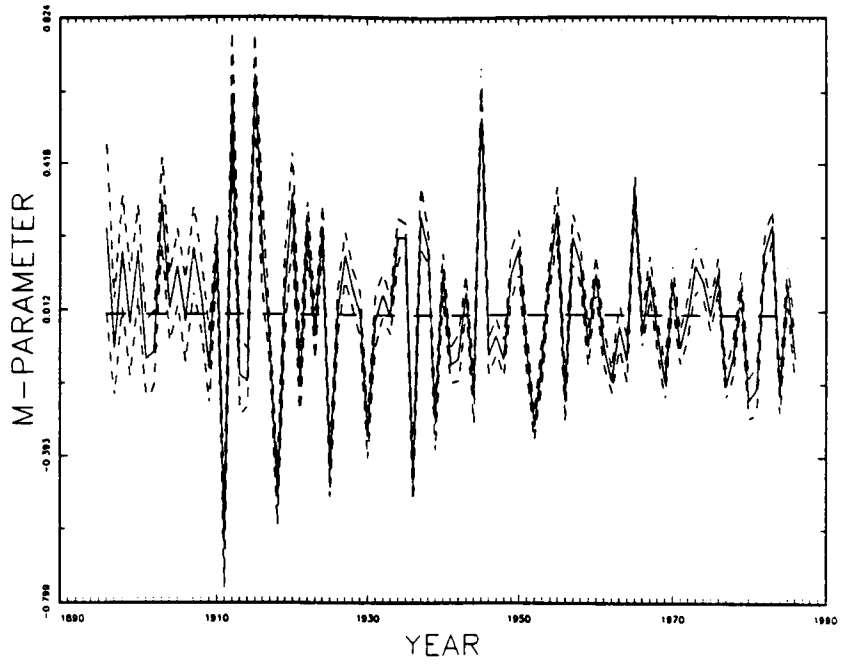


Figure A40. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 5.

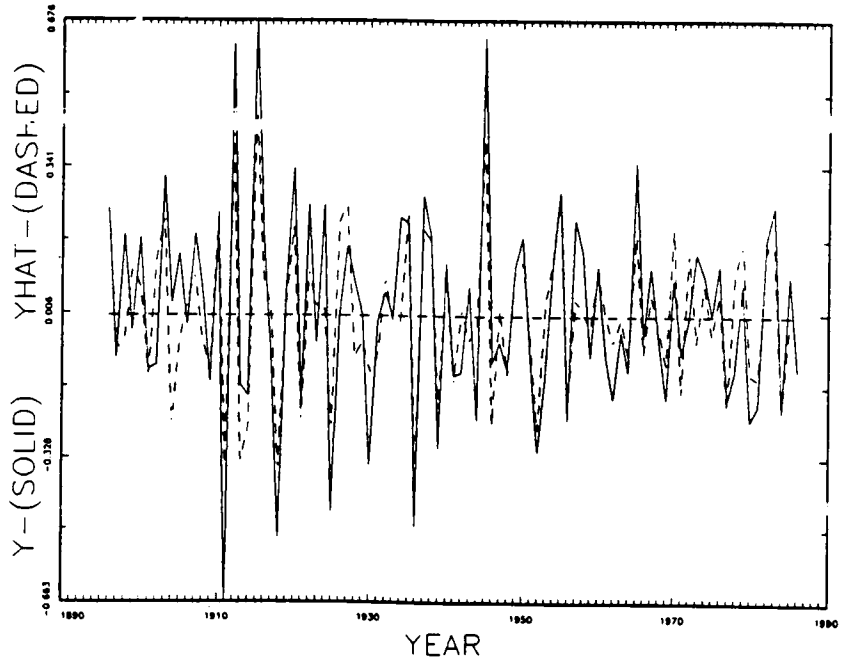
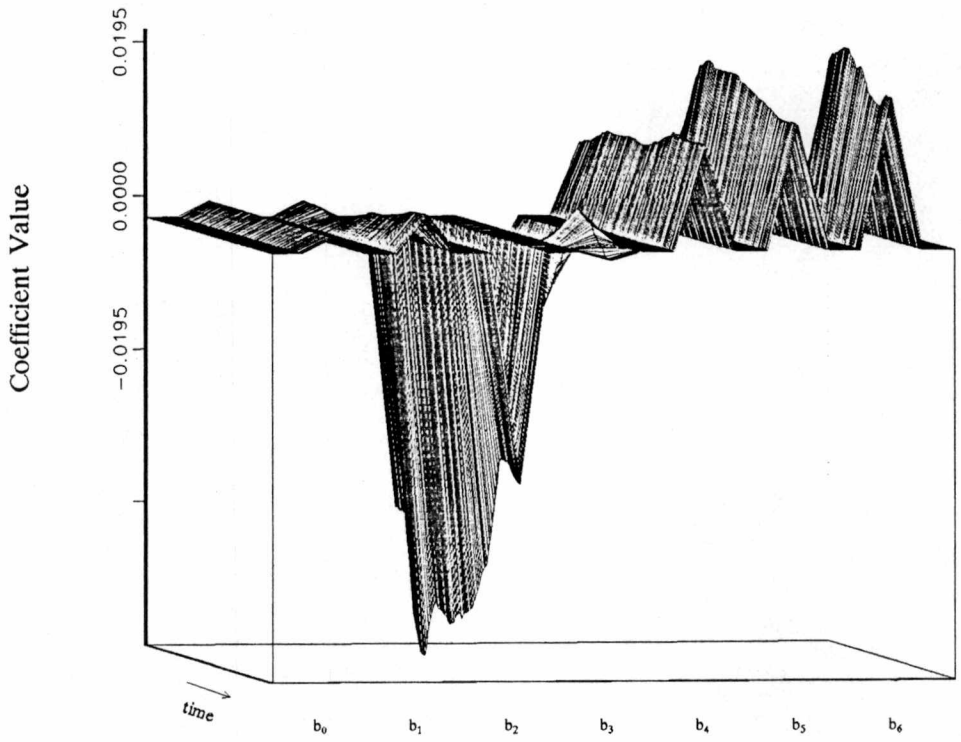


Figure A41. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 5.



Where:

b_0 = the intercept (non-varying)
b_1 = February temperature
b_2 = June temperature
b_3 = past April temperature
b_4 = past May temperature
b_5 = past August rain
b_6 = past December rain

Figure A42. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 5.

Table A14. Climate parameter estimates for LBL white oak, cluster 5.

YEAR	February temp. b_1	June temp. b_2	Past April temp. b_3	Past May temp. b_4	Past August rain b_5	Past December rain b_6
1897	-0.001	-0.040	-0.010	0.006	0.008	-0.001
1898	-0.001	-0.040	-0.010	0.007	0.007	-0.002
1899	-0.001	-0.040	-0.009	0.007	0.007	-0.002
1900	-0.001	-0.040	-0.009	0.007	0.007	-0.003
1901	-0.001	-0.040	-0.009	0.007	0.007	-0.003
1902	-0.001	-0.040	-0.010	0.007	0.008	-0.003
1903	-0.001	-0.040	-0.011	0.007	0.008	-0.003
1904	-0.001	-0.041*	-0.011	0.007	0.009	-0.003
1905	-0.001	-0.043*	-0.012	0.007	0.009	-0.002
1906	-0.001	-0.046*	-0.012	0.007	0.010	-0.002
1907	-0.001	-0.048*	-0.012	0.007	0.011	-0.001
1908	-0.001	-0.050*	-0.012	0.008	0.012	-0.001
1909	-0.001	-0.052*	-0.012	0.008	0.012	-0.000
1910	-0.001	-0.054*	-0.012	0.008	0.012	-0.000
1911	-0.001	-0.054*	-0.012	0.008	0.013	0.001
1912	-0.001	-0.055*	-0.012	0.008	0.015	0.001
1913	-0.001	-0.056*	-0.013	0.008	0.015	0.002
1914	-0.001	-0.057*	-0.013	0.009	0.016	0.003
1915	-0.001	-0.057*	-0.013	0.009	0.016	0.003
1916	-0.002	-0.057*	-0.013	0.009	0.017	0.004
1917	-0.002	-0.057*	-0.014	0.009	0.017	0.004
1918	-0.002	-0.057*	-0.014	0.009	0.017	0.004
1919	-0.002	-0.056*	-0.014	0.009	0.017	0.003
1920	-0.002	-0.054*	-0.015	0.009	0.018	0.002
1921	-0.002	-0.053*	-0.015	0.009	0.018	0.001
1922	-0.001	-0.052*	-0.016	0.009	0.018	0.001
1923	-0.001	-0.051*	-0.016	0.009	0.018	0.001
1924	-0.001	-0.051*	-0.016	0.009	0.018	0.002
1925	-0.001	-0.050*	-0.015	0.009	0.018	0.002
1926	-0.001	-0.050*	-0.015	0.009	0.017	0.001
1927	-0.001	-0.051*	-0.014	0.009	0.017	0.001
1928	-0.001	-0.051*	-0.014	0.009	0.017	0.002
1929	-0.001	-0.051*	-0.015	0.009	0.017	0.003
1930	-0.001	-0.051*	-0.014	0.009	0.017	0.005
1931	-0.001	-0.051*	-0.014	0.009	0.017	0.007
1932	-0.001	-0.052*	-0.013	0.009	0.017	0.008
1933	-0.001	-0.052*	-0.013	0.009	0.017	0.009
1934	-0.001	-0.052*	-0.013	0.009	0.017	0.010
1935	-0.001	-0.052*	-0.013	0.009	0.017	0.011
1936	-0.001	-0.052*	-0.012	0.009	0.017	0.012
1937	-0.000	-0.052*	-0.012	0.009	0.017	0.014
1938	-0.000	-0.052*	-0.011	0.009	0.017	0.014
1939	-0.000	-0.051*	-0.011	0.009	0.017	0.016
1940	-0.000	-0.051*	-0.010	0.008	0.017	0.017
1941	-0.000	-0.051*	-0.010	0.008	0.017	0.018
1942	-0.000	-0.051*	-0.009	0.008	0.017	0.019*
1943	0.000	-0.051*	-0.009	0.008	0.017	0.020*
1944	0.000	-0.051*	-0.008	0.009	0.017	0.020*
1945	0.000	-0.051*	-0.007	0.009	0.017	0.020*
1946	0.000	-0.051*	-0.007	0.009	0.016	0.020*
1947	0.000	-0.050*	-0.006	0.009	0.016	0.020*
1948	0.000	-0.050*	-0.006	0.009	0.016	0.020*
1949	0.000	-0.050*	-0.005	0.009	0.016	0.020*
1950	0.000	-0.050*	-0.005	0.009	0.016	0.021*

Table A14. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1951	0.000	-0.050*	-0.004	0.009	0.016	0.021*
1952	0.000	-0.049*	-0.004	0.009	0.016	0.021*
1953	0.001	-0.049*	-0.003	0.009	0.016	0.021*
1954	0.001	-0.048*	-0.003	0.010	0.016	0.021*
1955	0.001	-0.047*	-0.002	0.010	0.015	0.021*
1956	0.001	-0.047*	-0.001	0.010	0.015	0.021*
1957	0.001	-0.046*	-0.000	0.010	0.015	0.020*
1958	0.001	-0.045*	0.000	0.010*	0.015	0.020*
1959	0.001	-0.045*	0.001	0.010*	0.015	0.020*
1960	0.001	-0.044*	0.001	0.010*	0.015	0.019*
1961	0.001	-0.044*	0.002	0.010*	0.015	0.019*
1962	0.001	-0.043*	0.002	0.010*	0.015	0.019*
1963	0.001	-0.042*	0.001	0.011*	0.015	0.019*
1964	0.001	-0.041*	0.001	0.011*	0.014	0.019*
1965	0.001	-0.040*	0.001	0.011*	0.014	0.019*
1966	0.001	-0.038*	0.001	0.011*	0.014	0.019*
1967	0.001	-0.036*	0.001	0.011*	0.014	0.018*
1968	0.001	-0.035*	0.001	0.011*	0.014	0.017*
1969	0.001	-0.033*	0.000	0.011*	0.014	0.017*
1970	0.002	-0.031*	0.000	0.011*	0.014	0.016*
1971	0.002	-0.030*	-0.000	0.011*	0.013	0.016*
1972	0.002	-0.030*	-0.000	0.011*	0.013	0.016*
1973	0.002	-0.030*	-0.001	0.011*	0.013	0.016
1974	0.002	-0.030*	-0.001	0.011*	0.013	0.015
1975	0.002	-0.030*	-0.002	0.011*	0.013	0.015
1976	0.002	-0.030*	-0.002	0.011*	0.013	0.015
1977	0.002	-0.030*	-0.002	0.011*	0.013	0.015
1978	0.002	-0.030*	-0.002	0.011*	0.013	0.015
1979	0.002	-0.031*	-0.003	0.011	0.013	0.016
1980	0.002	-0.031*	-0.003	0.011	0.013	0.016
1981	0.002	-0.031*	-0.003	0.011	0.013	0.016
1982	0.002	-0.032*	-0.004	0.011	0.013	0.017
1983	0.002	-0.032*	-0.004	0.011	0.013	0.016
1984	0.002	-0.032*	-0.004	0.011	0.013	0.016
1985	0.002	-0.032*	-0.004	0.011	0.013	0.016
1986	0.002	-0.032*	-0.004	0.011	0.013	0.016

* indicates coefficient is significant at $P \leq 0.05$.

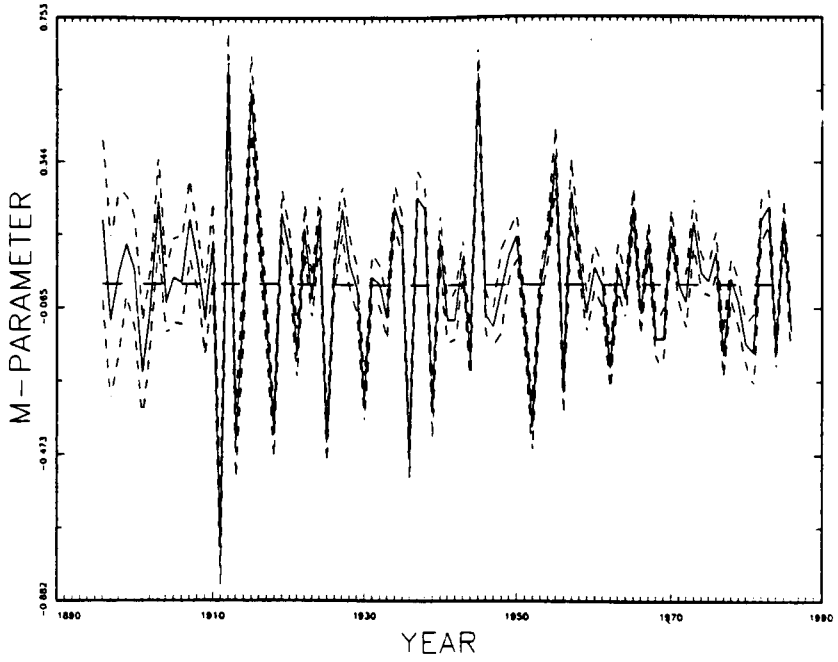


Figure A43. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 6.

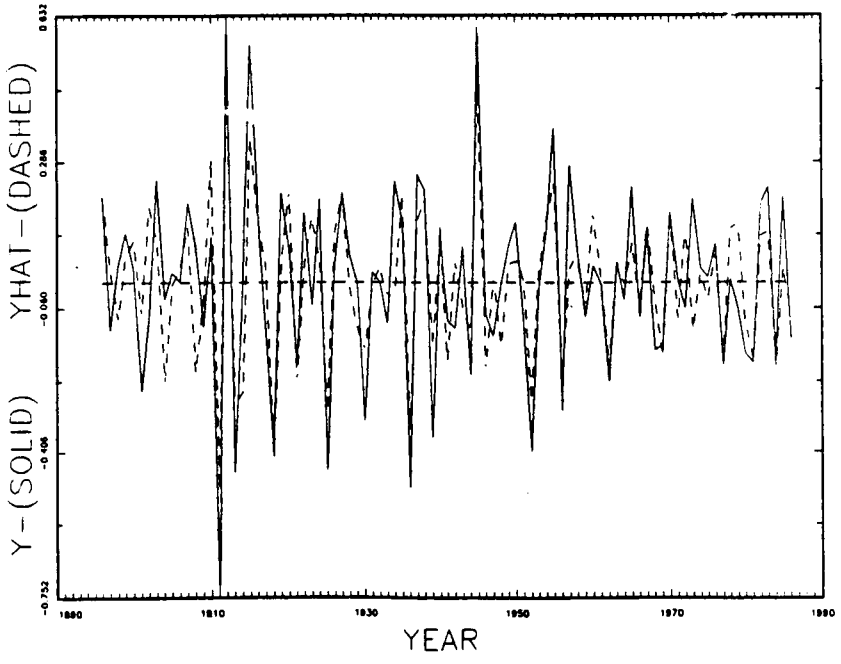
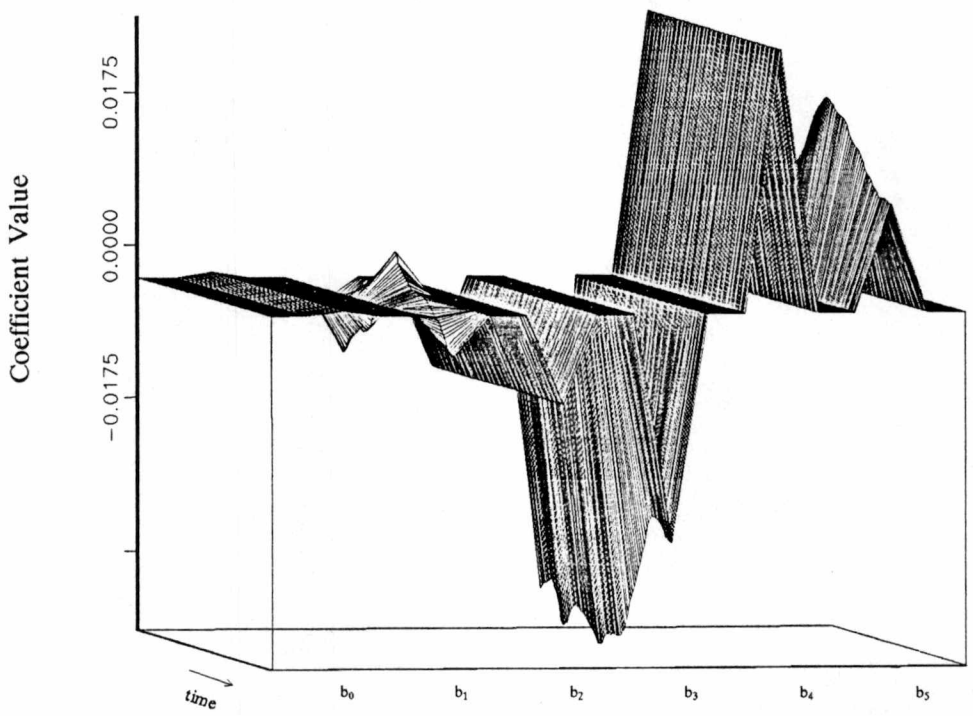


Figure A44. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 6.



Where:

b_0 = the intercept (non-varying)
b_1 = February temperature
b_2 = May temperature
b_3 = June temperature
b_4 = past August rain
b_5 = past December rain

Figure A45. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 6.

Table A15. Climate parameter estimates for LBL white oak, cluster 6.

YEAR	February temp. b_1	May temp. b_2	June temp. b_3	Past August rain b_4	Past December rain b_5
1897	-0.007	-0.014*	-0.039	0.026*	0.002
1898	-0.008	-0.014*	-0.039*	0.026*	0.002
1899	-0.008	-0.014*	-0.039*	0.026*	0.002
1900	-0.008	-0.014*	-0.039*	0.026*	0.002
1901	-0.008	-0.014*	-0.038*	0.026*	0.002
1902	-0.008	-0.014*	-0.038*	0.026*	0.002
1903	-0.009	-0.014*	-0.038*	0.026*	0.003
1904	-0.009	-0.014*	-0.038*	0.026*	0.003
1905	-0.010	-0.014*	-0.039*	0.026*	0.004
1906	-0.010	-0.014*	-0.039*	0.026*	0.005
1907	-0.011	-0.014*	-0.040*	0.026*	0.005
1908	-0.011	-0.014*	-0.040*	0.026*	0.006
1909	-0.011	-0.014*	-0.041*	0.026*	0.007
1910	-0.012	-0.014*	-0.042*	0.026*	0.008
1911	-0.012	-0.014*	-0.043*	0.026*	0.009
1912	-0.011	-0.014*	-0.043*	0.026*	0.009
1913	-0.011	-0.014*	-0.042*	0.026*	0.010
1914	-0.010	-0.014*	-0.043*	0.026*	0.010
1915	-0.010	-0.014*	-0.042*	0.026*	0.011
1916	-0.010	-0.014*	-0.041*	0.026*	0.011
1917	-0.010	-0.014*	-0.041*	0.026*	0.011
1918	-0.009	-0.014*	-0.040*	0.026*	0.011
1919	-0.009	-0.014*	-0.040*	0.026*	0.011
1920	-0.009	-0.014*	-0.040*	0.026*	0.011
1921	-0.009	-0.014*	-0.040*	0.026*	0.010
1922	-0.008	-0.014*	-0.040*	0.026*	0.010
1923	-0.008	-0.014*	-0.040*	0.026*	0.011
1924	-0.009	-0.014*	-0.041*	0.026*	0.011
1925	-0.009	-0.014*	-0.041*	0.026*	0.012
1926	-0.008	-0.014*	-0.041*	0.026*	0.012
1927	-0.008	-0.014*	-0.041*	0.026*	0.012
1928	-0.008	-0.014*	-0.041*	0.026*	0.013
1929	-0.008	-0.014*	-0.042*	0.026*	0.013
1930	-0.007	-0.014*	-0.042*	0.026*	0.014*
1931	-0.006	-0.014*	-0.042*	0.026*	0.015*
1932	-0.006	-0.014*	-0.043*	0.026*	0.015*
1933	-0.005	-0.014*	-0.043*	0.026*	0.016*
1934	-0.004	-0.014*	-0.043*	0.026*	0.016*
1935	-0.003	-0.014*	-0.044*	0.026*	0.017*
1936	-0.003	-0.014*	-0.044*	0.026*	0.017*
1937	-0.002	-0.014*	-0.044*	0.026*	0.017*
1938	-0.002	-0.014*	-0.044*	0.026*	0.018*
1939	-0.001	-0.014*	-0.043*	0.026*	0.018*
1940	-0.001	-0.014*	-0.043*	0.026*	0.018*
1941	-0.000	-0.014*	-0.043*	0.026*	0.018*
1942	0.000	-0.014*	-0.042*	0.026*	0.019*
1943	0.001	-0.014*	-0.042*	0.026*	0.019*
1944	0.001	-0.014*	-0.042*	0.026*	0.019*
1945	0.001	-0.014*	-0.042*	0.026*	0.018*
1946	0.002	-0.014*	-0.042*	0.026*	0.018*
1947	0.002	-0.014*	-0.042*	0.026*	0.018*
1948	0.001	-0.014*	-0.042*	0.026*	0.018*
1949	0.000	-0.014*	-0.042*	0.026*	0.017*
1950	-0.000	-0.014*	-0.042*	0.026*	0.017*

Table A15. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5
1951	-0.000	-0.014*	-0.042*	0.026*	0.017*
1952	-0.001	-0.014*	-0.042*	0.026*	0.017*
1953	-0.001	-0.014*	-0.041*	0.026*	0.017*
1954	-0.001	-0.014*	-0.041*	0.026*	0.017*
1955	-0.002	-0.014*	-0.040*	0.026*	0.017*
1956	-0.002	-0.014*	-0.039*	0.026*	0.016*
1957	-0.002	-0.014*	-0.038*	0.026*	0.015*
1958	-0.002	-0.014*	-0.037*	0.026*	0.015*
1959	-0.002	-0.014*	-0.037*	0.026*	0.015*
1960	-0.002	-0.014*	-0.036*	0.026*	0.014*
1961	-0.002	-0.014*	-0.036*	0.026*	0.014*
1962	-0.002	-0.014*	-0.035*	0.026*	0.014*
1963	-0.002	-0.014*	-0.034*	0.026*	0.014*
1964	-0.002	-0.014*	-0.033*	0.026*	0.014*
1965	-0.003	-0.014*	-0.033*	0.026*	0.013*
1966	-0.003	-0.014*	-0.032*	0.026*	0.013*
1967	-0.003	-0.014*	-0.031*	0.026*	0.012*
1968	-0.003	-0.014*	-0.030*	0.026*	0.012*
1969	-0.003	-0.014*	-0.029*	0.026*	0.011
1970	-0.004	-0.014*	-0.028*	0.026*	0.011
1971	-0.004	-0.014*	-0.028*	0.026*	0.011
1972	-0.004	-0.014*	-0.027*	0.026*	0.011
1973	-0.005	-0.014*	-0.028*	0.026*	0.010
1974	-0.005	-0.014*	-0.028*	0.026*	0.010
1975	-0.005	-0.014*	-0.028*	0.026*	0.010
1976	-0.005	-0.014*	-0.028*	0.026*	0.009
1977	-0.005	-0.014*	-0.028*	0.026*	0.009
1978	-0.006	-0.014*	-0.028*	0.026*	0.009
1979	-0.006	-0.014*	-0.028*	0.026*	0.009
1980	-0.007	-0.014*	-0.029*	0.026*	0.009
1981	-0.008	-0.014*	-0.029*	0.026*	0.009
1982	-0.008	-0.014*	-0.029*	0.026*	0.009
1983	-0.008	-0.014*	-0.030*	0.026*	0.009
1984	-0.008	-0.014*	-0.030*	0.026*	0.009
1985	-0.008	-0.014*	-0.030*	0.026*	0.009
1986	-0.008	-0.014*	-0.030*	0.026*	0.009

* Indicates coefficient is significant at $P \leq 0.05$.

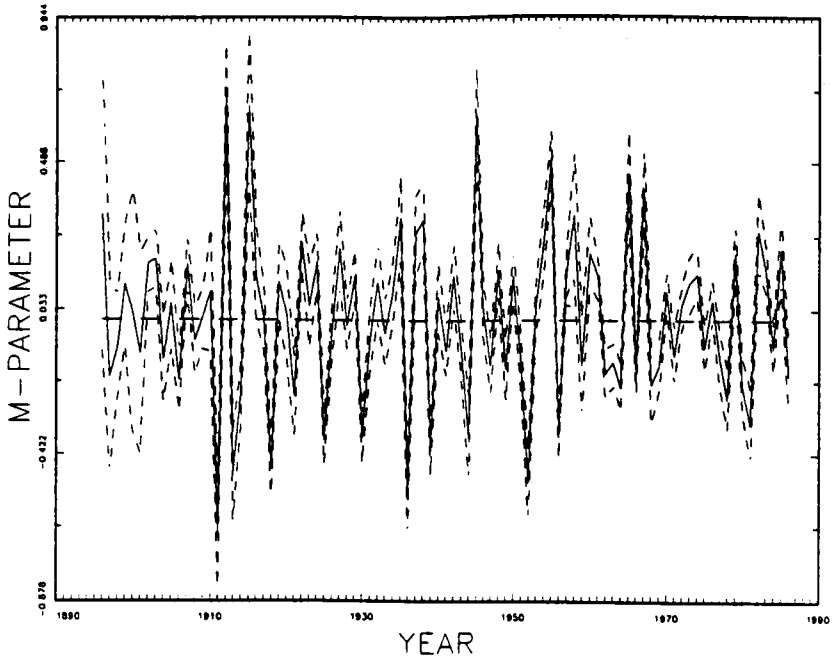


Figure A46. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 7.

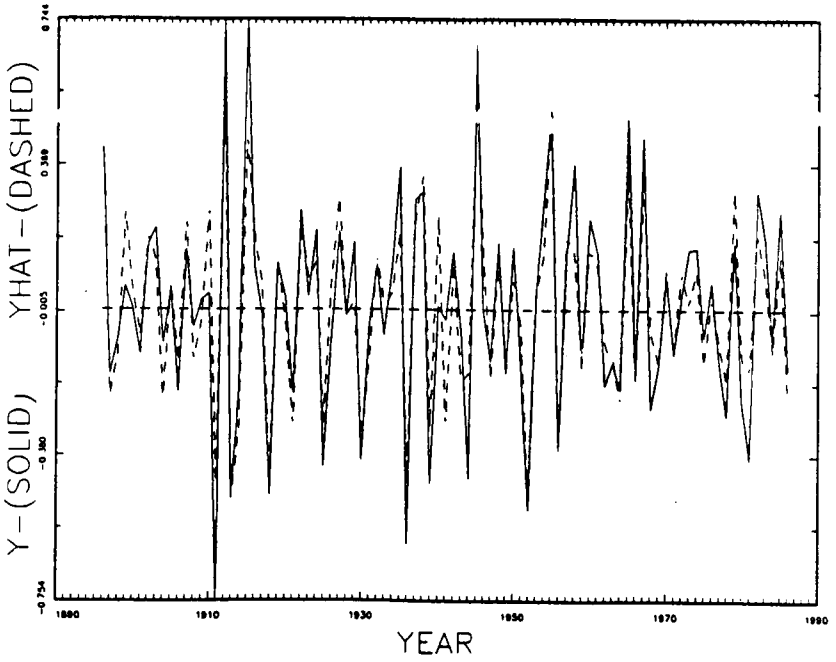
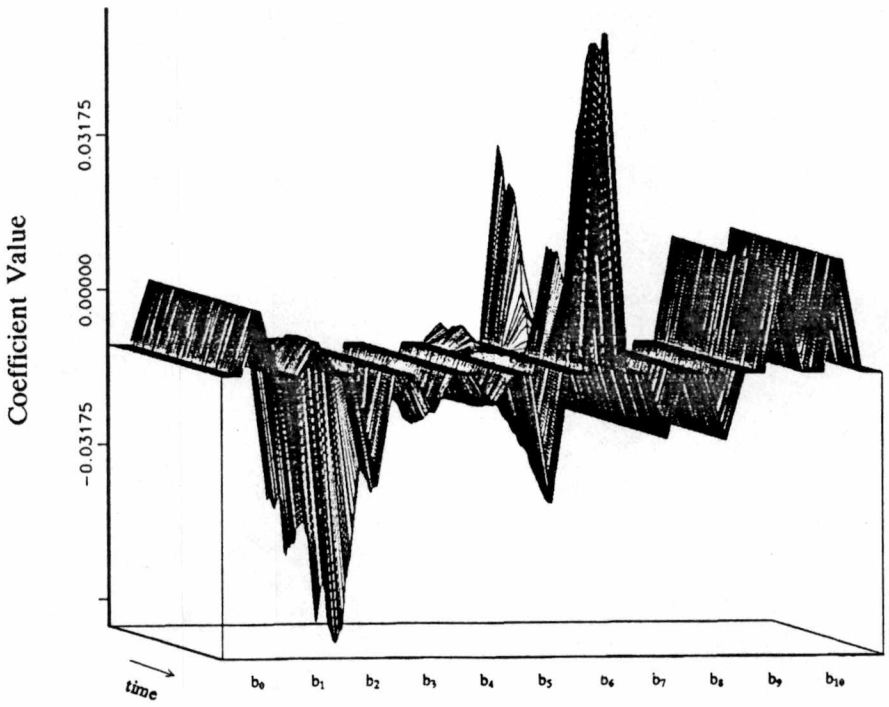


Figure A47. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 7.



Where:

b_0 = the intercept (non-varying)
b_1 = February temperature
b_2 = June temperature
b_3 = August temperature
b_4 = September temperature
b_5 = past July temperature
b_6 = June rain
b_7 = August rain
b_8 = past March rain
b_9 = past April rain
b_{10} = past December rain

Figure A48. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 7.

Table A16. Climate parameter estimates for LBL white oak, cluster 7.

YEAR	February temp. b_1	June temp. b_2	August temp. b_3	September temp. b_4	Past July temp. b_5	June rain b_6	August rain b_7	Past March rain b_8	Past April rain b_9	Past December rain b_{10}
1897	-0.008	-0.043	-0.028	-0.021*	-0.008	0.027	-0.025*	-0.025*	0.010	0.012*
1898	-0.008	-0.043	-0.028	-0.021*	-0.008	0.027	-0.025*	-0.025*	0.010	0.012*
1899	-0.008	-0.043	-0.027	-0.021*	-0.008	0.025	-0.025*	-0.025*	0.010	0.012*
1900	-0.008	-0.044*	-0.027*	-0.021*	-0.009	0.023	-0.025*	-0.025*	0.010	0.012*
1901	-0.009	-0.045*	-0.027*	-0.021*	-0.009	0.020	-0.025*	-0.025*	0.010	0.012*
1902	-0.009	-0.045*	-0.027*	-0.021*	-0.009	0.020	-0.025*	-0.025*	0.010	0.012*
1903	-0.009	-0.044*	-0.027*	-0.021*	-0.009	0.020	-0.025*	-0.025*	0.010	0.012*
1904	-0.009	-0.043*	-0.027*	-0.022*	-0.008	0.021	-0.025*	-0.025*	0.010	0.012*
1905	-0.010*	-0.042*	-0.026*	-0.022*	-0.008	0.022	-0.025*	-0.025*	0.010	0.012*
1906	-0.010*	-0.042*	-0.026*	-0.022*	-0.007	0.021	-0.025*	-0.025*	0.010	0.012*
1907	-0.010*	-0.043*	-0.026*	-0.022*	-0.007	0.021	-0.025*	-0.025*	0.010	0.012*
1908	-0.010*	-0.044*	-0.026*	-0.022*	-0.007	0.020	-0.025*	-0.025*	0.010	0.012*
1909	-0.010*	-0.045*	-0.026*	-0.022*	-0.007	0.020	-0.025*	-0.025*	0.010	0.012*
1910	-0.010*	-0.053*	-0.026*	-0.022*	-0.007	0.017	-0.025*	-0.025*	0.010	0.012*
1911	-0.010*	-0.054*	-0.026*	-0.022*	-0.007	0.014	-0.025*	-0.025*	0.010	0.012*
1912	-0.010*	-0.052*	-0.025*	-0.022*	-0.007	0.011	-0.025*	-0.025*	0.010	0.012*
1913	-0.010*	-0.051*	-0.025*	-0.022*	-0.007	0.009	-0.025*	-0.025*	0.010	0.012*
1914	-0.010*	-0.052*	-0.025*	-0.022*	-0.007	0.008	-0.025*	-0.025*	0.010	0.012*
1915	-0.010*	-0.051*	-0.024*	-0.022*	-0.007	0.000	-0.025*	-0.025*	0.010	0.012*
1916	-0.010*	-0.051*	-0.023*	-0.022*	-0.008	-0.002	-0.025*	-0.025*	0.010	0.012*
1917	-0.010*	-0.051*	-0.023*	-0.022*	-0.008	-0.003	-0.025*	-0.025*	0.010	0.012*
1918	-0.010*	-0.050*	-0.023*	-0.022*	-0.008	-0.004	-0.025*	-0.025*	0.010	0.012*
1919	-0.010*	-0.049*	-0.023*	-0.022*	-0.008	-0.006	-0.025*	-0.025*	0.010	0.012*
1920	-0.010*	-0.047*	-0.022*	-0.022*	-0.009	-0.009	-0.025*	-0.025*	0.010	0.012*
1921	-0.010*	-0.047*	-0.021*	-0.022*	-0.009	-0.011	-0.025*	-0.025*	0.010	0.012*
1922	-0.010*	-0.047*	-0.021*	-0.022*	-0.009	-0.012	-0.025*	-0.025*	0.010	0.012*
1923	-0.010*	-0.046*	-0.021*	-0.022*	-0.010	-0.014	-0.025*	-0.025*	0.010	0.012*
1924	-0.010*	-0.046*	-0.020*	-0.022*	-0.010	-0.015	-0.025*	-0.025*	0.010	0.012*
1925	-0.010*	-0.046*	-0.020*	-0.022*	-0.010	-0.015	-0.025*	-0.025*	0.010	0.012*
1926	-0.010*	-0.046*	-0.020*	-0.022*	-0.010	-0.015	-0.025*	-0.025*	0.010	0.012*
1927	-0.010*	-0.048*	-0.020*	-0.022*	-0.011	-0.014	-0.025*	-0.025*	0.010	0.012*
1928	-0.010*	-0.048*	-0.020*	-0.022*	-0.011	-0.014	-0.025*	-0.025*	0.010	0.012*

Table A16. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}
1929	-0.010*	-0.050*	-0.020*	-0.022*	-0.011	-0.010	-0.025*	-0.025*	0.010	0.012*
1930	-0.010*	-0.051*	-0.020*	-0.022*	-0.011	-0.008	-0.025*	-0.025*	0.010	0.012*
1931	-0.009*	-0.054*	-0.019*	-0.022*	-0.012	-0.004	-0.025*	-0.025*	0.010	0.012*
1932	-0.009*	-0.057*	-0.019*	-0.022*	-0.013	0.002	-0.025*	-0.025*	0.010	0.012*
1933	-0.008*	-0.060*	-0.018*	-0.022*	-0.013	0.005	-0.025*	-0.025*	0.010	0.012*
1934	-0.008*	-0.063*	-0.018*	-0.021*	-0.014	0.007	-0.025*	-0.025*	0.010	0.012*
1935	-0.008*	-0.066*	-0.017*	-0.021*	-0.015	0.011	-0.025*	-0.025*	0.010	0.012*
1936	-0.008*	-0.064*	-0.017*	-0.021*	-0.016	0.011	-0.025*	-0.025*	0.010	0.012*
1937	-0.007*	-0.062*	-0.017*	-0.020*	-0.018*	0.010	-0.025*	-0.025*	0.010	0.012*
1938	-0.007*	-0.061*	-0.016*	-0.020*	-0.019*	0.010	-0.025*	-0.025*	0.010	0.012*
1939	-0.007*	-0.060*	-0.016*	-0.020*	-0.020*	0.011	-0.025*	-0.025*	0.010	0.012*
1940	-0.007*	-0.057*	-0.016*	-0.020*	-0.021*	0.010	-0.025*	-0.025*	0.010	0.012*
1941	-0.007*	-0.058*	-0.016*	-0.020*	-0.021*	0.010	-0.025*	-0.025*	0.010	0.012*
1942	-0.007*	-0.058*	-0.016*	-0.020*	-0.021*	0.010	-0.025*	-0.025*	0.010	0.012*
1943	-0.007*	-0.060*	-0.016*	-0.020*	-0.022*	0.010	-0.025*	-0.025*	0.010	0.012*
1944	-0.007*	-0.063*	-0.017*	-0.019*	-0.022*	0.010	-0.025*	-0.025*	0.010	0.012*
1945	-0.006*	-0.066*	-0.017*	-0.019*	-0.022*	0.009	-0.025*	-0.025*	0.010	0.012*
1946	-0.006*	-0.066*	-0.017*	-0.019*	-0.023*	0.008	-0.025*	-0.025*	0.010	0.012*
1947	-0.006*	-0.067*	-0.018*	-0.019*	-0.023*	0.006	-0.025*	-0.025*	0.010	0.012*
1948	-0.006*	-0.067*	-0.018*	-0.019*	-0.023*	0.005	-0.025*	-0.025*	0.010	0.012*
1949	-0.006	-0.068*	-0.019*	-0.019*	-0.023*	0.004	-0.025*	-0.025*	0.010	0.012*
1950	-0.006	-0.068*	-0.019*	-0.019*	-0.024*	0.005	-0.025*	-0.025*	0.010	0.012*
1951	-0.006	-0.069*	-0.019*	-0.019*	-0.024*	0.007	-0.025*	-0.025*	0.010	0.012*
1952	-0.006	-0.068*	-0.019*	-0.019*	-0.025*	0.008	-0.025*	-0.025*	0.010	0.012*
1953	-0.006	-0.068*	-0.019*	-0.019*	-0.025*	0.010	-0.025*	-0.025*	0.010	0.012*
1954	-0.006	-0.066*	-0.019*	-0.019*	-0.025*	0.011	-0.025*	-0.025*	0.010	0.012*
1955	-0.006	-0.066*	-0.019*	-0.019*	-0.026*	0.012	-0.025*	-0.025*	0.010	0.012*
1956	-0.006	-0.066*	-0.020*	-0.019*	-0.026*	0.013	-0.025*	-0.025*	0.010	0.012*
1957	-0.006	-0.065*	-0.020*	-0.019*	-0.026*	0.014	-0.025*	-0.025*	0.010	0.012*
1958	-0.005	-0.060*	-0.021*	-0.019*	-0.027*	0.026	-0.025*	-0.025*	0.010	0.012*
1959	-0.005	-0.056*	-0.022*	-0.019*	-0.028*	0.034*	-0.025*	-0.025*	0.010	0.012*
1960	-0.005	-0.055*	-0.022*	-0.019*	-0.028*	0.036*	-0.025*	-0.025*	0.010	0.012*
1961	-0.005	-0.054*	-0.022*	-0.019*	-0.028*	0.037*	-0.025*	-0.025*	0.010	0.012*
1962	-0.005	-0.053*	-0.022*	-0.019*	-0.028*	0.039*	-0.025*	-0.025*	0.010	0.012*
1963	-0.005	-0.051*	-0.022*	-0.019*	-0.028*	0.040*	-0.025*	-0.025*	0.010	0.012*
1964	-0.004	-0.050*	-0.022*	-0.019*	-0.028*	0.042*	-0.025*	-0.025*	0.010	0.012*

Table A16. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}
1965	-0.004	-0.045*	-0.023*	-0.019*	-0.029*	0.046*	-0.025*	-0.025*	0.010	0.012*
1966	-0.004	-0.044*	-0.023*	-0.019*	-0.029*	0.046*	-0.025*	-0.025*	0.010	0.012*
1967	-0.004	-0.040*	-0.023*	-0.019*	-0.029*	0.049*	-0.025*	-0.025*	0.010	0.012*
1968	-0.004	-0.036*	-0.022*	-0.019*	-0.031*	0.051*	-0.025*	-0.025*	0.010	0.012*
1969	-0.004	-0.034*	-0.022*	-0.019*	-0.032*	0.052*	-0.025*	-0.025*	0.010	0.012*
1970	-0.004	-0.033*	-0.022*	-0.019*	-0.032*	0.053*	-0.025*	-0.025*	0.010	0.012*
1971	-0.004	-0.031*	-0.022*	-0.019*	-0.033*	0.055*	-0.025*	-0.025*	0.010	0.012*
1972	-0.004	-0.031*	-0.022*	-0.019*	-0.033*	0.055*	-0.025*	-0.025*	0.010	0.012*
1973	-0.004	-0.032*	-0.022*	-0.019*	-0.034*	0.055*	-0.025*	-0.025*	0.010	0.012*
1974	-0.004	-0.032*	-0.021*	-0.019*	-0.034*	0.055*	-0.025*	-0.025*	0.010	0.012*
1975	-0.004	-0.033*	-0.021*	-0.019*	-0.035*	0.056*	-0.025*	-0.025*	0.010	0.012*
1976	-0.004	-0.033*	-0.021*	-0.019*	-0.035*	0.056*	-0.025*	-0.025*	0.010	0.012*
1977	-0.004	-0.033*	-0.021*	-0.018*	-0.036*	0.056*	-0.025*	-0.025*	0.010	0.012*
1978	-0.004	-0.034*	-0.020*	-0.018*	-0.036*	0.055*	-0.025*	-0.025*	0.010	0.012*
1979	-0.004	-0.035*	-0.020*	-0.018*	-0.036*	0.055*	-0.025*	-0.025*	0.010	0.012*
1980	-0.004	-0.036*	-0.020*	-0.018*	-0.037*	0.054*	-0.025*	-0.025*	0.010	0.012*
1981	-0.004	-0.036*	-0.019*	-0.018*	-0.037*	0.055*	-0.025*	-0.025*	0.010	0.012*
1982	-0.004	-0.034*	-0.019*	-0.018*	-0.038*	0.058*	-0.025*	-0.025*	0.010	0.012*
1983	-0.004	-0.034*	-0.019*	-0.018*	-0.038*	0.058*	-0.025*	-0.025*	0.010	0.012*
1984	-0.004	-0.034*	-0.019*	-0.018*	-0.038*	0.058*	-0.025*	-0.025*	0.010	0.012*
1985	-0.004	-0.034*	-0.019*	-0.018*	-0.038*	0.058*	-0.025*	-0.025*	0.010	0.012*
1986	-0.004	-0.034*	-0.019*	-0.018*	-0.038*	0.058*	-0.025*	-0.025*	0.010	0.012*

* Indicates coefficient is significant at $P \leq 0.05$.

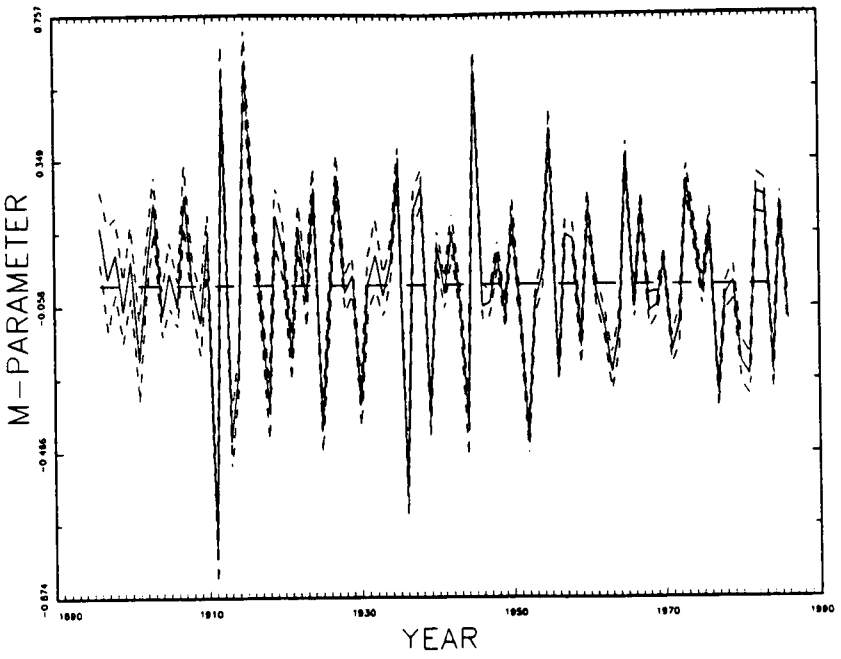


Figure A49. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 8.

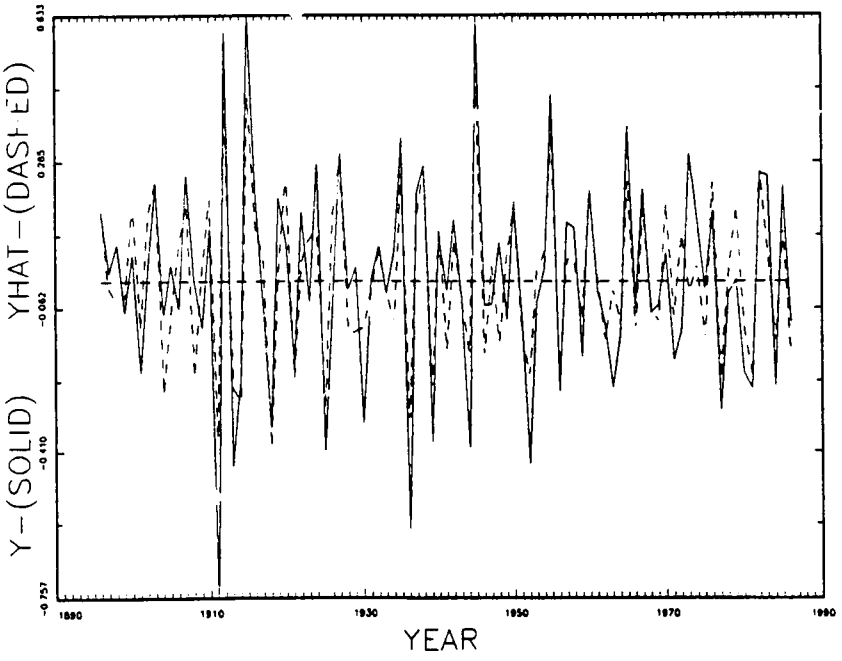
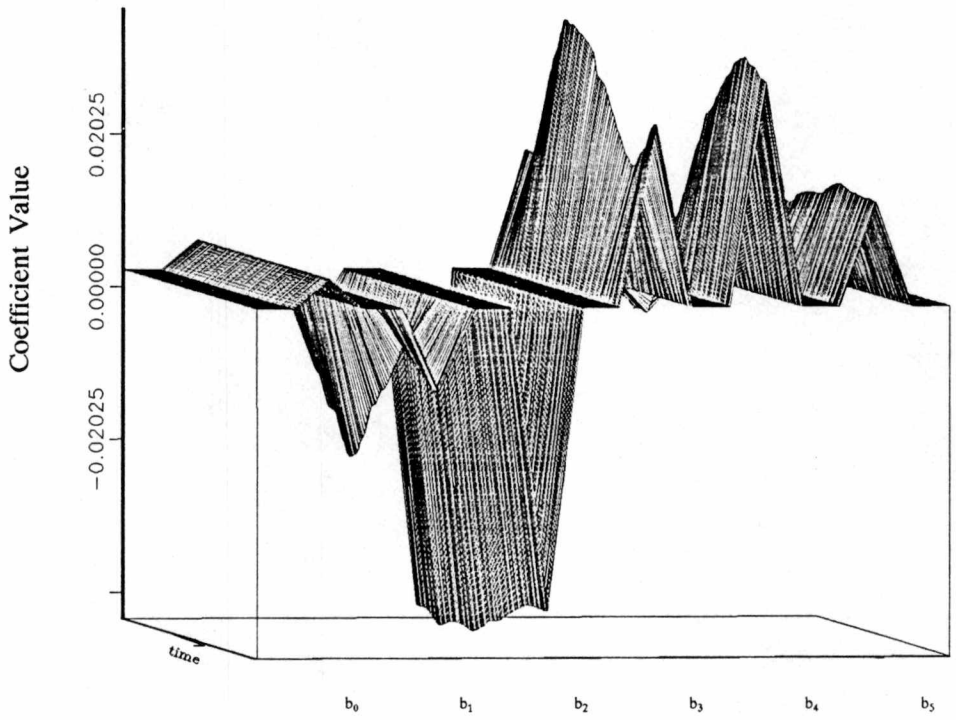


Figure A50. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 8.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = past August rain
b_4 = past October rain
b_5 = past December rain

Figure A51. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 8.

Table A17. Climate parameter estimates for LBL white oak, cluster 8.

YEAR	May temp. b_1	June temp. b_2	Past August rain b_3	Past October rain b_4	Past December rain b_5
1897	-0.007	-0.042*	0.018	-0.003	0.011
1898	-0.008	-0.042*	0.018	-0.003	0.011
1899	-0.008	-0.042*	0.018	-0.003	0.011
1900	-0.009	-0.042*	0.018	-0.003	0.011
1901	-0.011	-0.042*	0.018	-0.003	0.011
1902	-0.011	-0.042*	0.018	-0.003	0.011
1903	-0.011	-0.042*	0.019	-0.003	0.011
1904	-0.011	-0.042*	0.019	-0.003	0.012
1905	-0.011	-0.043*	0.020	-0.003	0.012
1906	-0.011	-0.043*	0.021	-0.003	0.012
1907	-0.012	-0.043*	0.022	-0.002	0.012
1908	-0.013	-0.043*	0.023	-0.002	0.012
1909	-0.014	-0.044*	0.025	-0.001	0.012
1910	-0.015	-0.044*	0.026	-0.001	0.013
1911	-0.015	-0.044*	0.027	0.000	0.013
1912	-0.015	-0.044*	0.028	0.002	0.013
1913	-0.015	-0.044*	0.029	0.002	0.013
1914	-0.015	-0.044*	0.030	0.002	0.013
1915	-0.016	-0.044*	0.031	0.003	0.013
1916	-0.016	-0.044*	0.032	0.004	0.013
1917	-0.016	-0.043*	0.032	0.004	0.013
1918	-0.017	-0.043*	0.033*	0.005	0.013
1919	-0.018	-0.043*	0.034*	0.005	0.013
1920	-0.019	-0.043*	0.035*	0.006	0.013
1921	-0.019	-0.043*	0.035*	0.006	0.013
1922	-0.020	-0.043*	0.036*	0.007	0.013
1923	-0.021	-0.043*	0.037*	0.007	0.013
1924	-0.021	-0.043*	0.037*	0.007	0.013
1925	-0.021	-0.043*	0.037*	0.008	0.013
1926	-0.021	-0.043*	0.037*	0.009	0.013
1927	-0.021	-0.043*	0.036*	0.010	0.013
1928	-0.021	-0.043*	0.036*	0.011	0.013
1929	-0.020	-0.043*	0.037*	0.011	0.013
1930	-0.020	-0.043*	0.036*	0.012	0.013
1931	-0.019	-0.043*	0.036*	0.013	0.013
1932	-0.019	-0.043*	0.036*	0.015	0.014
1933	-0.018	-0.043*	0.036*	0.015	0.014
1934	-0.018	-0.044*	0.036*	0.016	0.014*
1935	-0.017	-0.044*	0.036*	0.017	0.014*
1936	-0.016	-0.043*	0.035*	0.018	0.014*
1937	-0.015	-0.043*	0.035*	0.019	0.014*
1938	-0.015	-0.043*	0.035*	0.020	0.015*
1939	-0.014	-0.043*	0.035*	0.021	0.015*
1940	-0.013	-0.043*	0.035*	0.021	0.015*
1941	-0.013	-0.043*	0.034*	0.022	0.015*
1942	-0.013	-0.042*	0.034*	0.023*	0.015*
1943	-0.013	-0.042*	0.034*	0.023*	0.015*
1944	-0.012	-0.042*	0.032*	0.025*	0.015*
1945	-0.012	-0.042*	0.031*	0.025*	0.015*
1946	-0.011	-0.042*	0.031*	0.026*	0.015*
1947	-0.011	-0.041*	0.030*	0.026*	0.015*
1948	-0.011	-0.041*	0.030*	0.026*	0.015*
1949	-0.010	-0.041*	0.030*	0.026*	0.015*
1950	-0.010	-0.041*	0.030*	0.027*	0.015*

Table A17. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5
1951	-0.010	-0.041*	0.030*	0.027*	0.015*
1952	-0.009	-0.041*	0.029*	0.028*	0.016*
1953	-0.009	-0.041*	0.028*	0.028*	0.016*
1954	-0.008	-0.041*	0.028*	0.029*	0.016*
1955	-0.007	-0.041*	0.027*	0.030*	0.016*
1956	-0.007	-0.040*	0.026*	0.030*	0.016*
1957	-0.007	-0.040*	0.026*	0.030*	0.017*
1958	-0.006	-0.040*	0.025*	0.031*	0.017*
1959	-0.005	-0.040*	0.024*	0.031*	0.017*
1960	-0.005	-0.040*	0.024*	0.032*	0.017*
1961	-0.004	-0.039*	0.023*	0.032*	0.017*
1962	-0.004	-0.039*	0.023*	0.032*	0.017*
1963	-0.004	-0.039*	0.022*	0.033*	0.017*
1964	-0.005	-0.039*	0.022*	0.033*	0.017*
1965	-0.005	-0.039*	0.021*	0.033*	0.017*
1966	-0.005	-0.039*	0.021*	0.034*	0.017*
1967	-0.006	-0.038*	0.021*	0.034*	0.017*
1968	-0.006	-0.038*	0.020	0.034*	0.016*
1969	-0.006	-0.038*	0.020	0.034*	0.016*
1970	-0.006	-0.038*	0.020	0.034*	0.016*
1971	-0.006	-0.038*	0.020	0.034*	0.016*
1972	-0.007	-0.038*	0.020	0.035*	0.016*
1973	-0.007	-0.038*	0.021	0.034*	0.016*
1974	-0.007	-0.038*	0.022	0.034*	0.016*
1975	-0.007	-0.038*	0.022	0.034*	0.016*
1976	-0.007	-0.038*	0.022	0.034*	0.016*
1977	-0.007	-0.038*	0.023	0.034*	0.016*
1978	-0.008	-0.038*	0.023	0.034*	0.016*
1979	-0.008	-0.038*	0.023	0.033*	0.016*
1980	-0.008	-0.038*	0.024	0.033*	0.016*
1981	-0.009	-0.038*	0.025	0.033*	0.016*
1982	-0.009	-0.038*	0.026	0.032*	0.016*
1983	-0.009	-0.038*	0.026	0.032*	0.016*
1984	-0.009	-0.038*	0.026	0.032*	0.016*
1985	-0.009	-0.038*	0.026	0.032*	0.016*
1986	-0.009	-0.038*	0.026	0.032*	0.016*

* Indicates coefficient is significant at $P \leq 0.05$.

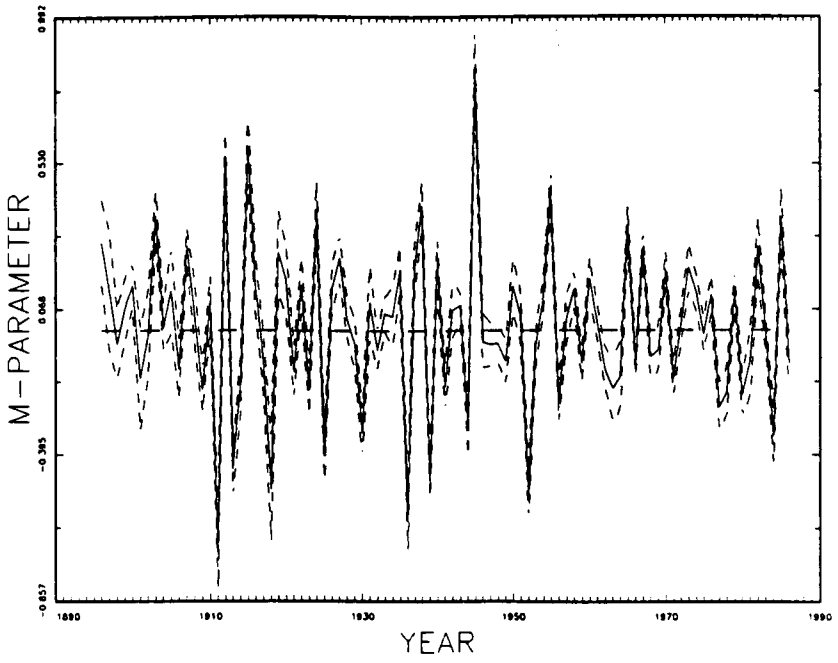


Figure A52. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes white oak, cluster 9.

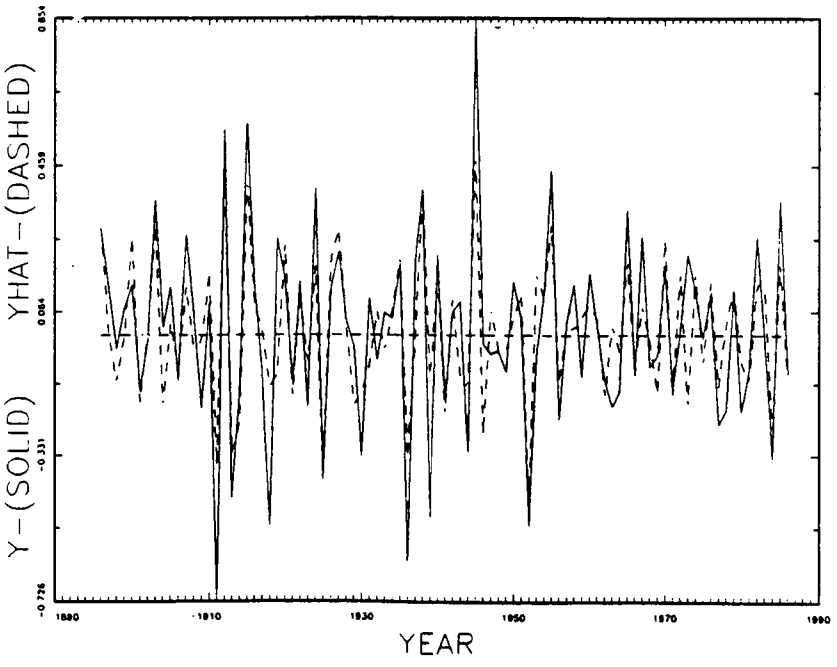
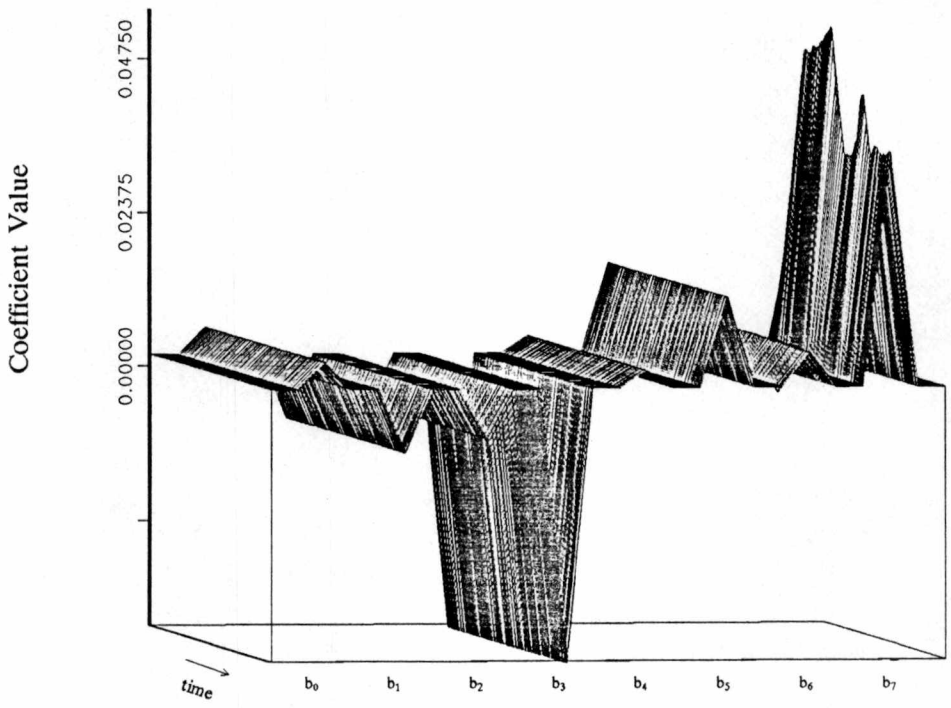


Figure A53. Graph of predicted and actual standardized growth, Land Between the Lakes white oak, cluster 9.



Where:

b_0 = the intercept (non-varying)
b_1 = January temperature
b_2 = May temperature
b_3 = June temperature
b_4 = past December temperature
b_5 = June rain
b_6 = past April rain
b_7 = past August rain

Figure A54. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes white oak, cluster 9.

Table A18. Climate parameter estimates for LBL white oak, cluster 9.

YEAR	June temp. b_1	May temp. b_2	June temp. b_3	Past December temp. b_4	June rain b_5	Past April rain b_6	Past August rain b_7
1897	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	-0.003
1898	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	-0.003
1899	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	-0.003
1900	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	-0.003
1901	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	-0.004
1902	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	-0.004
1903	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	-0.004
1904	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	-0.002
1905	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.001
1906	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.003
1907	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.004
1908	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.008
1909	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.010
1910	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.013
1911	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.017
1912	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.020
1913	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.023
1914	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.026
1915	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.029
1916	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.031
1917	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.033
1918	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.038
1919	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.042*
1920	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.046*
1921	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.047*
1922	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.049*
1923	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.050*
1924	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.050*
1925	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.050*
1926	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.049*
1927	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.050*
1928	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.050*
1929	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.051*
1930	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.051*
1931	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.051*
1932	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.051*
1933	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.051*
1934	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.052*
1935	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.052*
1936	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.052*
1937	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.052*
1938	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.053*
1939	-0.008*	-0.006	-0.040*	0.004	0.016	0.008	0.053*
1940	-0.008*	-0.006	-0.040*	0.004	0.016	0.008	0.054*
1941	-0.008*	-0.006	-0.040*	0.004	0.016	0.008	0.054*
1942	-0.008*	-0.006	-0.040*	0.004	0.016	0.008	0.055*
1943	-0.008*	-0.006	-0.040*	0.004	0.016	0.008	0.054*
1944	-0.008*	-0.006	-0.040*	0.004	0.016	0.008	0.052*
1945	-0.008*	-0.006	-0.040*	0.004	0.016	0.008	0.046*
1946	-0.008*	-0.006	-0.040*	0.004	0.016	0.008	0.044*
1947	-0.008*	-0.006	-0.040*	0.004	0.016	0.008	0.043*
1948	-0.008*	-0.006	-0.040*	0.004	0.016	0.008	0.042*
1949	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.041*
1950	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.039*
1951	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037*

Table A18. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7
1952	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.035*
1953	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.035*
1954	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.036*
1955	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.035*
1956	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.035*
1957	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.035*
1958	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.036*
1959	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037*
1960	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.038*
1961	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.038*
1962	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.039*
1963	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.041*
1964	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.044*
1965	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.045*
1966	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.046*
1967	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.044*
1968	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.041*
1969	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.039*
1970	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.038*
1971	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037*
1972	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.036*
1973	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037*
1974	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.038*
1975	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.038*
1976	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.038*
1977	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037*
1978	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037*
1979	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037
1980	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037
1981	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037
1982	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037
1983	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.037
1984	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.038
1985	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.038
1986	-0.008*	-0.006	-0.040*	0.004	0.016	0.007	0.038

* Indicates coefficient is significant at $P \leq 0.05$.

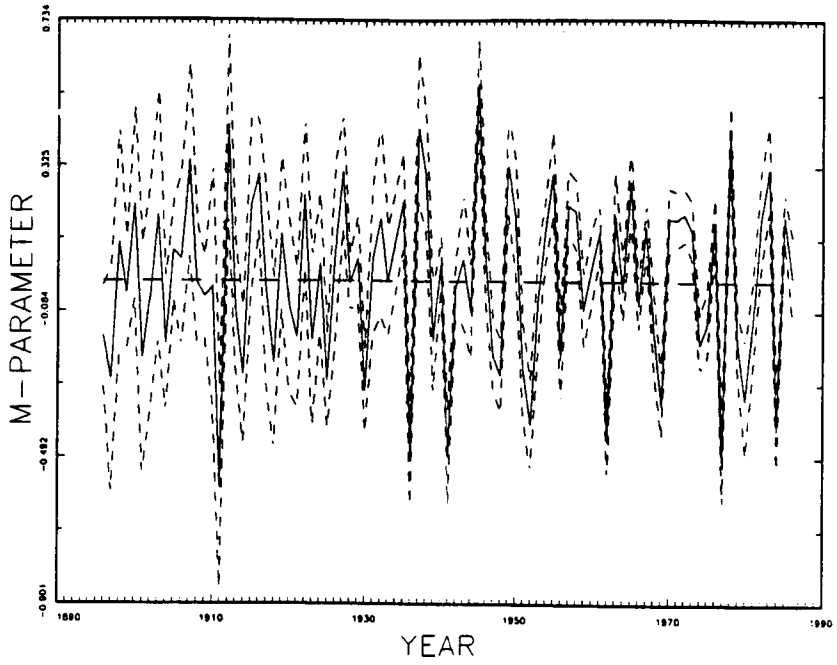


Figure A55. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 1.

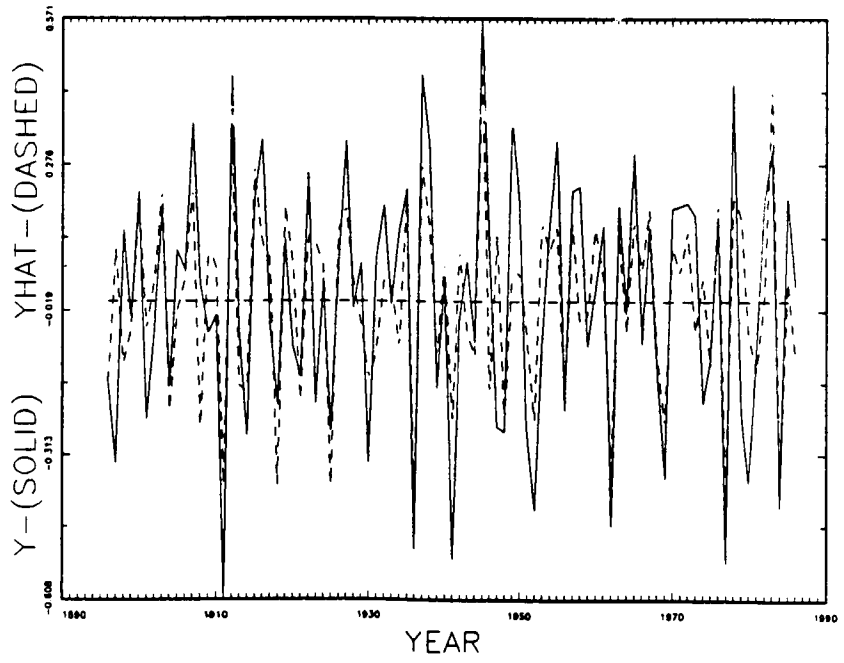
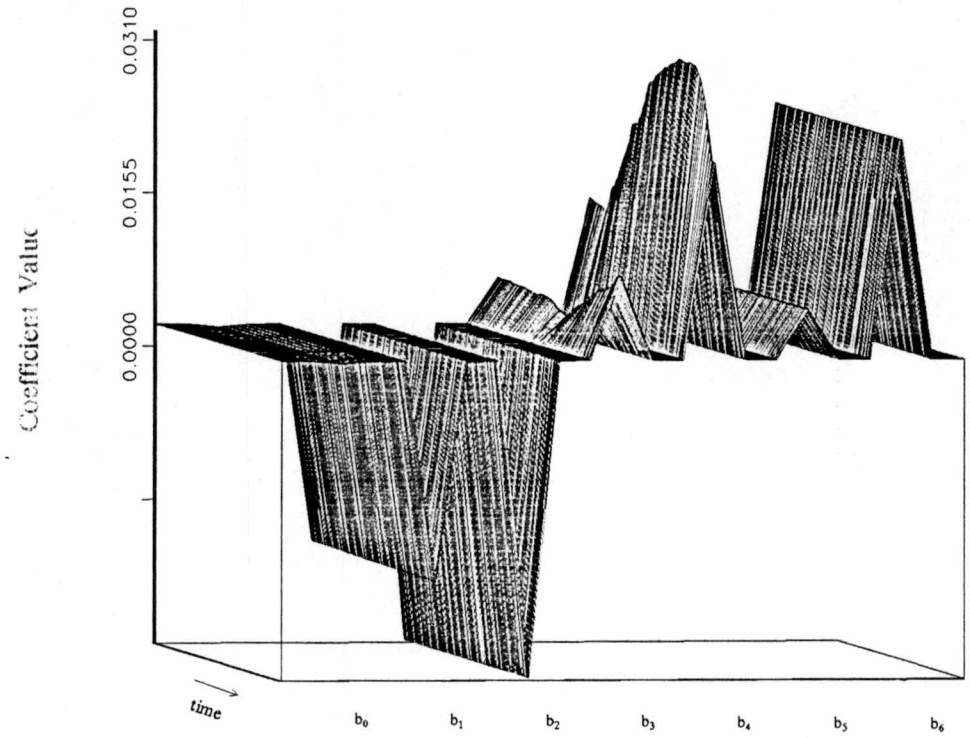


Figure A56. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = past December temperature
b_4 = May rain
b_5 = June rain
b_6 = past August rain

Figure A57. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 1.

Table A19. Climate parameter estimates for Wayne County white oak, cluster 1.

YEAR	May temp. b_1	June temp. b_2	Past December temp. b_3	May rain b_4	June rain b_5	Past August rain b_6
1897	-0.017	-0.030*	0.008*	0.024*	0.008	0.026*
1898	-0.017	-0.030*	0.008*	0.024*	0.008	0.026*
1899	-0.017	-0.030*	0.008*	0.024*	0.008	0.026*
1900	-0.017	-0.030*	0.008*	0.024*	0.008	0.026*
1901	-0.017	-0.030*	0.008*	0.024*	0.008	0.026*
1902	-0.017	-0.030*	0.008*	0.024*	0.008	0.026*
1903	-0.017	-0.030*	0.008*	0.024*	0.008	0.026*
1904	-0.017	-0.030*	0.008*	0.024*	0.008	0.026*
1905	-0.017	-0.030*	0.008*	0.024*	0.008	0.026*
1906	-0.017*	-0.030*	0.008*	0.024*	0.008	0.026*
1907	-0.017*	-0.030*	0.008*	0.024*	0.008	0.026*
1908	-0.017*	-0.030*	0.008*	0.024*	0.008	0.026*
1909	-0.017*	-0.030*	0.008*	0.024*	0.008	0.026*
1910	-0.017*	-0.030*	0.008*	0.024*	0.008	0.026*
1911	-0.017*	-0.030*	0.008*	0.024*	0.008	0.026*
1912	-0.017*	-0.030*	0.008*	0.024*	0.008	0.026*
1913	-0.017*	-0.030*	0.008*	0.024*	0.008	0.026*
1914	-0.017*	-0.030*	0.008*	0.024*	0.008	0.026*
1915	-0.017*	-0.030*	0.008*	0.024*	0.008	0.026*
1916	-0.018*	-0.030*	0.008*	0.024*	0.008	0.026*
1917	-0.018*	-0.030*	0.008*	0.024*	0.008	0.026*
1918	-0.018*	-0.030*	0.008*	0.024*	0.008	0.026*
1919	-0.018*	-0.030*	0.008*	0.024*	0.008	0.026*
1920	-0.018*	-0.030*	0.008*	0.024*	0.008	0.026*
1921	-0.018*	-0.030*	0.008*	0.024*	0.008	0.026*
1922	-0.018*	-0.030*	0.008*	0.024*	0.008	0.026*
1923	-0.018*	-0.030*	0.008*	0.024*	0.008	0.026*
1924	-0.019*	-0.030*	0.008*	0.024*	0.008	0.026*
1925	-0.019*	-0.030*	0.008*	0.024*	0.008	0.026*
1926	-0.019*	-0.031*	0.008*	0.024*	0.008	0.026*
1927	-0.019*	-0.031*	0.008*	0.024*	0.008	0.026*
1928	-0.019*	-0.031*	0.008*	0.024*	0.008	0.026*
1929	-0.019*	-0.031*	0.008*	0.024*	0.008	0.026*
1930	-0.019*	-0.031*	0.008*	0.024*	0.008	0.026*
1931	-0.019*	-0.031*	0.008*	0.024*	0.008	0.026*
1932	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1933	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1934	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1935	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1936	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1937	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1938	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1939	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1940	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1941	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1942	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1943	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1944	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1945	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1946	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1947	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1948	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1949	-0.020*	-0.031*	0.008*	0.024*	0.008	0.026*
1950	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1951	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*

Table A19. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1952	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1953	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1954	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1955	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1956	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1957	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1958	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1959	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1960	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1961	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1962	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1963	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1964	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1965	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1966	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1967	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1968	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1969	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1970	-0.021*	-0.030*	0.008*	0.024*	0.008	0.026*
1971	-0.021*	-0.030*	0.008*	0.024*	0.008	0.026*
1972	-0.021*	-0.030*	0.008*	0.024*	0.008	0.026*
1973	-0.021*	-0.030*	0.008*	0.024*	0.008	0.026*
1974	-0.021*	-0.030*	0.008*	0.024*	0.008	0.026*
1975	-0.021*	-0.030*	0.008*	0.024*	0.008	0.026*
1976	-0.021*	-0.030*	0.008*	0.024*	0.008	0.026*
1977	-0.021*	-0.030*	0.008*	0.024*	0.008	0.026*
1978	-0.021*	-0.030*	0.008*	0.024*	0.008	0.026*
1979	-0.021*	-0.030*	0.008*	0.024*	0.008	0.026*
1980	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1981	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1982	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1983	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1984	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1985	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*
1986	-0.021*	-0.031*	0.008*	0.024*	0.008	0.026*

* Indicates coefficient is significant at $P \leq 0.05$.

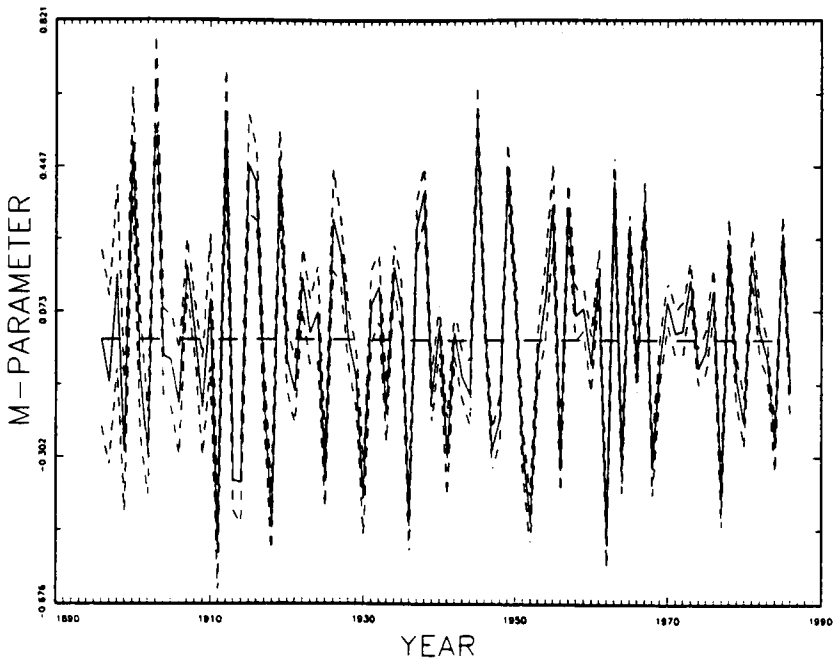


Figure A58. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 2.

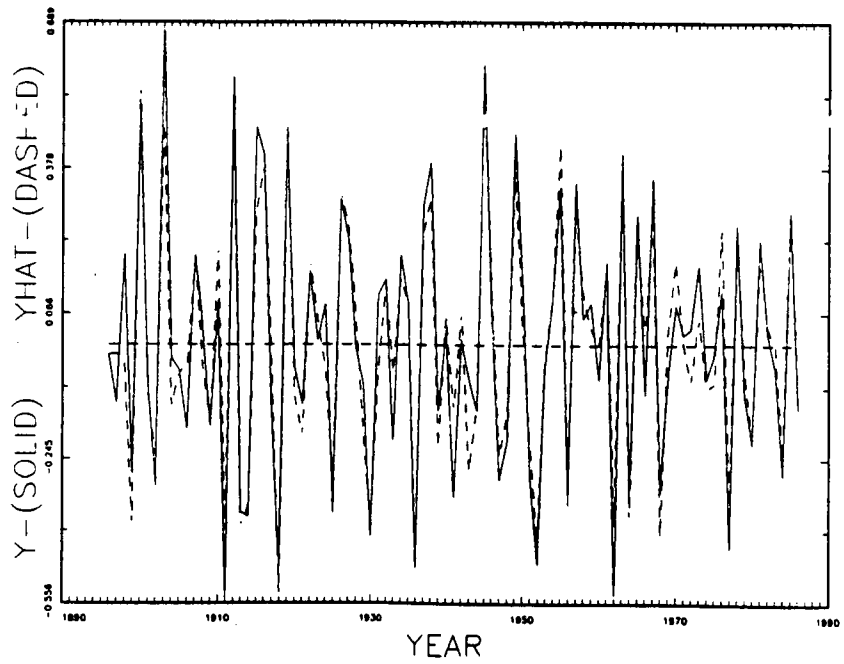
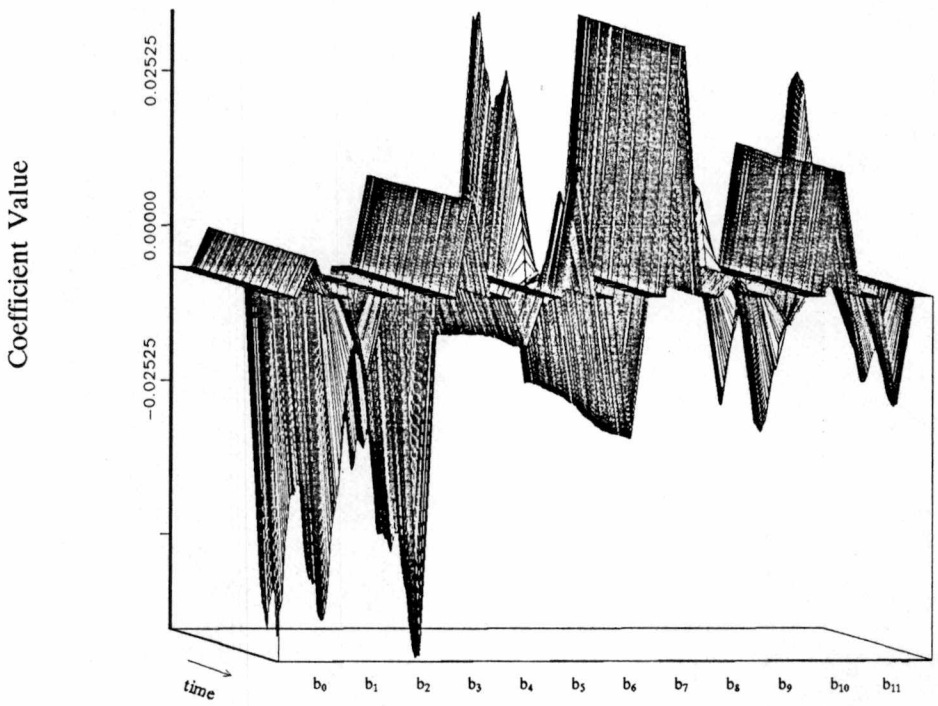


Figure A59. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = August temperature
b_3 = past May temperature
b_4 = past June temperature
b_5 = past December temperature
b_6 = February rain
b_7 = June rain
b_8 = July rain
b_9 = past March rain
b_{10} = past April rain
b_{11} = past May rain

Figure A60. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 2.

Table A20. Climate parameter estimates for Wayne County white oak, cluster 2.

YEAR	June temp. b_1	August temp. b_2	Past May temp. b_3	Past June temp. b_4	Past December temp. b_5	February rain b_6	June rain b_7	July rain b_8	Past March rain b_9	Past April rain b_{10}	Past May rain b_{11}
1897	-0.062*	-0.021	0.009*	-0.028	0.030	-0.027*	0.034*	0.002	0.005	0.012*	0.010
1898	-0.062*	-0.021	0.009*	-0.028	0.029	-0.027*	0.034*	0.002	0.004	0.012*	0.010
1899	-0.063*	-0.021	0.009*	-0.029	0.030	-0.027*	0.034*	0.002	0.004	0.012*	0.010
1900	-0.063*	-0.022	0.009*	-0.029	0.030	-0.027*	0.034*	0.002	0.005	0.012*	0.010
1901	-0.063*	-0.022	0.009*	-0.029*	0.030*	-0.027*	0.034*	0.002	0.006	0.012*	0.011
1902	-0.064*	-0.022	0.009*	-0.029*	0.030*	-0.027*	0.034*	0.002	0.006	0.012*	0.011
1903	-0.062*	-0.022	0.009*	-0.029*	0.029*	-0.027*	0.034*	0.002	0.006	0.012*	0.011
1904	-0.062*	-0.022	0.009*	-0.029*	0.028*	-0.027*	0.034*	0.002	0.006	0.012*	0.011
1905	-0.061*	-0.022	0.009*	-0.029*	0.027*	-0.027*	0.034*	0.002	0.005	0.012*	0.011
1906	-0.060*	-0.021	0.009*	-0.028*	0.025*	-0.027*	0.034*	0.002	0.005	0.012*	0.011
1907	-0.060*	-0.021	0.009*	-0.028*	0.024*	-0.027*	0.034*	0.002	0.005	0.012*	0.011
1908	-0.060*	-0.021	0.009*	-0.028*	0.024*	-0.027*	0.034*	0.002	0.005	0.012*	0.011
1909	-0.061*	-0.021	0.009*	-0.027*	0.024*	-0.027*	0.034*	0.002	0.004	0.012*	0.009
1910	-0.062*	-0.020	0.009*	-0.025*	0.022*	-0.027*	0.034*	0.002	0.004	0.012*	0.007
1911	-0.061*	-0.019	0.009*	-0.024*	0.022*	-0.027*	0.034*	0.002	0.003	0.012*	0.007
1912	-0.059*	-0.019	0.009*	-0.024*	0.021*	-0.027*	0.034*	0.002	0.001	0.012*	0.005
1913	-0.058*	-0.019	0.009*	-0.024*	0.021*	-0.027*	0.034*	0.002	-0.001	0.012*	0.005
1914	-0.057*	-0.019	0.009*	-0.024*	0.021*	-0.027*	0.034*	0.002	-0.003	0.012*	0.004
1915	-0.053*	-0.018	0.009*	-0.023*	0.022*	-0.027*	0.034*	0.002	-0.005	0.012*	0.003
1916	-0.052*	-0.018	0.009*	-0.023*	0.022*	-0.027*	0.034*	0.002	-0.006	0.012*	0.002
1917	-0.050*	-0.018	0.009*	-0.023*	0.022*	-0.027*	0.034*	0.002	-0.007	0.012*	0.001
1918	-0.049*	-0.019	0.009*	-0.023*	0.022*	-0.027*	0.034*	0.002	-0.008	0.012*	0.001
1919	-0.048*	-0.020	0.009*	-0.023*	0.023*	-0.027*	0.034*	0.002	-0.010	0.012*	-0.000
1920	-0.047*	-0.021	0.009*	-0.023*	0.023*	-0.027*	0.034*	0.002	-0.011	0.012*	-0.001
1921	-0.047*	-0.022	0.009*	-0.023*	0.023*	-0.027*	0.034*	0.002	-0.013	0.012*	-0.001
1922	-0.046*	-0.023	0.009*	-0.022*	0.023*	-0.027*	0.034*	0.002	-0.014	0.012*	-0.002
1923	-0.046*	-0.025*	0.009*	-0.022*	0.023*	-0.027*	0.034*	0.002	-0.015	0.012*	-0.002
1924	-0.046*	-0.027*	0.009*	-0.021*	0.023*	-0.027*	0.034*	0.002	-0.017	0.012*	-0.004
1925	-0.046*	-0.029*	0.009*	-0.021*	0.023*	-0.027*	0.034*	0.002	-0.018	0.012*	-0.005
1926	-0.045*	-0.032*	0.009*	-0.020*	0.022*	-0.027*	0.034*	0.002	-0.020*	0.012*	-0.007
1927	-0.045*	-0.033*	0.009*	-0.020*	0.021*	-0.027*	0.034*	0.002	-0.022*	0.012*	-0.008
1928	-0.046*	-0.034*	0.009*	-0.019*	0.021*	-0.027*	0.034*	0.002	-0.022*	0.012*	-0.008
1929	-0.046*	-0.034*	0.009*	-0.019*	0.020*	-0.027*	0.034*	0.002	-0.022*	0.012*	-0.008

Table A20. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}	b_{11}
1930	-0.047*	-0.034*	0.009*	-0.018*	0.019*	-0.027*	0.034*	0.002	-0.021*	0.012*	-0.009
1931	-0.049*	-0.033*	0.009*	-0.018*	0.018*	-0.027*	0.034*	0.002	-0.020*	0.012*	-0.009
1932	-0.050*	-0.033*	0.009*	-0.017	0.017*	-0.027*	0.034*	0.002	-0.019	0.012*	-0.009
1933	-0.051*	-0.033*	0.009*	-0.017	0.015*	-0.027*	0.034*	0.002	-0.018	0.012*	-0.009
1934	-0.052*	-0.034*	0.009*	-0.017	0.013*	-0.027*	0.034*	0.002	-0.018	0.012*	-0.009
1935	-0.052*	-0.034*	0.009*	-0.016	0.012*	-0.027*	0.034*	0.002	-0.018	0.012*	-0.009
1936	-0.052*	-0.034*	0.009*	-0.016	0.009	-0.027*	0.034*	0.002	-0.017	0.012*	-0.009
1937	-0.053*	-0.035*	0.009*	-0.016*	0.007	-0.027*	0.034*	0.002	-0.017	0.012*	-0.009
1938	-0.052*	-0.035*	0.009*	-0.016*	0.005	-0.027*	0.034*	0.002	-0.016	0.012*	-0.010
1939	-0.053*	-0.035*	0.009*	-0.016	0.003	-0.027*	0.034*	0.002	-0.015	0.012*	-0.010
1940	-0.053*	-0.035*	0.009*	-0.015	0.001	-0.027*	0.034*	0.002	-0.014	0.012*	-0.010
1941	-0.053*	-0.034*	0.009*	-0.015	-0.002	-0.027*	0.034*	0.002	-0.013	0.012*	-0.011
1942	-0.052*	-0.034*	0.009*	-0.014	-0.004	-0.027*	0.034*	0.002	-0.012	0.012*	-0.012
1943	-0.053*	-0.035*	0.009*	-0.014	-0.004	-0.027*	0.034*	0.002	-0.013	0.012*	-0.013
1944	-0.054*	-0.037*	0.009*	-0.013	-0.005	-0.027*	0.034*	0.002	-0.013	0.012*	-0.014
1945	-0.055*	-0.038*	0.009*	-0.013	-0.005	-0.027*	0.034*	0.002	-0.014	0.012*	-0.015
1946	-0.055*	-0.039*	0.009*	-0.013	-0.005	-0.027*	0.034*	0.002	-0.014	0.012*	-0.015
1947	-0.055*	-0.040*	0.009*	-0.013	-0.004	-0.027*	0.034*	0.002	-0.014	0.012*	-0.016
1948	-0.055*	-0.041*	0.009*	-0.013	-0.004	-0.027*	0.034*	0.002	-0.015	0.012*	-0.016
1949	-0.054*	-0.042*	0.009*	-0.012	-0.004	-0.027*	0.034*	0.002	-0.016	0.012*	-0.016
1950	-0.054*	-0.042*	0.009*	-0.012	-0.004	-0.027*	0.034*	0.002	-0.017	0.012*	-0.017
1951	-0.053*	-0.043*	0.009*	-0.012	-0.004	-0.027*	0.034*	0.002	-0.018*	0.012*	-0.017
1952	-0.052*	-0.043*	0.009*	-0.012	-0.004	-0.027*	0.034*	0.002	-0.018*	0.012*	-0.017
1953	-0.051*	-0.043*	0.009*	-0.012	-0.004	-0.027*	0.034*	0.002	-0.019*	0.012*	-0.018
1954	-0.048*	-0.044*	0.009*	-0.011	-0.004	-0.027*	0.034*	0.002	-0.021*	0.012*	-0.019*
1955	-0.046*	-0.045*	0.009*	-0.011	-0.004	-0.027*	0.034*	0.002	-0.024*	0.012*	-0.021*
1956	-0.044*	-0.045*	0.009*	-0.011	-0.004	-0.027*	0.034*	0.002	-0.025*	0.012*	-0.021*
1957	-0.043*	-0.045*	0.009*	-0.011	-0.005	-0.027*	0.034*	0.002	-0.025*	0.012*	-0.022*
1958	-0.042*	-0.046*	0.009*	-0.011	-0.006	-0.027*	0.034*	0.002	-0.025*	0.012*	-0.022*
1959	-0.041*	-0.046*	0.009*	-0.011	-0.006	-0.027*	0.034*	0.002	-0.025*	0.012*	-0.022*
1960	-0.039*	-0.047*	0.009*	-0.011	-0.006	-0.027*	0.034*	0.002	-0.025*	0.012*	-0.021*
1961	-0.038*	-0.047*	0.009*	-0.011	-0.005	-0.027*	0.034*	0.002	-0.025*	0.012*	-0.021*
1962	-0.037*	-0.047*	0.009*	-0.011	-0.003	-0.027*	0.034*	0.002	-0.025*	0.012*	-0.021*
1963	-0.034*	-0.047*	0.009*	-0.012	-0.001	-0.027*	0.034*	0.002	-0.024*	0.012*	-0.020*
1964	-0.033*	-0.047*	0.009*	-0.012	0.002	-0.027*	0.034*	0.002	-0.024*	0.012*	-0.019*
1965	-0.031*	-0.047*	0.009*	-0.012	0.003	-0.027*	0.034*	0.002	-0.024*	0.012*	-0.019*

Table A20. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}	b_{11}
1966	-0.030*	-0.047*	0.009*	-0.013	0.004	-0.027*	0.034*	0.002	-0.023*	0.012*	-0.019*
1967	-0.028*	-0.047*	0.009*	-0.013	0.005	-0.027*	0.034*	0.002	-0.022*	0.012*	-0.018*
1968	-0.026*	-0.048*	0.009*	-0.014	0.007	-0.027*	0.034*	0.002	-0.021*	0.012*	-0.018*
1969	-0.025*	-0.049*	0.009*	-0.015	0.007	-0.027*	0.034*	0.002	-0.020*	0.012*	-0.018*
1970	-0.023*	-0.050*	0.009*	-0.016	0.007	-0.027*	0.034*	0.002	-0.019*	0.012*	-0.019*
1971	-0.023*	-0.051*	0.009*	-0.016	0.007	-0.027*	0.034*	0.002	-0.019*	0.012*	-0.019*
1972	-0.021*	-0.051*	0.009*	-0.017	0.006	-0.027*	0.034*	0.002	-0.018*	0.012*	-0.020*
1973	-0.021*	-0.052*	0.009*	-0.017	0.007	-0.027*	0.034*	0.002	-0.018*	0.012*	-0.021*
1974	-0.021*	-0.052*	0.009*	-0.017	0.007	-0.027*	0.034*	0.002	-0.018*	0.012*	-0.021*
1975	-0.021*	-0.053*	0.009*	-0.016	0.008	-0.027*	0.034*	0.002	-0.017*	0.012*	-0.021*
1976	-0.021*	-0.054*	0.009*	-0.016	0.009	-0.027*	0.034*	0.002	-0.015*	0.012*	-0.022*
1977	-0.021*	-0.054*	0.009*	-0.016	0.010	-0.027*	0.034*	0.002	-0.015*	0.012*	-0.023*
1978	-0.021*	-0.055*	0.009*	-0.015	0.010	-0.027*	0.034*	0.002	-0.014	0.012*	-0.023*
1979	-0.022*	-0.056*	0.009*	-0.015	0.010	-0.027*	0.034*	0.002	-0.013	0.012*	-0.023*
1980	-0.022*	-0.056*	0.009*	-0.015	0.011	-0.027*	0.034*	0.002	-0.012	0.012*	-0.023*
1981	-0.022	-0.057*	0.009*	-0.014	0.011*	-0.027*	0.034*	0.002	-0.012	0.012*	-0.024*
1982	-0.022	-0.057*	0.009*	-0.014	0.012*	-0.027*	0.034*	0.002	-0.012	0.012*	-0.024*
1983	-0.022	-0.057*	0.009*	-0.014	0.013*	-0.027*	0.034*	0.002	-0.012	0.012*	-0.024*
1984	-0.023	-0.057*	0.009*	-0.014	0.013*	-0.027*	0.034*	0.002	-0.012	0.012*	-0.024*
1985	-0.023	-0.057*	0.009*	-0.014	0.014*	-0.027*	0.034*	0.002	-0.012	0.012*	-0.024*
1986	-0.023	-0.057*	0.009*	-0.014	0.014*	-0.027*	0.034*	0.002	-0.012	0.012*	-0.024*

* Indicates coefficient is significant at $P \leq 0.05$.

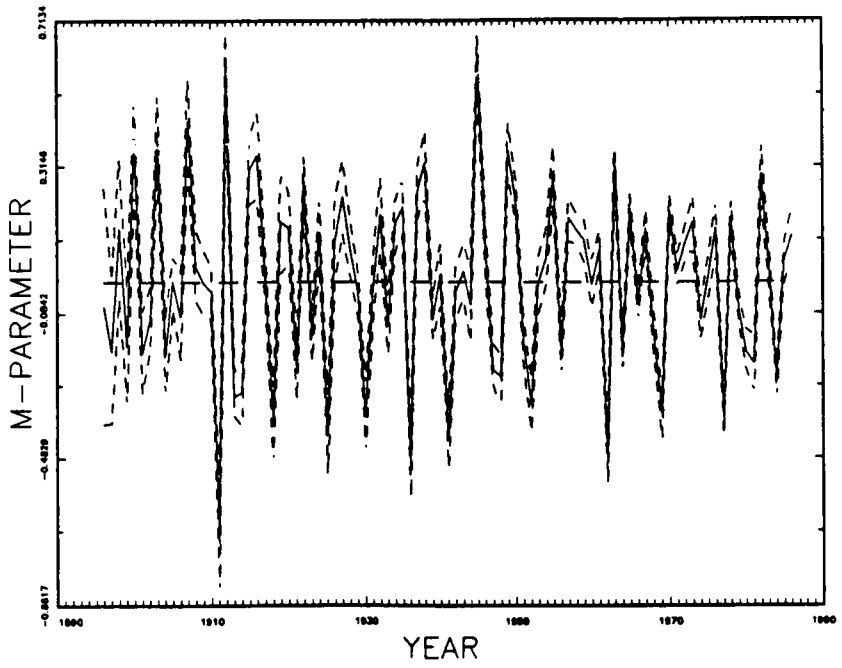


Figure A61. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 3.

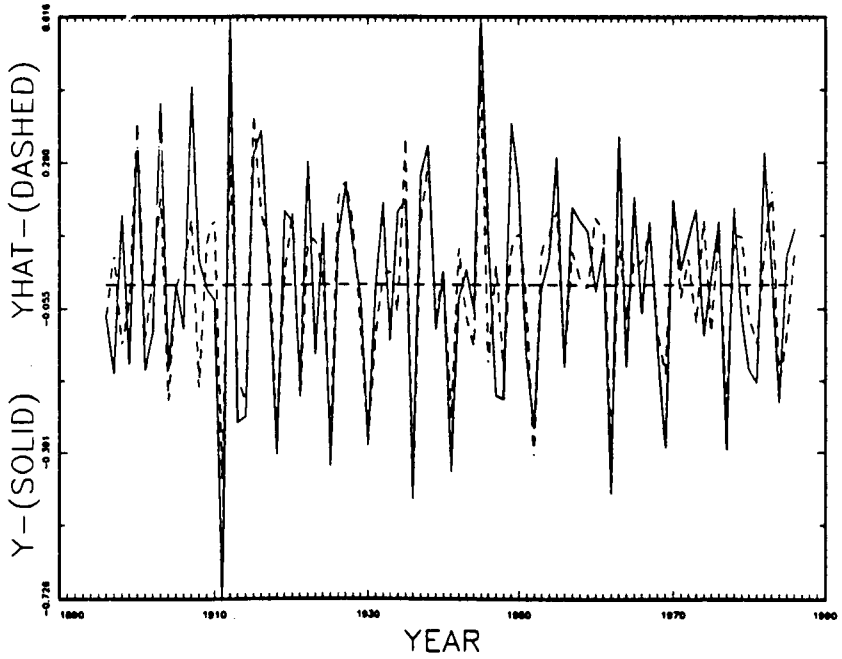
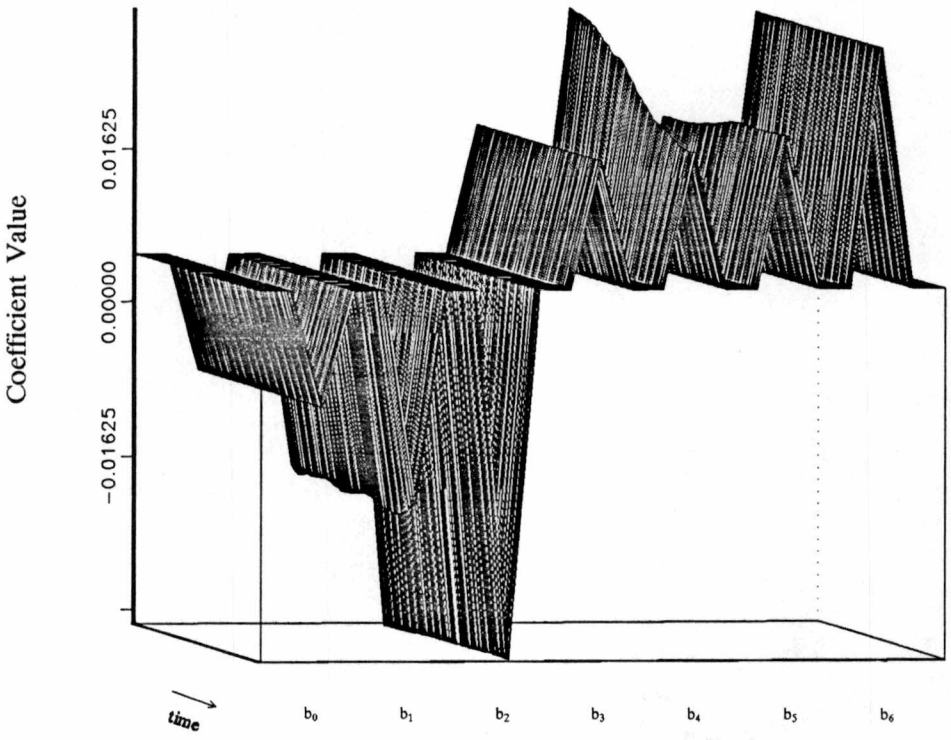


Figure A62. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 3.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = May rain
b_4 = June rain
b_5 = past June rain
b_6 = past August rain

Figure A63. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 3.

Table A21. Climate parameter estimates for Wayne County white oak, cluster 3.

YEAR	May temp. b_1	June temp. b_2	May rain b_3	June rain b_4	Past June rain b_5	Past August rain b_6
1897	-0.017*	-0.034*	0.025	0.031*	0.019	0.028*
1898	-0.017*	-0.034*	0.024	0.031*	0.019	0.028*
1899	-0.018*	-0.034*	0.024	0.031*	0.019	0.028*
1900	-0.018*	-0.034*	0.024	0.031*	0.019	0.028*
1901	-0.018*	-0.034*	0.024	0.031*	0.019	0.028*
1902	-0.018*	-0.034*	0.024	0.031*	0.019	0.028*
1903	-0.018*	-0.034*	0.024	0.031*	0.019	0.028*
1904	-0.018*	-0.034*	0.024	0.030*	0.019	0.028*
1905	-0.018*	-0.034*	0.024	0.030*	0.019	0.028*
1906	-0.018*	-0.034*	0.023	0.030*	0.019	0.028*
1907	-0.017*	-0.034*	0.022	0.030*	0.019	0.029*
1908	-0.017*	-0.034*	0.022	0.030*	0.019*	0.029*
1909	-0.017*	-0.034*	0.022	0.030*	0.019*	0.029*
1910	-0.018*	-0.034*	0.022	0.030*	0.019*	0.029*
1911	-0.018*	-0.034*	0.022	0.030*	0.019*	0.029*
1912	-0.018*	-0.034*	0.021	0.030*	0.019*	0.029*
1913	-0.018*	-0.034*	0.021	0.030*	0.019*	0.029*
1914	-0.018*	-0.034*	0.021	0.030*	0.019*	0.029*
1915	-0.018*	-0.034*	0.020	0.030*	0.019*	0.029*
1916	-0.018*	-0.034*	0.020	0.029*	0.019*	0.029*
1917	-0.018*	-0.034*	0.020	0.029*	0.019*	0.029*
1918	-0.018*	-0.034*	0.019	0.029*	0.019*	0.029*
1919	-0.018*	-0.034*	0.018	0.029*	0.020*	0.030*
1920	-0.018*	-0.034*	0.018	0.028*	0.020*	0.030*
1921	-0.018*	-0.034*	0.017	0.028*	0.020*	0.030*
1922	-0.018*	-0.034*	0.017	0.028*	0.020*	0.030*
1923	-0.018*	-0.034*	0.016	0.028*	0.020*	0.030*
1924	-0.018*	-0.034*	0.016	0.028*	0.020*	0.030*
1925	-0.018*	-0.034*	0.016	0.027*	0.020*	0.030*
1926	-0.018*	-0.034*	0.015	0.027*	0.020*	0.030*
1927	-0.018*	-0.034*	0.015	0.027*	0.020*	0.030*
1928	-0.018*	-0.034*	0.015	0.027*	0.020*	0.030*
1929	-0.018*	-0.034*	0.014	0.027*	0.020*	0.030*
1930	-0.018*	-0.034*	0.014	0.027*	0.020*	0.030*
1931	-0.018*	-0.034*	0.013	0.027*	0.020*	0.030*
1932	-0.018*	-0.034*	0.013	0.027*	0.020*	0.030*
1933	-0.018*	-0.034*	0.013	0.027*	0.021*	0.030*
1934	-0.018*	-0.034*	0.014	0.026*	0.021*	0.030*
1935	-0.018*	-0.034*	0.015	0.026*	0.021*	0.030*
1936	-0.018*	-0.034*	0.017	0.026*	0.021*	0.030*
1937	-0.018*	-0.034*	0.018	0.026*	0.021*	0.030*
1938	-0.018*	-0.034*	0.019	0.025*	0.021*	0.030*
1939	-0.018*	-0.034*	0.020	0.025*	0.021*	0.030*
1940	-0.018*	-0.034*	0.021	0.025*	0.021*	0.030*
1941	-0.018*	-0.034*	0.022*	0.025*	0.021*	0.030*
1942	-0.018*	-0.034*	0.023*	0.024*	0.021*	0.030*
1943	-0.018*	-0.034*	0.023*	0.024*	0.021*	0.030*
1944	-0.018*	-0.034*	0.024*	0.024*	0.022*	0.030*
1945	-0.018*	-0.034*	0.025*	0.023*	0.022*	0.030*
1946	-0.018*	-0.034*	0.025*	0.023*	0.022*	0.030*
1947	-0.018*	-0.034*	0.026*	0.023*	0.022*	0.030*
1948	-0.018*	-0.034*	0.026*	0.023*	0.022*	0.030*
1949	-0.018*	-0.034*	0.027*	0.023*	0.022*	0.030*
1950	-0.018*	-0.034*	0.027*	0.022*	0.022*	0.030*
1951	-0.018*	-0.034*	0.027*	0.022*	0.022*	0.030*

Table A21. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1952	-0.018*	-0.034*	0.027*	0.022*	0.022*	0.030*
1953	-0.018*	-0.034*	0.027*	0.022*	0.022*	0.030*
1954	-0.018*	-0.034*	0.027*	0.021*	0.022*	0.030*
1955	-0.018*	-0.034*	0.027*	0.021*	0.022*	0.030*
1956	-0.018*	-0.034*	0.027*	0.021*	0.022*	0.030*
1957	-0.018*	-0.034*	0.027*	0.021*	0.022*	0.030*
1958	-0.018*	-0.034*	0.027*	0.021*	0.022*	0.031*
1959	-0.018*	-0.034*	0.028*	0.021*	0.022*	0.031*
1960	-0.018*	-0.034*	0.028*	0.021*	0.022*	0.031*
1961	-0.018*	-0.034*	0.028*	0.021*	0.022*	0.031*
1962	-0.019*	-0.034*	0.027*	0.020*	0.022*	0.031*
1963	-0.019*	-0.034*	0.027*	0.020*	0.022*	0.031*
1964	-0.019*	-0.034*	0.027*	0.020*	0.022*	0.031*
1965	-0.019*	-0.034*	0.027*	0.020*	0.022*	0.031*
1966	-0.019*	-0.034*	0.027*	0.020*	0.022*	0.031*
1967	-0.019*	-0.033*	0.026*	0.020*	0.022*	0.031*
1968	-0.019*	-0.033*	0.026*	0.020*	0.022*	0.031*
1969	-0.019*	-0.033*	0.026*	0.019*	0.022*	0.031*
1970	-0.019*	-0.033*	0.026*	0.019*	0.022*	0.031*
1971	-0.019*	-0.033*	0.025*	0.019*	0.022*	0.031*
1972	-0.019*	-0.033*	0.025*	0.019*	0.022*	0.031*
1973	-0.019*	-0.033*	0.024*	0.019*	0.022*	0.031*
1974	-0.019*	-0.033*	0.023*	0.019	0.022*	0.031*
1975	-0.019*	-0.033*	0.023*	0.019	0.022*	0.031*
1976	-0.019*	-0.033*	0.021*	0.019	0.022*	0.031*
1977	-0.019*	-0.033*	0.021*	0.019	0.022*	0.031*
1978	-0.018*	-0.033*	0.020*	0.019	0.022*	0.031*
1979	-0.018*	-0.033*	0.019	0.019	0.022*	0.031*
1980	-0.018*	-0.033*	0.018	0.019	0.022*	0.031*
1981	-0.018*	-0.033*	0.016	0.019	0.022*	0.031*
1982	-0.018*	-0.033*	0.013	0.019	0.022*	0.031*
1983	-0.018*	-0.034*	0.013	0.019	0.022*	0.031*
1984	-0.018*	-0.034*	0.013	0.019	0.022*	0.031*
1985	-0.018*	-0.034*	0.013	0.019	0.022*	0.031*
1986	-0.018*	-0.034*	0.013	0.019	0.022*	0.031*

* Indicates coefficient is significant at $P \leq 0.05$.

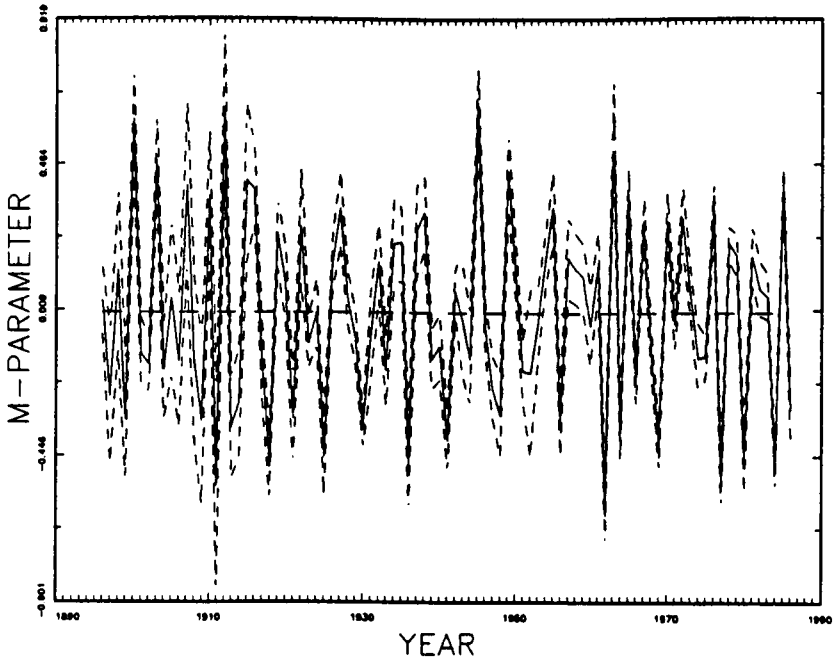


Figure A64. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 4.

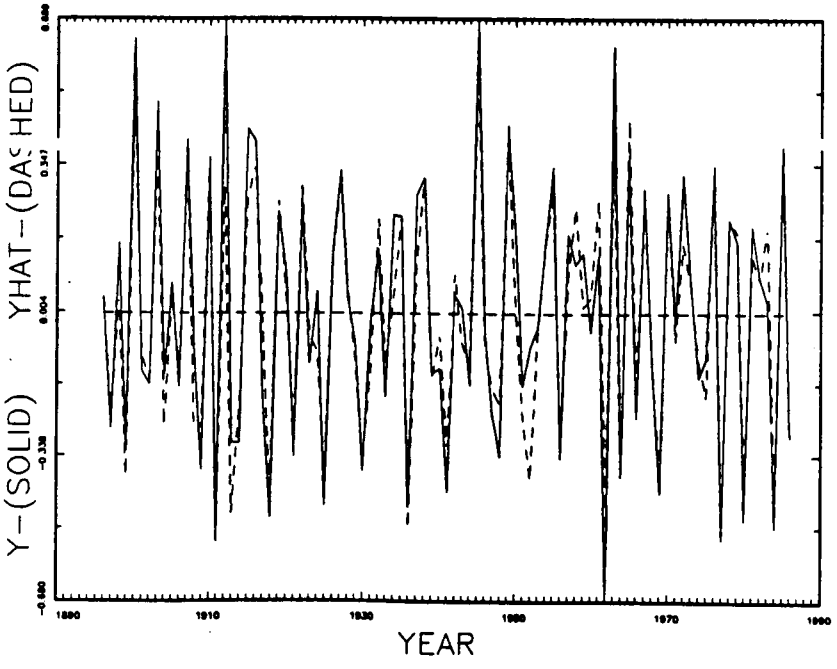
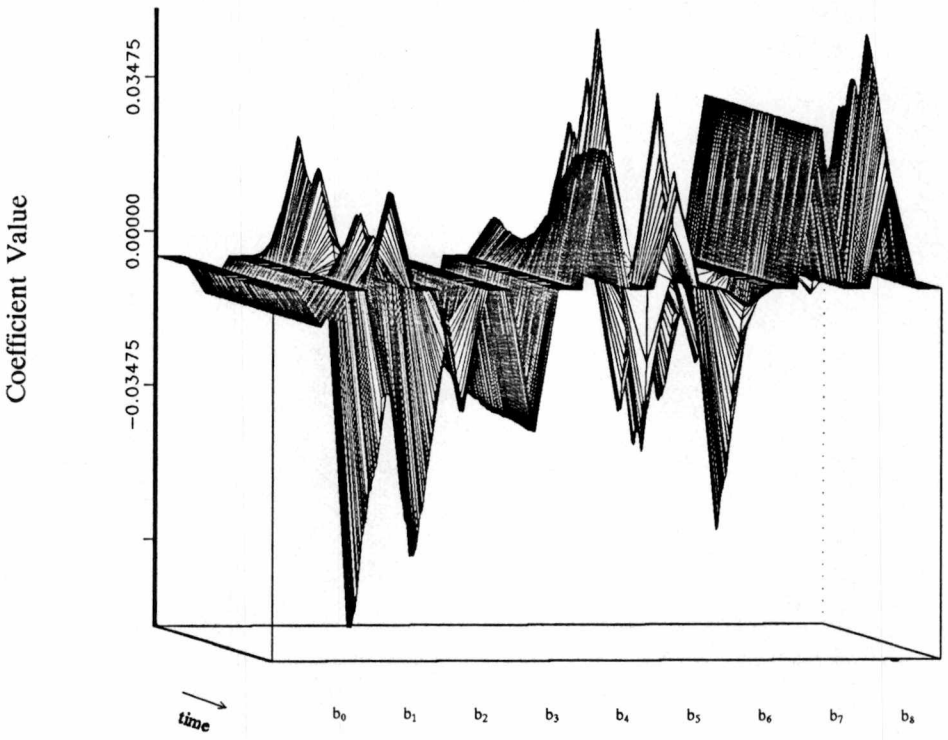


Figure A65. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 4.



Where:

b_0 = the intercept (non-varying)
b_1 = March temperature
b_2 = June temperature
b_3 = August temperature
b_4 = past May temperature
b_5 = past December temperature
b_6 = February rain
b_7 = June rain
b_8 = past December rain

Figure A66. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 4.

Table A22. Climate parameter estimates for Wayne County white oak, cluster 4.

YEAR	March temp. b_1	June temp. b_2	August temp. b_3	Past May temp. b_4	Past December temp. b_5	February rain b_6	June rain b_7	Past December rain b_8
1896	0.013*	-0.066*	-0.026*	0.003	0.022	-0.034	0.036*	0.002
1897	0.013*	-0.066*	-0.026*	0.003	0.022	-0.034	0.036*	0.002
1898	0.013*	-0.065*	-0.026*	0.004	0.022	-0.034	0.035*	0.002
1899	0.013*	-0.065*	-0.026*	0.004	0.022	-0.034	0.035*	0.002
1900	0.013*	-0.064*	-0.026*	0.004	0.022	-0.034	0.035*	0.002
1901	0.013*	-0.064*	-0.026*	0.004	0.022	-0.034	0.035*	0.002
1902	0.013*	-0.064*	-0.026*	0.004	0.022	-0.034	0.035*	0.002
1903	0.013*	-0.063*	-0.026*	0.004	0.021	-0.034	0.035*	0.002
1904	0.013*	-0.063*	-0.026*	0.004	0.021	-0.034	0.035*	0.002
1905	0.013*	-0.062*	-0.026*	0.004	0.021	-0.033	0.034*	0.002
1906	0.013*	-0.062*	-0.026*	0.004	0.021	-0.033	0.033*	0.002
1907	0.013*	-0.061*	-0.026*	0.004	0.020	-0.032	0.033*	0.003
1908	0.013*	-0.060*	-0.026*	0.003	0.020	-0.031	0.032*	0.003
1909	0.013*	-0.059*	-0.026*	0.003	0.020	-0.030	0.031*	0.003
1910	0.014*	-0.059*	-0.026*	0.003	0.020	-0.029	0.031*	0.003
1911	0.014*	-0.057*	-0.026*	0.004	0.021	-0.027	0.030*	0.004
1912	0.014*	-0.055*	-0.026*	0.003	0.020	-0.026	0.029*	0.004
1913	0.014*	-0.055*	-0.026*	0.003	0.021	-0.025	0.029*	0.004
1914	0.014*	-0.055*	-0.027*	0.003	0.021	-0.025	0.029*	0.004
1915	0.014*	-0.054*	-0.027*	0.004	0.023*	-0.024	0.028*	0.005
1916	0.014*	-0.053*	-0.027*	0.003	0.023*	-0.024	0.028*	0.005
1917	0.014*	-0.053*	-0.027*	0.003	0.023*	-0.024	0.028*	0.005
1918	0.014*	-0.052*	-0.027*	0.003	0.022*	-0.023	0.028*	0.005
1919	0.014*	-0.052*	-0.027*	0.003	0.023*	-0.023	0.028*	0.005
1920	0.014*	-0.051*	-0.027*	0.003	0.023*	-0.023	0.028*	0.005
1921	0.014*	-0.050*	-0.027*	0.004	0.024*	-0.022	0.027*	0.005
1922	0.014*	-0.048*	-0.027*	0.004	0.025*	-0.021	0.027*	0.004
1923	0.014*	-0.048*	-0.027*	0.004	0.025*	-0.021	0.027*	0.005
1924	0.014*	-0.048*	-0.027*	0.004	0.025*	-0.021	0.027*	0.005
1925	0.014*	-0.048*	-0.028*	0.004	0.024*	-0.020	0.026*	0.005
1926	0.014*	-0.047*	-0.028*	0.004	0.024*	-0.019	0.026*	0.005
1927	0.014*	-0.047*	-0.028*	0.004	0.023*	-0.019	0.026*	0.006
1928	0.014*	-0.047*	-0.028*	0.004	0.022*	-0.018	0.026*	0.006
1929	0.014*	-0.047*	-0.028*	0.005	0.021*	-0.018	0.026*	0.006
1930	0.014*	-0.047*	-0.028*	0.005	0.021*	-0.018	0.026*	0.006
1931	0.014*	-0.048*	-0.028*	0.005	0.019*	-0.018	0.026*	0.007
1932	0.014*	-0.048*	-0.028*	0.006	0.018*	-0.018	0.026*	0.007
1933	0.014*	-0.048*	-0.028*	0.006	0.017*	-0.018	0.026*	0.008
1934	0.014*	-0.048*	-0.028*	0.006	0.014	-0.017	0.025*	0.009
1935	0.014*	-0.048*	-0.028*	0.007	0.012	-0.017	0.025*	0.009
1936	0.014*	-0.049*	-0.028*	0.007	0.011	-0.017	0.025*	0.010
1937	0.014*	-0.050*	-0.028*	0.008	0.009	-0.016	0.025*	0.010
1938	0.014*	-0.050*	-0.028*	0.008	0.007	-0.016	0.025*	0.011
1939	0.014*	-0.051*	-0.028*	0.008	0.007	-0.016	0.025*	0.011
1940	0.014*	-0.052*	-0.028*	0.009	0.005	-0.017	0.024*	0.012
1941	0.014*	-0.052*	-0.028*	0.009	0.005	-0.018	0.024*	0.012
1942	0.014*	-0.052*	-0.028*	0.009	0.005	-0.020	0.024*	0.012
1943	0.014*	-0.053*	-0.028*	0.010	0.004	-0.024*	0.024*	0.013
1944	0.014*	-0.054*	-0.028*	0.010	0.004	-0.026*	0.023*	0.014
1945	0.014*	-0.054*	-0.028*	0.010	0.004	-0.027*	0.023*	0.014
1946	0.014*	-0.054*	-0.028*	0.011	0.004	-0.027*	0.023*	0.014
1947	0.014*	-0.054*	-0.028*	0.011	0.004	-0.028*	0.023*	0.015
1948	0.014*	-0.054*	-0.028*	0.012	0.003	-0.028*	0.022*	0.015
1949	0.014*	-0.054*	-0.028*	0.012	0.003	-0.028*	0.022*	0.016

Table A22. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
1950	0.014*	-0.054*	-0.028*	0.012	0.003	-0.029*	0.022*	0.016
1951	0.014*	-0.053*	-0.028*	0.012	0.002	-0.029*	0.022*	0.016
1952	0.014*	-0.052*	-0.028*	0.014*	-0.001	-0.034*	0.021*	0.018*
1953	0.014*	-0.051*	-0.028*	0.015*	-0.002	-0.035*	0.021*	0.018*
1954	0.014*	-0.051*	-0.028*	0.015*	-0.002	-0.035*	0.021*	0.018*
1955	0.014*	-0.050*	-0.028*	0.015*	-0.002	-0.036*	0.021*	0.019*
1956	0.014*	-0.049*	-0.028*	0.016*	-0.003	-0.036*	0.021*	0.019*
1957	0.014*	-0.048*	-0.028*	0.016*	-0.003	-0.037*	0.021*	0.019*
1958	0.014*	-0.046*	-0.028*	0.017*	-0.004	-0.038*	0.021*	0.019*
1959	0.014*	-0.045*	-0.029*	0.017*	-0.002	-0.038*	0.021*	0.019*
1960	0.014*	-0.043*	-0.029*	0.018*	-0.000	-0.040*	0.020*	0.020*
1961	0.014*	-0.042*	-0.029*	0.018*	0.001	-0.041*	0.020*	0.020*
1962	0.014*	-0.041*	-0.029*	0.018*	0.003	-0.041*	0.020*	0.021*
1963	0.014*	-0.038*	-0.029*	0.019*	0.008	-0.040*	0.020*	0.022*
1964	0.013*	-0.037*	-0.029*	0.019*	0.011	-0.039*	0.020*	0.022*
1965	0.013*	-0.035*	-0.029*	0.019*	0.012	-0.039*	0.020	0.023*
1966	0.013*	-0.034*	-0.029*	0.019*	0.013*	-0.039*	0.020	0.023*
1967	0.013*	-0.034*	-0.029*	0.019*	0.014*	-0.038*	0.020	0.023*
1968	0.013*	-0.033*	-0.029*	0.019*	0.016*	-0.038*	0.020	0.023*
1969	0.013*	-0.032*	-0.029*	0.019*	0.016*	-0.037*	0.019	0.023*
1970	0.013*	-0.030*	-0.029*	0.020*	0.017*	-0.036*	0.019	0.022*
1971	0.013*	-0.030*	-0.029*	0.020*	0.017*	-0.035*	0.019	0.022*
1972	0.013*	-0.028*	-0.029*	0.021*	0.017*	-0.034*	0.019	0.022*
1973	0.013*	-0.027*	-0.029*	0.021*	0.017*	-0.034*	0.018	0.022*
1974	0.013*	-0.027*	-0.029*	0.021*	0.017*	-0.032*	0.018	0.022*
1975	0.013*	-0.027*	-0.029*	0.021*	0.017*	-0.032*	0.018	0.022*
1976	0.013*	-0.028*	-0.029*	0.021*	0.018*	-0.031*	0.018	0.022*
1977	0.013*	-0.028*	-0.029*	0.021*	0.018*	-0.031*	0.018	0.021*
1978	0.013*	-0.028*	-0.029*	0.021*	0.018*	-0.031*	0.018	0.021*
1979	0.013*	-0.029*	-0.029*	0.021*	0.018*	-0.031*	0.018	0.021*
1980	0.013*	-0.029*	-0.029*	0.021*	0.018*	-0.030*	0.018	0.020*
1981	0.013*	-0.030*	-0.029*	0.021*	0.018*	-0.029*	0.018	0.020*
1982	0.013*	-0.031*	-0.029*	0.021*	0.018*	-0.029	0.018	0.020*
1983	0.013*	-0.031*	-0.029*	0.021*	0.019*	-0.029	0.018	0.020*
1984	0.013*	-0.031*	-0.029*	0.021*	0.019*	-0.029	0.018	0.020*
1985	0.013*	-0.031*	-0.029*	0.021*	0.019*	-0.029	0.018	0.020*
1986	0.013*	-0.031*	-0.029*	0.021*	0.019*	-0.029	0.018	0.020*

* Indicates coefficient is significant at $P \leq 0.05$.

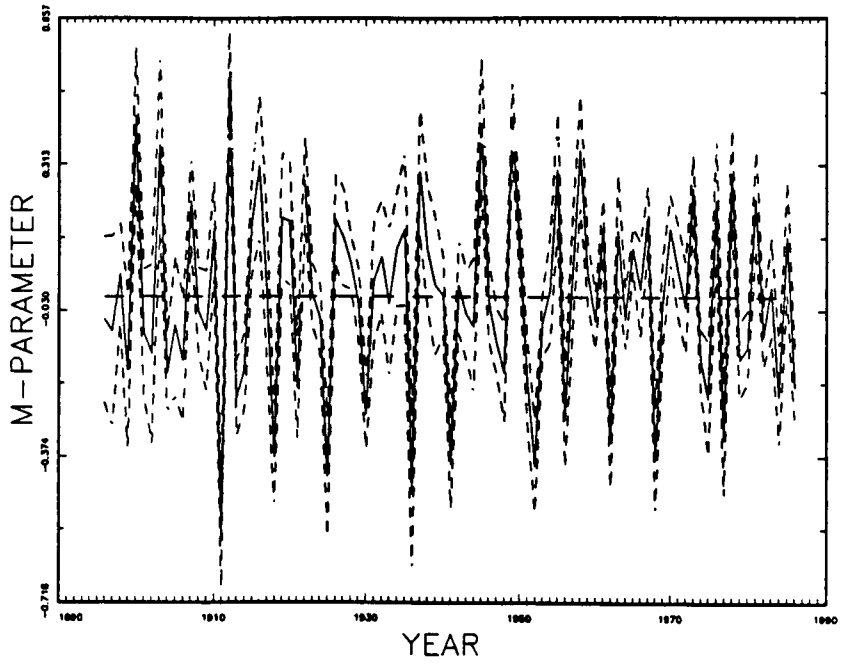


Figure A67. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 5.

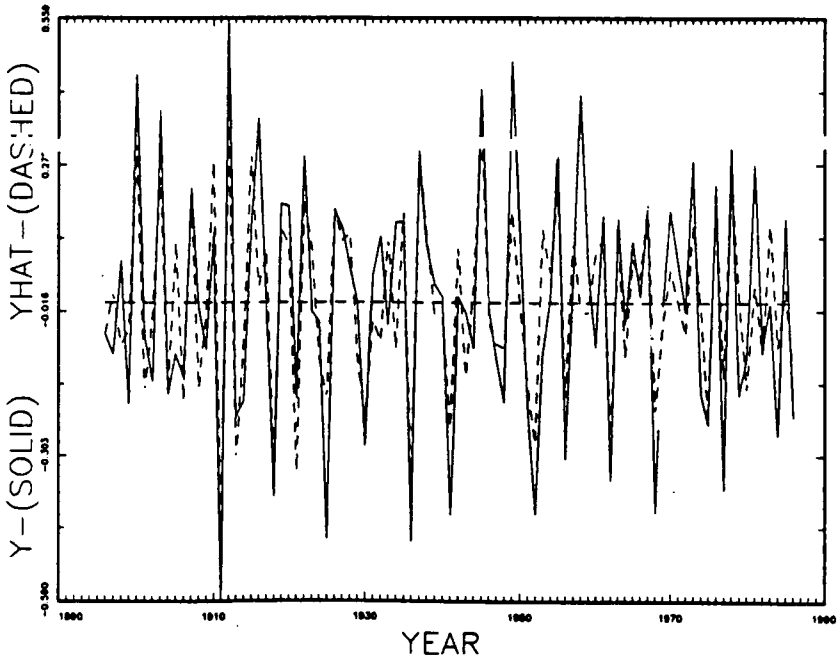
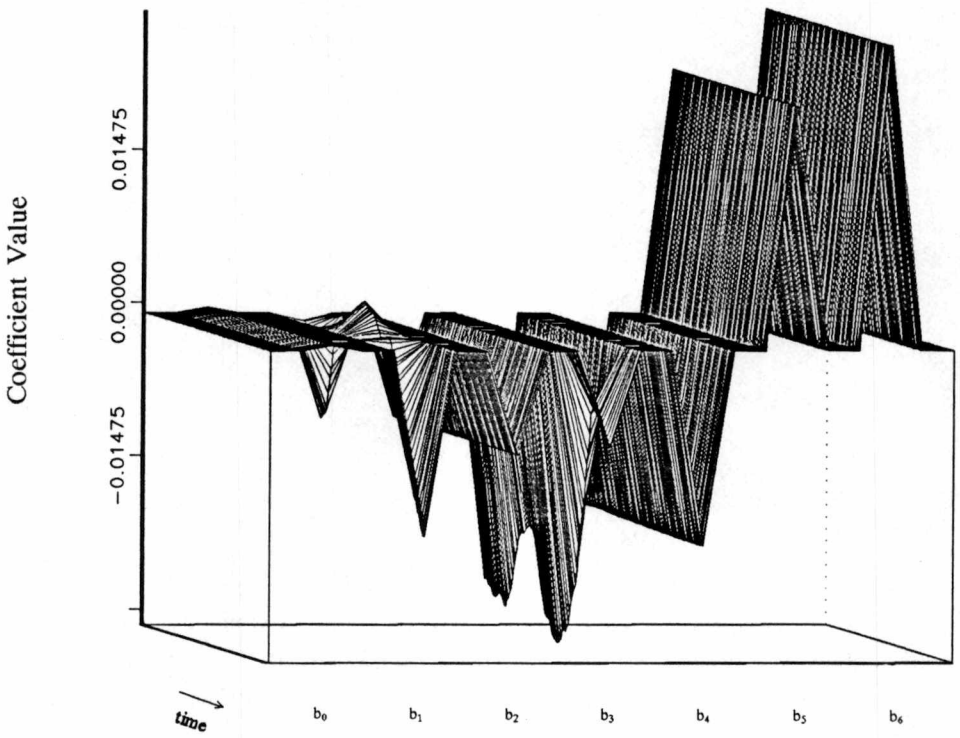


Figure A68. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 5.



Where:

b_0 = the intercept (non-varying)
b_1 = February temperature
b_2 = May temperature
b_3 = June temperature
b_4 = August temperature
b_5 = May rain
b_6 = June rain

Figure A69. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 5.

Table A23. Climate parameter estimates for Wayne County white oak, cluster 5.

YEAR	February temp. b_1	May temp. b_2	June temp. b_3	August temp. b_4	May rain b_5	June rain b_6
1897	-0.017*	-0.034*	0.025	0.031*	0.019	0.028*
1898	-0.017*	-0.034*	0.024	0.031*	0.019	0.028*
1899	-0.018*	-0.034*	0.024	0.031*	0.019	0.028*
1900	-0.018*	-0.034*	0.024	0.031*	0.019	0.028*
1901	-0.018*	-0.034*	0.024	0.031*	0.019	0.028*
1902	-0.018*	-0.034*	0.024	0.031*	0.019	0.028*
1903	-0.018*	-0.034*	0.024	0.031*	0.019	0.028*
1904	-0.018*	-0.034*	0.024	0.030*	0.019	0.028*
1905	-0.018*	-0.034*	0.024	0.030*	0.019	0.028*
1906	-0.018*	-0.034*	0.023	0.030*	0.019	0.028*
1907	-0.017*	-0.034*	0.022	0.030*	0.019	0.029*
1908	-0.017*	-0.034*	0.022	0.030*	0.019*	0.029*
1909	-0.017*	-0.034*	0.022	0.030*	0.019*	0.029*
1910	-0.018*	-0.034*	0.022	0.030*	0.019*	0.029*
1911	-0.018*	-0.034*	0.022	0.030*	0.019*	0.029*
1912	-0.018*	-0.034*	0.021	0.030*	0.019*	0.029*
1913	-0.018*	-0.034*	0.021	0.030*	0.019*	0.029*
1914	-0.018*	-0.034*	0.021	0.030*	0.019*	0.029*
1915	-0.018*	-0.034*	0.020	0.030*	0.019*	0.029*
1916	-0.018*	-0.034*	0.020	0.029*	0.019*	0.029*
1917	-0.018*	-0.034*	0.020	0.029*	0.019*	0.029*
1918	-0.018*	-0.034*	0.019	0.029*	0.019*	0.029*
1919	-0.018*	-0.034*	0.018	0.029*	0.020*	0.030*
1920	-0.018*	-0.034*	0.018	0.028*	0.020*	0.030*
1921	-0.018*	-0.034*	0.017	0.028*	0.020*	0.030*
1922	-0.018*	-0.034*	0.017	0.028*	0.020*	0.030*
1923	-0.018*	-0.034*	0.016	0.028*	0.020*	0.030*
1924	-0.018*	-0.034*	0.016	0.028*	0.020*	0.030*
1925	-0.018*	-0.034*	0.016	0.027*	0.020*	0.030*
1926	-0.018*	-0.034*	0.015	0.027*	0.020*	0.030*
1927	-0.018*	-0.034*	0.015	0.027*	0.020*	0.030*
1928	-0.018*	-0.034*	0.015	0.027*	0.020*	0.030*
1929	-0.018*	-0.034*	0.014	0.027*	0.020*	0.030*
1930	-0.018*	-0.034*	0.014	0.027*	0.020*	0.030*
1931	-0.018*	-0.034*	0.013	0.027*	0.020*	0.030*
1932	-0.018*	-0.034*	0.013	0.027*	0.020*	0.030*
1933	-0.018*	-0.034*	0.013	0.027*	0.021*	0.030*
1934	-0.018*	-0.034*	0.014	0.026*	0.021*	0.030*
1935	-0.018*	-0.034*	0.015	0.026*	0.021*	0.030*
1936	-0.018*	-0.034*	0.017	0.026*	0.021*	0.030*
1937	-0.018*	-0.034*	0.018	0.026*	0.021*	0.030*
1938	-0.018*	-0.034*	0.019	0.025*	0.021*	0.030*
1939	-0.018*	-0.034*	0.020	0.025*	0.021*	0.030*
1940	-0.018*	-0.034*	0.021	0.025*	0.021*	0.030*
1941	-0.018*	-0.034*	0.022*	0.025*	0.021*	0.030*
1942	-0.018*	-0.034*	0.023*	0.024*	0.021*	0.030*
1943	-0.018*	-0.034*	0.023*	0.024*	0.021*	0.030*
1944	-0.018*	-0.034*	0.024*	0.024*	0.022*	0.030*
1945	-0.018*	-0.034*	0.025*	0.023*	0.022*	0.030*
1946	-0.018*	-0.034*	0.025*	0.023*	0.022*	0.030*
1947	-0.018*	-0.034*	0.026*	0.023*	0.022*	0.030*
1948	-0.018*	-0.034*	0.026*	0.023*	0.022*	0.030*
1949	-0.018*	-0.034*	0.027*	0.023*	0.022*	0.030*
1950	-0.018*	-0.034*	0.027*	0.022*	0.022*	0.030*
1951	-0.018*	-0.034*	0.027*	0.022*	0.022*	0.030*
1952	-0.018*	-0.034*	0.027*	0.022*	0.022*	0.030*

Table A23. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1953	-0.018*	-0.034*	0.027*	0.022*	0.022*	0.030*
1954	-0.018*	-0.034*	0.027*	0.021*	0.022*	0.030*
1955	-0.018*	-0.034*	0.027*	0.021*	0.022*	0.030*
1956	-0.018*	-0.034*	0.027*	0.021*	0.022*	0.030*
1957	-0.018*	-0.034*	0.027*	0.021*	0.022*	0.030*
1958	-0.018*	-0.034*	0.027*	0.021*	0.022*	0.031*
1959	-0.018*	-0.034*	0.028*	0.021*	0.022*	0.031*
1960	-0.018*	-0.034*	0.028*	0.021*	0.022*	0.031*
1961	-0.018*	-0.034*	0.028*	0.021*	0.022*	0.031*
1962	-0.019*	-0.034*	0.027*	0.020*	0.022*	0.031*
1963	-0.019*	-0.034*	0.027*	0.020*	0.022*	0.031*
1964	-0.019*	-0.034*	0.027*	0.020*	0.022*	0.031*
1965	-0.019*	-0.034*	0.027*	0.020*	0.022*	0.031*
1966	-0.019*	-0.034*	0.027*	0.020*	0.022*	0.031*
1967	-0.019*	-0.033*	0.026*	0.020*	0.022*	0.031*
1968	-0.019*	-0.033*	0.026*	0.020*	0.022*	0.031*
1969	-0.019*	-0.033*	0.026*	0.019*	0.022*	0.031*
1970	-0.019*	-0.033*	0.026*	0.019*	0.022*	0.031*
1971	-0.019*	-0.033*	0.025*	0.019*	0.022*	0.031*
1972	-0.019*	-0.033*	0.025*	0.019*	0.022*	0.031*
1973	-0.019*	-0.033*	0.024*	0.019*	0.022*	0.031*
1974	-0.019*	-0.033*	0.023*	0.019	0.022*	0.031*
1975	-0.019*	-0.033*	0.023*	0.019	0.022*	0.031*
1976	-0.019*	-0.033*	0.021*	0.019	0.022*	0.031*
1977	-0.019*	-0.033*	0.021*	0.019	0.022*	0.031*
1978	-0.018*	-0.033*	0.020*	0.019	0.022*	0.031*
1979	-0.018*	-0.033*	0.019	0.019	0.022*	0.031*
1980	-0.018*	-0.033*	0.018	0.019	0.022*	0.031*
1981	-0.018*	-0.033*	0.016	0.019	0.022*	0.031*
1982	-0.018*	-0.033*	0.013	0.019	0.022*	0.031*
1983	-0.018*	-0.034*	0.013	0.019	0.022*	0.031*
1984	-0.018*	-0.034*	0.013	0.019	0.022*	0.031*
1985	-0.018*	-0.034*	0.013	0.019	0.022*	0.031*
1986	-0.018*	-0.034*	0.013	0.019	0.022*	0.031*

* Indicates coefficient is significant at $P \leq 0.05$.

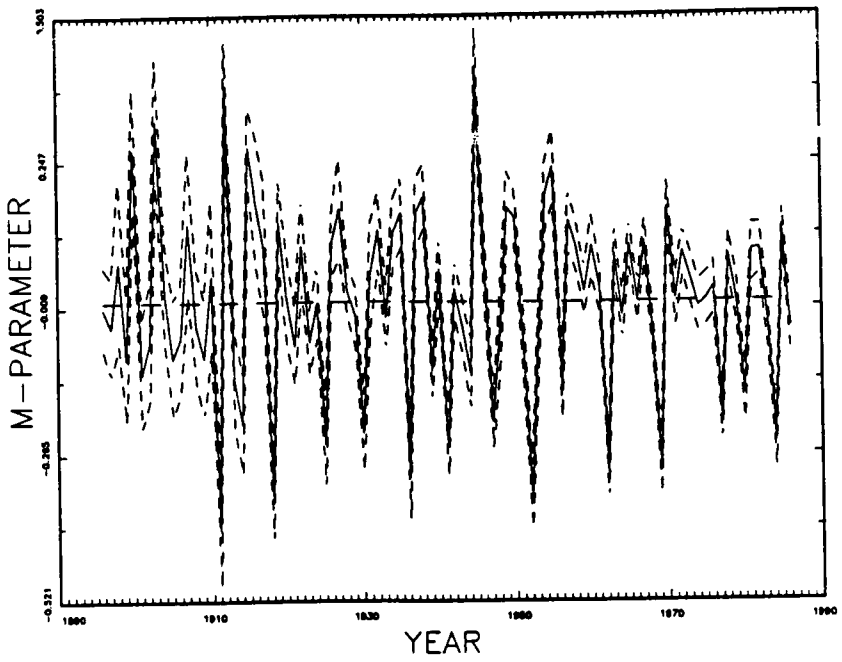


Figure A70. Graph of M-parameter and associated 95% confidence interval over time, Wayne County white oak, cluster 6.

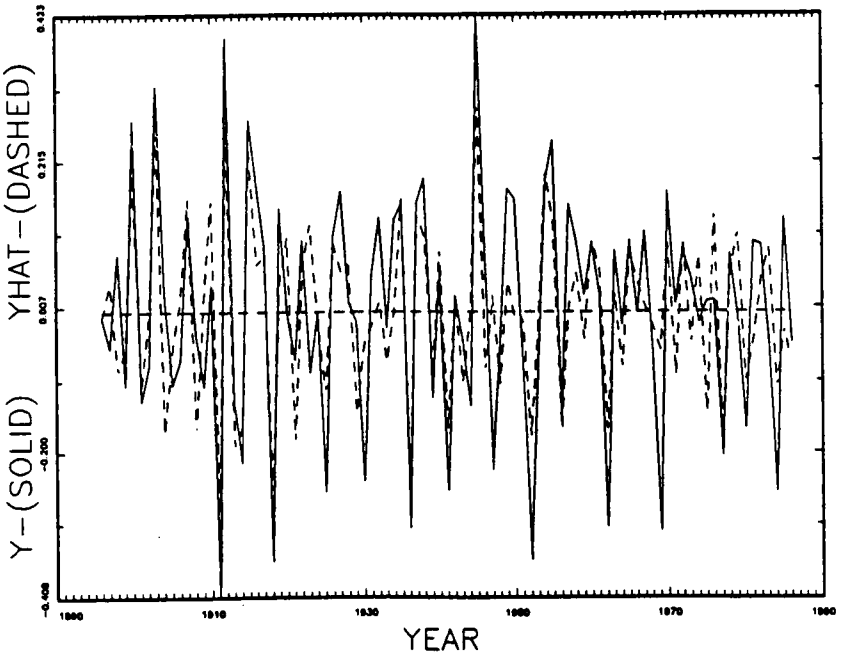
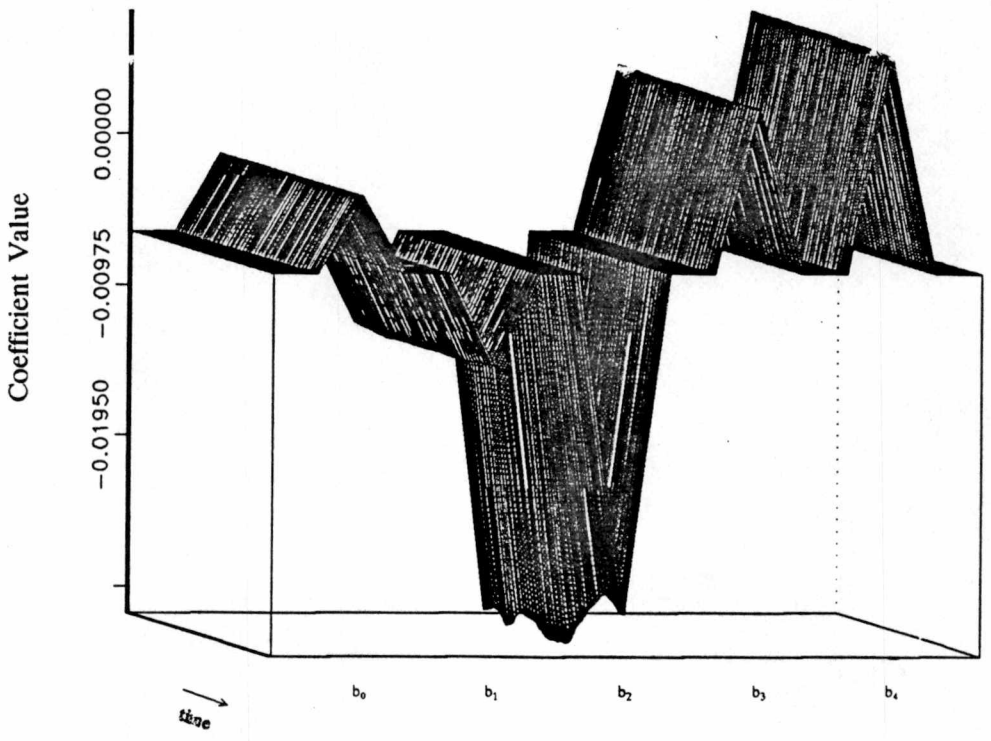


Figure A71. Graph of predicted and actual standardized growth, Wayne County white oak, cluster 6.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = June rain
b_4 = past December rain

Figure A72. Three dimensional graph of changes in parameter coefficients over time, Wayne County white oak, cluster 6.

Table A24. Climate parameter estimates for Wayne County white oak, cluster 6.

YEAR	May temperature b_1	June temperature b_2	June rain b_3	Past December rain b_4
1897	-0.012*	-0.031*	0.005	0.008
1898	-0.012*	-0.031*	0.005	0.008
1899	-0.012*	-0.031*	0.004	0.008
1900	-0.012*	-0.031*	0.004	0.008
1901	-0.012*	-0.031*	0.004	0.008
1902	-0.012*	-0.030*	0.004	0.008
1903	-0.012*	-0.030*	0.004	0.008*
1904	-0.012*	-0.030*	0.004	0.008*
1905	-0.012*	-0.031*	0.004	0.008*
1906	-0.012*	-0.031*	0.004	0.008*
1907	-0.012*	-0.031*	0.004	0.008*
1908	-0.012*	-0.031*	0.004	0.008*
1909	-0.012*	-0.031*	0.004	0.008*
1910	-0.012*	-0.031*	0.004	0.008*
1911	-0.012*	-0.031*	0.004	0.008*
1912	-0.012*	-0.031*	0.004	0.008*
1913	-0.012*	-0.031*	0.004	0.008*
1914	-0.013*	-0.031*	0.004	0.008*
1915	-0.013*	-0.031*	0.004	0.008*
1916	-0.013*	-0.031*	0.004	0.008*
1917	-0.013*	-0.031*	0.004	0.008*
1918	-0.013*	-0.030*	0.004	0.008*
1919	-0.013*	-0.030*	0.004	0.008*
1920	-0.013*	-0.030*	0.004	0.008*
1921	-0.013*	-0.030*	0.004	0.008*
1922	-0.012*	-0.030*	0.004	0.008*
1923	-0.012*	-0.030*	0.004	0.008*
1924	-0.012*	-0.030*	0.004	0.008*
1925	-0.012*	-0.030*	0.004	0.008*
1926	-0.012*	-0.030*	0.004	0.008*
1927	-0.012*	-0.030*	0.004	0.008*
1928	-0.012*	-0.030*	0.004	0.008*
1929	-0.012*	-0.030*	0.004	0.008*
1930	-0.012*	-0.031*	0.004	0.008*
1931	-0.012*	-0.031*	0.004	0.008*
1932	-0.012*	-0.031*	0.004	0.008*
1933	-0.012*	-0.031*	0.004	0.008*
1934	-0.012*	-0.031*	0.004	0.008*
1935	-0.012*	-0.031*	0.004	0.008*
1936	-0.012*	-0.031*	0.004	0.008*
1937	-0.012*	-0.031*	0.004	0.008*
1938	-0.012*	-0.031*	0.004	0.008*
1939	-0.012*	-0.031*	0.004	0.008*
1940	-0.012*	-0.031*	0.004	0.008*
1941	-0.012*	-0.031*	0.004	0.008*
1942	-0.012*	-0.031*	0.004	0.008*
1943	-0.012*	-0.031*	0.004	0.008*
1944	-0.012*	-0.031*	0.004	0.008*
1945	-0.012*	-0.031*	0.004	0.008*
1946	-0.012*	-0.031*	0.004	0.008*
1947	-0.012*	-0.031*	0.004	0.008*
1948	-0.012*	-0.031*	0.004	0.008*
1949	-0.012*	-0.031*	0.004	0.008*
1950	-0.012*	-0.031*	0.004	0.008*

Table A24. Continued.

YEAR	b_1	b_2	b_3	b_4
1951	-0.012*	-0.031*	0.004	0.008*
1952	-0.012*	-0.031*	0.004	0.008*
1953	-0.012*	-0.031*	0.004	0.008*
1954	-0.012*	-0.031*	0.004	0.008*
1955	-0.012*	-0.030*	0.004	0.008*
1956	-0.012*	-0.030*	0.004	0.008*
1957	-0.012*	-0.030*	0.004	0.008*
1958	-0.013*	-0.030*	0.004	0.008*
1959	-0.013*	-0.030*	0.004	0.008*
1960	-0.013*	-0.029*	0.004	0.008*
1961	-0.013*	-0.029*	0.004	0.008*
1962	-0.013*	-0.029*	0.004	0.008*
1963	-0.013*	-0.029*	0.004	0.008*
1964	-0.012*	-0.029*	0.004	0.008*
1965	-0.012*	-0.028*	0.004	0.008*
1966	-0.012*	-0.028*	0.004	0.008*
1967	-0.012*	-0.028*	0.004	0.008*
1968	-0.012*	-0.028*	0.004	0.008*
1969	-0.012*	-0.028*	0.004	0.008*
1970	-0.012*	-0.028*	0.004	0.008*
1971	-0.012*	-0.028*	0.004	0.008*
1972	-0.012*	-0.027*	0.004	0.008*
1973	-0.012*	-0.027*	0.004	0.008*
1974	-0.012*	-0.027*	0.004	0.008*
1975	-0.012*	-0.027*	0.004	0.008*
1976	-0.012*	-0.028*	0.004	0.008*
1977	-0.012*	-0.028*	0.004	0.008*
1978	-0.012*	-0.028*	0.004	0.008*
1979	-0.012*	-0.028*	0.004	0.008*
1980	-0.012*	-0.028*	0.004	0.008*
1981	-0.012*	-0.028*	0.004	0.008*
1982	-0.012*	-0.028*	0.004	0.008*
1983	-0.012*	-0.028*	0.004	0.008*
1984	-0.012*	-0.028*	0.004	0.008*
1985	-0.012*	-0.028*	0.004	0.008*
1986	-0.012*	-0.028*	0.004	0.008*

* Indicates coefficient is significant at $P \leq 0.05$.

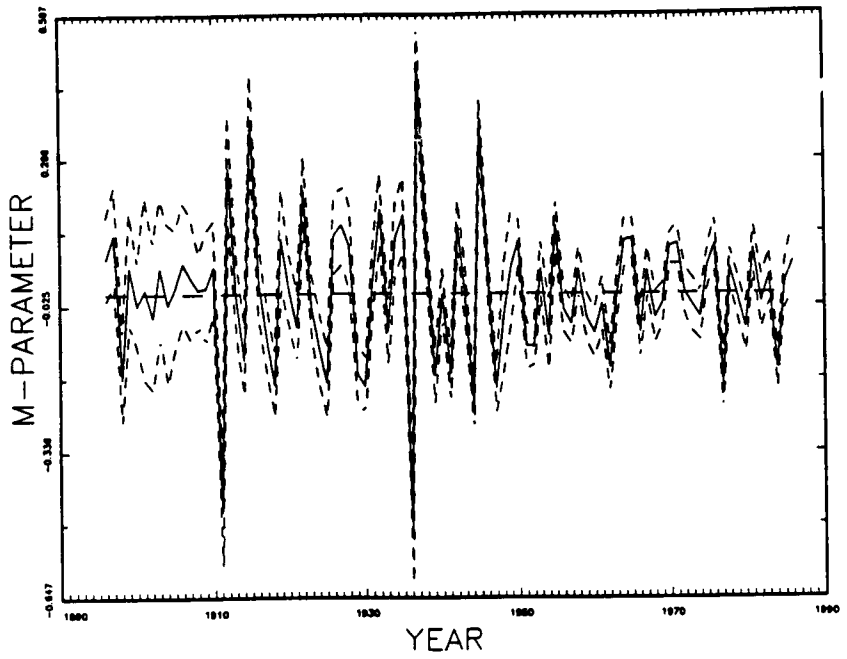


Figure A73. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 1.

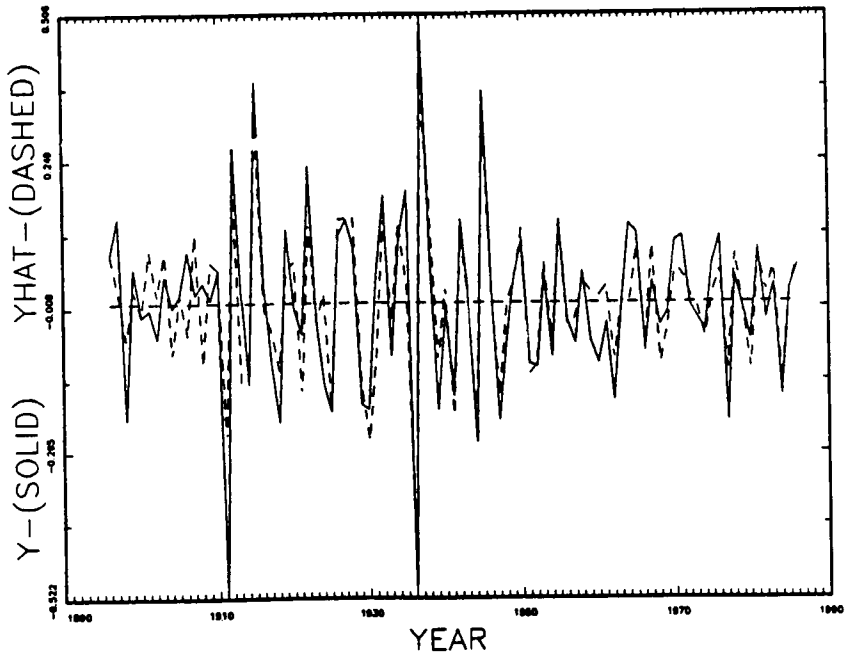
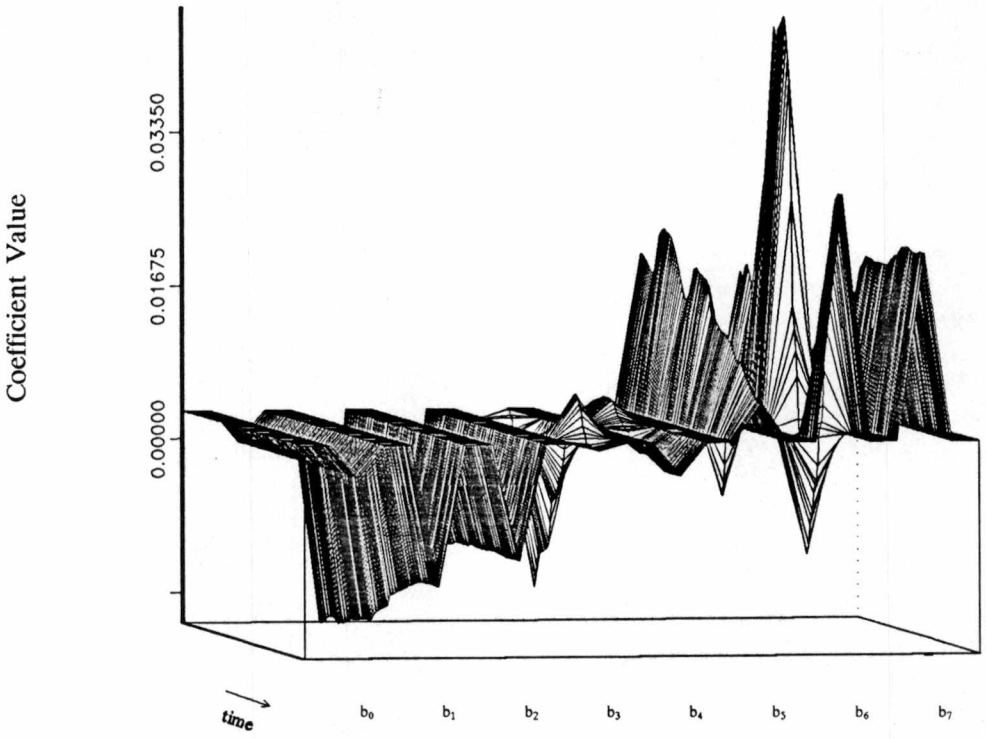


Figure A74. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = August temperature
b_3 = September temperature
b_4 = past June temperature
b_5 = May rain
b_6 = June rain
b_7 = past August rain

Figure A75. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 1.

Table A25. Climate parameter estimates for Emory River chestnut oak, cluster 1.

YEAR	June temp. b_1	August temp. b_2	September temp. b_3	Past June temp. b_4	May rain b_5	June rain b_6	Past August rain b_7
1897	-0.020	-0.012	-0.007	-0.002	0.020	-0.005	0.006
1898	-0.020	-0.012	-0.006	-0.002	0.020	-0.003	0.006
1899	-0.020	-0.012	-0.005	-0.001	0.019	0.000	0.006
1900	-0.020	-0.012	-0.005	-0.001	0.019	0.001	0.006
1901	-0.019	-0.012	-0.003	-0.001	0.019	-0.000	0.007
1902	-0.019*	-0.012	-0.003	-0.001	0.019	-0.001	0.008
1903	-0.019*	-0.011	-0.002	-0.000	0.019	-0.001	0.009
1904	-0.019*	-0.011	-0.001	0.000	0.018	0.000	0.010
1905	-0.019*	-0.011	-0.001	0.000	0.018	0.001	0.010
1906	-0.019*	-0.011	-0.001	0.001	0.018	0.005	0.010
1907	-0.019*	-0.011	-0.002	0.001	0.019	0.009	0.011
1908	-0.019*	-0.011	-0.003	0.001	0.020	0.010	0.011
1909	-0.019*	-0.011	-0.004	0.002	0.021	0.015	0.012
1910	-0.020*	-0.011	-0.004	0.002	0.022	0.018	0.012
1911	-0.020*	-0.011	-0.004	0.002	0.023	0.018	0.012
1912	-0.019*	-0.011	-0.003	0.002	0.023	0.018	0.013
1913	-0.019*	-0.011	-0.001	0.003	0.023	0.018	0.013
1914	-0.019*	-0.011	0.000	0.003	0.023*	0.019	0.013
1915	-0.019*	-0.011	0.001	0.003	0.023*	0.019	0.013
1916	-0.019*	-0.011	0.003	0.004	0.023*	0.019	0.013
1917	-0.019*	-0.011	0.004	0.004	0.023*	0.018	0.013
1918	-0.019*	-0.011	0.004	0.004	0.023*	0.017	0.013
1919	-0.019*	-0.011	0.003	0.004	0.023*	0.016	0.013
1920	-0.019*	-0.011	0.003	0.005	0.022*	0.016	0.013
1921	-0.019*	-0.011	0.002	0.005	0.022*	0.018	0.013
1922	-0.019*	-0.011	0.002	0.005	0.021*	0.018	0.013
1923	-0.019*	-0.011	0.001	0.005	0.020*	0.019	0.013
1924	-0.019*	-0.011	-0.000	0.005	0.020*	0.020	0.013
1925	-0.018*	-0.011	-0.001	0.005	0.019*	0.021	0.013
1926	-0.018*	-0.010	-0.003	0.005	0.018*	0.023	0.014
1927	-0.018*	-0.010	-0.004	0.005	0.018*	0.025	0.014
1928	-0.018*	-0.010	-0.006	0.006	0.017*	0.029*	0.014
1929	-0.018*	-0.010	-0.007	0.006	0.016*	0.029*	0.015
1930	-0.018*	-0.010	-0.008	0.006	0.016*	0.030*	0.015
1931	-0.018*	-0.010	-0.010	0.006	0.017*	0.034*	0.015
1932	-0.018*	-0.010	-0.011	0.006	0.017*	0.036*	0.016*
1933	-0.018*	-0.010	-0.012	0.006	0.018*	0.036*	0.016*
1934	-0.018*	-0.010	-0.013	0.006	0.018*	0.037*	0.016*
1935	-0.018*	-0.010	-0.014	0.005	0.019*	0.041*	0.017*
1936	-0.018*	-0.010	-0.015*	0.005	0.020*	0.046*	0.018*
1937	-0.017*	-0.010	-0.013*	0.005	0.020*	0.045*	0.019*
1938	-0.017*	-0.010	-0.012*	0.004	0.020*	0.045*	0.020*
1939	-0.017*	-0.010	-0.011*	0.004	0.020*	0.046*	0.020*
1940	-0.017*	-0.010	-0.011*	0.004	0.020*	0.046*	0.020*
1941	-0.017*	-0.010	-0.011*	0.004	0.019*	0.047*	0.021*
1942	-0.017*	-0.010	-0.011	0.003	0.019*	0.047*	0.021*
1943	-0.016*	-0.010	-0.010	0.003	0.019*	0.047*	0.021*
1944	-0.016*	-0.010	-0.010	0.003	0.019*	0.047*	0.021*
1945	-0.016*	-0.010	-0.010	0.003	0.019*	0.045*	0.021*
1946	-0.016*	-0.010	-0.010	0.003	0.019*	0.043*	0.021*
1947	-0.016*	-0.010	-0.009	0.003	0.018*	0.041*	0.021*
1948	-0.015*	-0.009	-0.007	0.002	0.017*	0.028*	0.021*
1949	-0.015*	-0.009	-0.005	0.001	0.015*	0.016	0.021*
1950	-0.015*	-0.009	-0.005	0.001	0.015	0.014	0.021*

Table A25. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7
1951	-0.015*	-0.009	-0.004	0.001	0.015	0.011	0.021*
1952	-0.015*	-0.009	-0.004	0.001	0.015	0.009	0.021*
1953	-0.014*	-0.009	-0.004	0.001	0.015	0.004	0.021*
1954	-0.014*	-0.009	-0.003	0.001	0.014	-0.002	0.021*
1955	-0.014*	-0.009	-0.002	0.001	0.014	-0.006	0.021*
1956	-0.014*	-0.009	-0.002	0.001	0.014	-0.008	0.021*
1957	-0.014*	-0.009	-0.001	0.001	0.014	-0.009	0.021*
1958	-0.014*	-0.009	0.000	0.001	0.014	-0.010	0.021*
1959	-0.014*	-0.009	0.001	0.001	0.014	-0.010	0.021*
1960	-0.014*	-0.009	0.003	0.001	0.014	-0.009	0.021*
1961	-0.014*	-0.009	0.004	0.001	0.013	-0.007	0.022*
1962	-0.013*	-0.009	0.005	0.001	0.013	-0.006	0.022*
1963	-0.013*	-0.009	0.006	0.001	0.013	-0.005	0.022*
1964	-0.013*	-0.009	0.007	0.000	0.012	-0.003	0.022*
1965	-0.013*	-0.009	0.007	0.000	0.012	-0.003	0.022*
1966	-0.013*	-0.009	0.007	0.000	0.012	-0.002	0.022*
1967	-0.013*	-0.009	0.008	0.000	0.011	-0.000	0.023*
1968	-0.013*	-0.009	0.007	-0.000	0.011	0.003	0.023*
1969	-0.013*	-0.009	0.007	-0.000	0.011	0.004	0.023*
1970	-0.013*	-0.009	0.007	-0.000	0.011	0.004	0.023*
1971	-0.012*	-0.009	0.006	-0.000	0.011	0.006	0.023*
1972	-0.012*	-0.009	0.005	-0.000	0.010	0.010	0.024*
1973	-0.012*	-0.009	0.004	-0.000	0.010	0.015	0.024*
1974	-0.012*	-0.010	0.004	-0.001	0.010	0.019	0.024*
1975	-0.012*	-0.010	0.003	-0.001	0.009	0.021*	0.024*
1976	-0.012*	-0.010	0.002	-0.001	0.009	0.024*	0.023*
1977	-0.012*	-0.010	0.002	-0.001	0.009	0.025*	0.023*
1978	-0.012*	-0.010	0.002	-0.001	0.008	0.026*	0.023*
1979	-0.012*	-0.010	0.003	-0.001	0.008	0.027*	0.023*
1980	-0.012*	-0.010	0.002	-0.001	0.008	0.028*	0.023*
1981	-0.012*	-0.010	0.002	-0.001	0.008	0.029*	0.023*
1982	-0.012*	-0.010	0.002	-0.001	0.007	0.030*	0.023*
1983	-0.012*	-0.009	0.002	-0.001	0.007	0.030*	0.023*
1984	-0.012*	-0.009	0.002	-0.001	0.007	0.030*	0.023*
1985	-0.012*	-0.009	0.002	-0.001	0.007	0.030	0.023*
1986	-0.012*	-0.009	0.002	-0.001	0.007	0.030	0.023*

* Indicates coefficient is significant at $P \leq 0.05$.

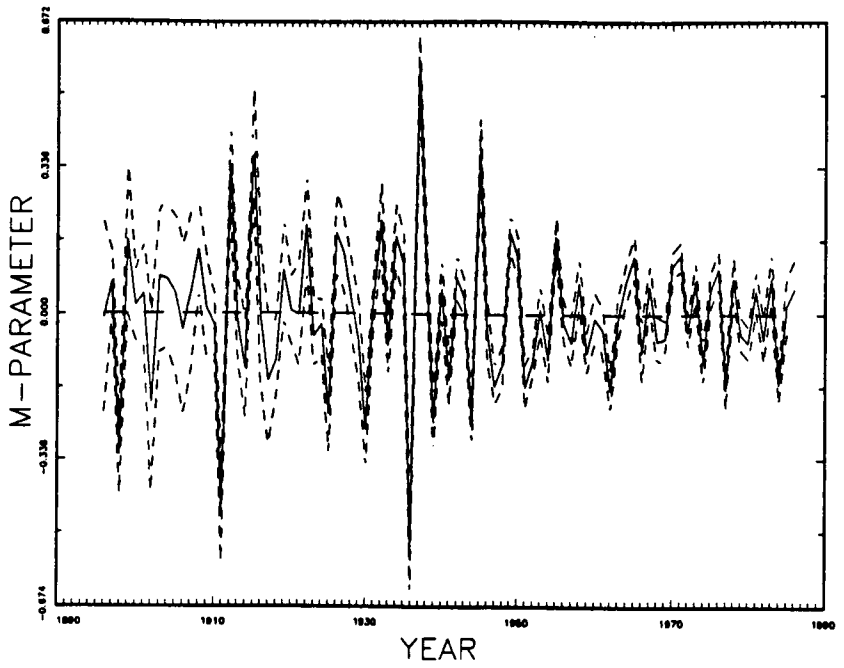


Figure A76. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 2.

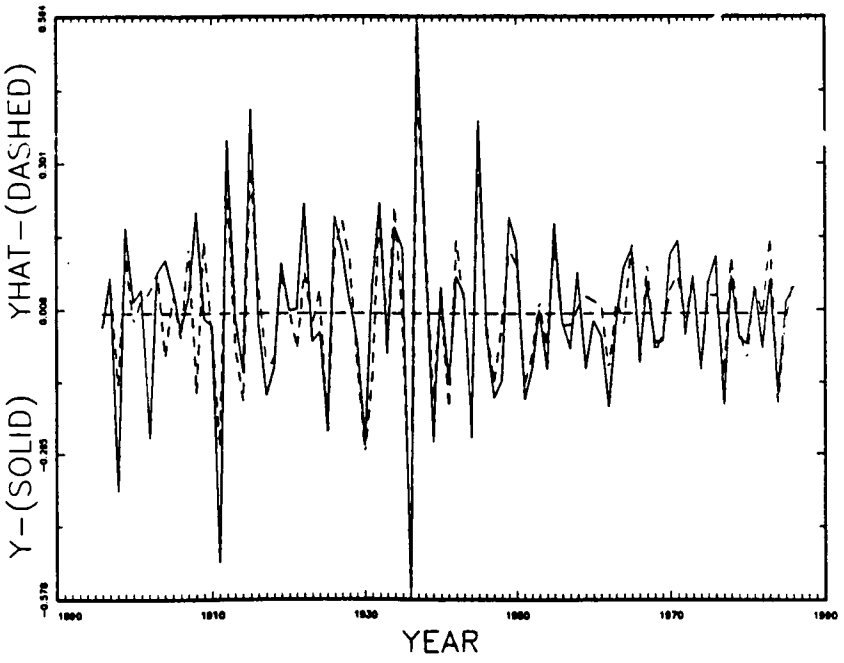
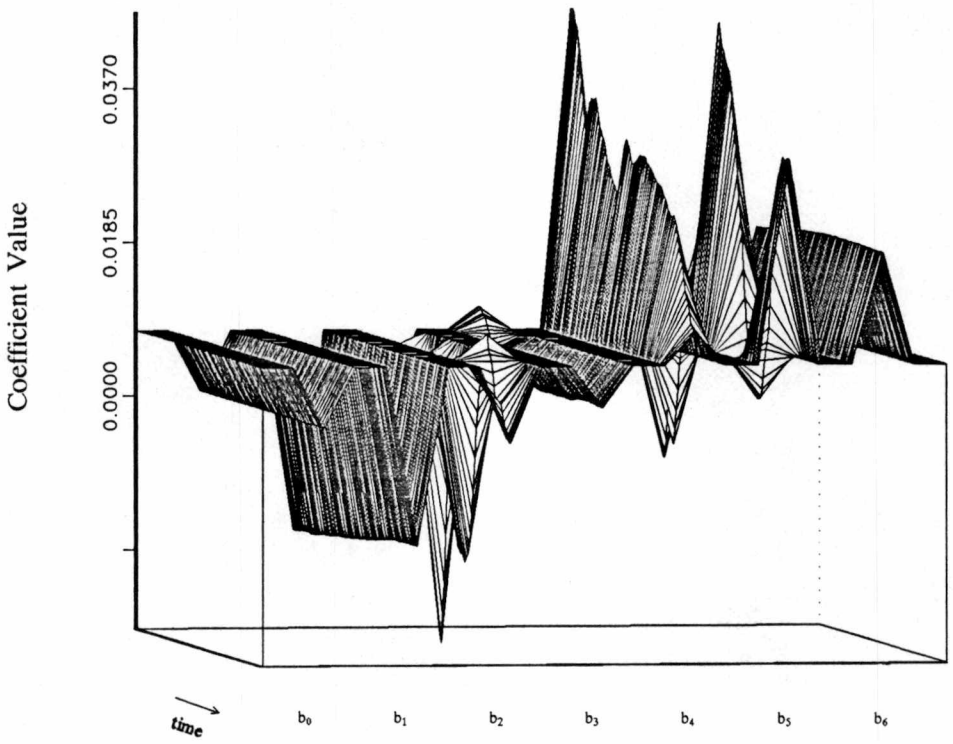


Figure A77. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = September temperature
b_3 = past May temperature
b_4 = May rain
b_5 = June rain
b_6 = past August rain

Figure A78. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 2.

Table A26. Climate parameter estimates for Emory River chestnut oak, cluster 2.

YEAR	June temp. b_1	September temp. b_2	Past May temp. b_3	May rain b_4	June rain b_5	Past August rain b_6
1897	-0.016*	-0.002	0.010	0.046	-0.007	0.020*
1898	-0.016*	-0.001	0.010	0.046	-0.006	0.020*
1899	-0.016*	0.004	0.010	0.045	0.000	0.020*
1900	-0.016*	0.003	0.010	0.045	-0.001	0.020*
1901	-0.016*	0.004	0.009	0.044	-0.002	0.020*
1902	-0.016*	0.005	0.009	0.041	-0.004	0.020*
1903	-0.016*	0.006	0.008	0.040	-0.006	0.020*
1904	-0.016*	0.004	0.008	0.038	-0.004	0.020*
1905	-0.016*	0.001	0.007	0.036	-0.002	0.020*
1906	-0.016*	-0.003	0.006	0.033	0.001	0.020*
1907	-0.016*	-0.008	0.006	0.032	0.004	0.020*
1908	-0.016*	-0.009	0.006	0.033	0.005	0.020*
1909	-0.016*	-0.012	0.006	0.035	0.009	0.021*
1910	-0.016*	-0.014	0.006	0.036	0.010	0.021*
1911	-0.016*	-0.013	0.006	0.036	0.010	0.021*
1912	-0.016*	-0.012	0.005	0.036	0.011	0.021*
1913	-0.016*	-0.009	0.005	0.036*	0.011	0.021*
1914	-0.016*	-0.005	0.005	0.036*	0.013	0.021*
1915	-0.016*	-0.002	0.005	0.036*	0.013	0.021*
1916	-0.016*	0.001	0.005	0.034*	0.015	0.021*
1917	-0.016*	0.004	0.005	0.033*	0.016	0.021*
1918	-0.016*	0.005	0.005	0.033*	0.017	0.021*
1919	-0.016*	0.005	0.004	0.032*	0.017	0.021*
1920	-0.016*	0.005	0.004	0.032*	0.018	0.021*
1921	-0.016*	0.003	0.004	0.031*	0.020	0.021*
1922	-0.016*	0.005	0.004	0.030*	0.020	0.021*
1923	-0.016*	0.006	0.004	0.029*	0.020	0.021*
1924	-0.016*	0.004	0.004	0.029*	0.020	0.021*
1925	-0.015*	0.003	0.004	0.028*	0.021	0.021*
1926	-0.015*	0.002	0.004	0.027*	0.020	0.021*
1927	-0.015*	0.001	0.004	0.027*	0.020	0.021*
1928	-0.015*	-0.002	0.003	0.026*	0.022	0.021*
1929	-0.015*	-0.006	0.003	0.026*	0.025	0.021*
1930	-0.015*	-0.009	0.003	0.026*	0.028	0.021*
1931	-0.015*	-0.013	0.003	0.026*	0.031	0.021*
1932	-0.015*	-0.019	0.003	0.028*	0.035*	0.021*
1933	-0.015*	-0.021	0.003	0.029*	0.037*	0.021*
1934	-0.015*	-0.024*	0.003	0.030*	0.039*	0.021*
1935	-0.015*	-0.027*	0.003	0.032*	0.044*	0.021*
1936	-0.015*	-0.028*	0.003	0.032*	0.046*	0.021*
1937	-0.015*	-0.024*	0.003	0.032*	0.045*	0.021*
1938	-0.015*	-0.021*	0.003	0.032*	0.044*	0.021*
1939	-0.015*	-0.015*	0.003	0.031*	0.043*	0.021*
1940	-0.015*	-0.009	0.003	0.030*	0.042*	0.021*
1941	-0.015*	-0.008	0.003	0.030*	0.042*	0.021*
1942	-0.015*	-0.009	0.003	0.030*	0.041*	0.021*
1943	-0.015*	-0.010	0.003	0.030*	0.041*	0.021*
1944	-0.015*	-0.010	0.003	0.030*	0.040*	0.021*
1945	-0.015*	-0.012	0.003	0.031*	0.038*	0.021*
1946	-0.015*	-0.014	0.003	0.031*	0.035*	0.021*
1947	-0.015*	-0.014	0.003	0.031*	0.034*	0.021*
1948	-0.015*	-0.016*	0.003	0.031*	0.032*	0.021*
1949	-0.015*	-0.016*	0.003	0.031*	0.029*	0.021*
1950	-0.015*	-0.016*	0.003	0.031*	0.026*	0.021*

Table A26. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1951	-0.015*	-0.016*	0.003	0.030*	0.023*	0.021*
1952	-0.015*	-0.017*	0.003	0.030*	0.022*	0.021*
1953	-0.015*	-0.017*	0.003	0.030*	0.018	0.021*
1954	-0.015*	-0.017*	0.003	0.030*	0.014	0.021*
1955	-0.014*	-0.016*	0.003	0.029*	0.012	0.021*
1956	-0.014*	-0.016	0.003	0.029*	0.009	0.021*
1957	-0.014*	-0.014	0.003	0.029*	0.007	0.021*
1958	-0.014*	-0.011	0.003	0.028*	0.005	0.021*
1959	-0.014*	-0.009	0.003	0.028*	0.004	0.021*
1960	-0.014*	-0.004	0.003	0.028*	0.004	0.021*
1961	-0.014*	-0.001	0.003	0.028*	0.004	0.021*
1962	-0.014*	0.001	0.003	0.028*	0.004	0.021*
1963	-0.014*	0.003	0.003	0.027*	0.003	0.021*
1964	-0.014*	0.005	0.003	0.027*	0.003	0.021*
1965	-0.014*	0.006	0.003	0.026*	0.003	0.021*
1966	-0.014*	0.009	0.003	0.026*	0.004	0.021*
1967	-0.014*	0.010	0.003	0.025*	0.005	0.021*
1968	-0.014*	0.010	0.003	0.025*	0.007	0.021*
1969	-0.014*	0.011	0.003	0.025*	0.009	0.021*
1970	-0.014*	0.009	0.003	0.025*	0.010	0.021*
1971	-0.014*	0.009	0.003	0.025*	0.012	0.021*
1972	-0.014*	0.008	0.003	0.024*	0.014	0.021*
1973	-0.014*	0.006	0.003	0.023*	0.018*	0.021*
1974	-0.014*	0.005	0.003	0.021*	0.023*	0.021*
1975	-0.014*	0.003	0.003	0.020*	0.026*	0.021*
1976	-0.014*	0.002	0.003	0.019*	0.028*	0.021*
1977	-0.014*	0.002	0.003	0.018*	0.029*	0.021*
1978	-0.014*	0.003	0.003	0.016*	0.030*	0.021*
1979	-0.014*	0.003	0.003	0.016*	0.031*	0.021*
1980	-0.014*	0.002	0.003	0.015*	0.032*	0.021*
1981	-0.014*	0.001	0.003	0.014*	0.032*	0.021*
1982	-0.014*	-0.000	0.003	0.013	0.032*	0.021*
1983	-0.014*	-0.001	0.003	0.012	0.032*	0.021*
1984	-0.014*	-0.001	0.003	0.012	0.032*	0.021*
1985	-0.014*	-0.001	0.003	0.012	0.033	0.021*
1986	-0.014*	-0.001	0.003	0.012	0.033	0.021*

* Indicates coefficient is significant at $P \leq 0.05$.

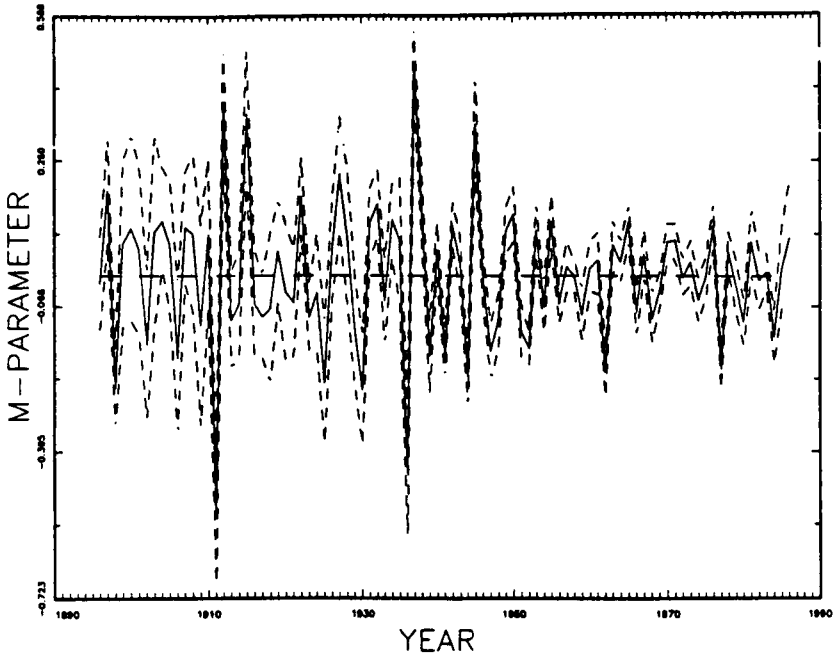


Figure A79. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 3.

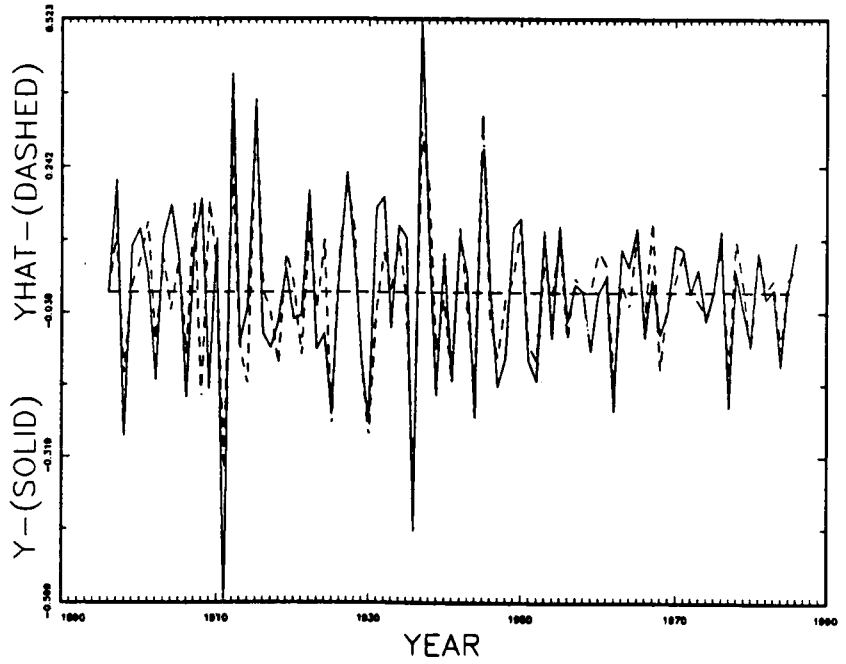
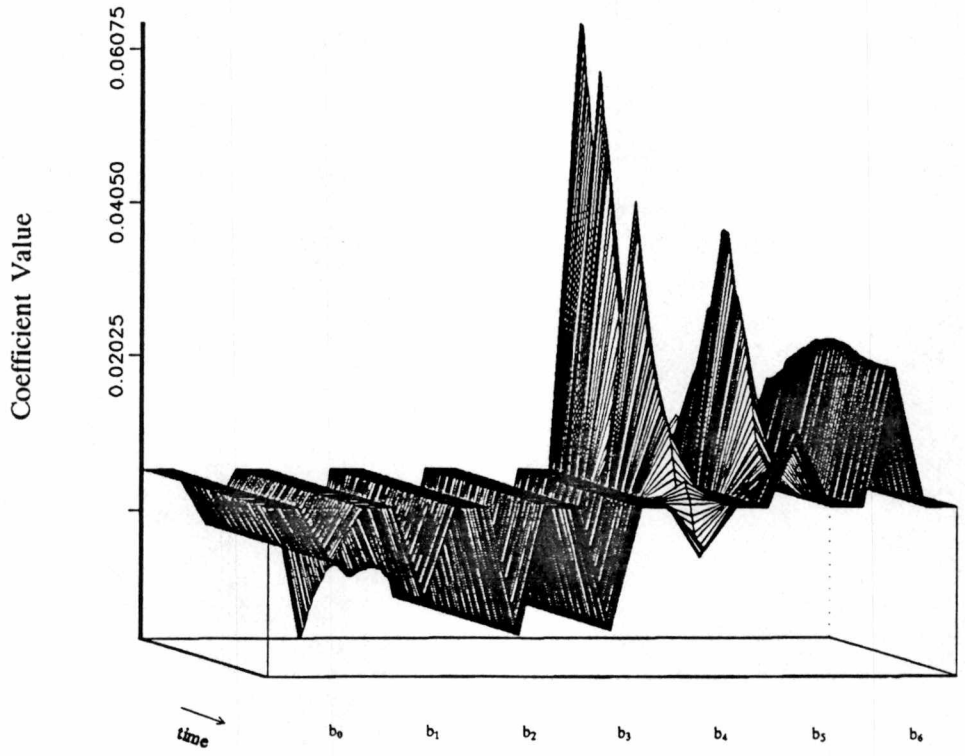


Figure A80. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 3.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = August temperature
b_4 = May rain
b_5 = June rain
b_6 = past August rain

Figure A81. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 3.

Table A27. Climate parameter estimates for Emory River chestnut oak, cluster 3.

YEAR	May temp. b_1	June temp. b_2	August temp. b_3	May rain b_4	June rain b_5	Past August rain b_6
1897	-0.017*	-0.012*	-0.011*	0.064	0.012	0.017
1898	-0.017*	-0.012*	-0.011*	0.063	0.012	0.017
1899	-0.016*	-0.012*	-0.011*	0.060	0.013	0.017
1900	-0.015	-0.012*	-0.011*	0.057	0.012	0.018
1901	-0.015	-0.012*	-0.011*	0.056	0.010	0.018
1902	-0.014	-0.012*	-0.011*	0.054	0.009	0.018
1903	-0.013	-0.012*	-0.011*	0.051	0.006	0.018
1904	-0.013	-0.012*	-0.011*	0.050	0.007	0.018
1905	-0.012	-0.012*	-0.011*	0.048	0.008	0.019
1906	-0.011	-0.012*	-0.011*	0.044	0.009	0.019
1907	-0.011	-0.012*	-0.011*	0.043	0.009	0.019
1908	-0.010	-0.012*	-0.011*	0.046	0.011	0.019
1909	-0.010	-0.012*	-0.011*	0.054*	0.015	0.020*
1910	-0.010	-0.012*	-0.011*	0.058*	0.018	0.020*
1911	-0.009	-0.012*	-0.011*	0.057*	0.019	0.021*
1912	-0.009	-0.012*	-0.011*	0.055*	0.019	0.021*
1913	-0.008	-0.012*	-0.011*	0.052*	0.020	0.021*
1914	-0.008	-0.012*	-0.011*	0.052*	0.020	0.021*
1915	-0.007	-0.012*	-0.011*	0.050*	0.021	0.021*
1916	-0.007	-0.012*	-0.011*	0.049*	0.022	0.022*
1917	-0.007	-0.012*	-0.011*	0.047*	0.022	0.022*
1918	-0.006	-0.012*	-0.011*	0.043*	0.024	0.022*
1919	-0.006	-0.012*	-0.011*	0.041*	0.025	0.022*
1920	-0.006	-0.012*	-0.011*	0.036	0.026	0.022*
1921	-0.006	-0.012*	-0.011*	0.034	0.028	0.023*
1922	-0.006	-0.012*	-0.011*	0.032	0.028	0.023*
1923	-0.006	-0.012*	-0.011*	0.031	0.028	0.023*
1924	-0.006	-0.012*	-0.011*	0.027	0.029	0.023*
1925	-0.006	-0.012*	-0.011*	0.024	0.030	0.023*
1926	-0.006	-0.012*	-0.011*	0.023	0.031*	0.023*
1927	-0.006	-0.012*	-0.011*	0.020	0.032*	0.024*
1928	-0.007	-0.012*	-0.011*	0.017	0.034*	0.024*
1929	-0.007	-0.012*	-0.011*	0.015	0.036*	0.024*
1930	-0.007	-0.012*	-0.011*	0.013	0.037*	0.024*
1931	-0.007	-0.012*	-0.011*	0.015	0.039*	0.024*
1932	-0.007	-0.012*	-0.011*	0.017	0.039*	0.024*
1933	-0.007	-0.012*	-0.011*	0.021	0.039*	0.024*
1934	-0.007	-0.012*	-0.011*	0.025	0.039*	0.024*
1935	-0.006	-0.012*	-0.011*	0.035*	0.039*	0.024*
1936	-0.006	-0.012*	-0.011*	0.043*	0.038*	0.025*
1937	-0.006	-0.012*	-0.011*	0.041*	0.036*	0.025*
1938	-0.006	-0.012*	-0.011*	0.040*	0.033*	0.025*
1939	-0.006	-0.012*	-0.011*	0.037*	0.032*	0.025*
1940	-0.006	-0.012*	-0.011*	0.034*	0.031*	0.025*
1941	-0.006	-0.012*	-0.011*	0.032*	0.031*	0.025*
1942	-0.005	-0.012*	-0.011*	0.031*	0.030*	0.025*
1943	-0.005	-0.012*	-0.011*	0.030*	0.030*	0.025*
1944	-0.005	-0.012*	-0.011*	0.028*	0.029*	0.025*
1945	-0.005	-0.012*	-0.011*	0.026*	0.027*	0.025*
1946	-0.005	-0.012*	-0.011*	0.025*	0.026*	0.025*
1947	-0.005	-0.012*	-0.011*	0.024*	0.025*	0.025*
1948	-0.005	-0.012*	-0.011*	0.023*	0.024*	0.025*
1949	-0.005	-0.012*	-0.011*	0.022*	0.022*	0.025*
1950	-0.005	-0.012*	-0.011*	0.021*	0.020*	0.025*

Table A27. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1951	-0.005	-0.012*	-0.011*	0.020	0.018*	0.025*
1952	-0.005	-0.012*	-0.011*	0.019	0.017*	0.025*
1953	-0.005	-0.012*	-0.011*	0.019	0.016*	0.025*
1954	-0.005	-0.012*	-0.011*	0.018	0.014	0.025*
1955	-0.005	-0.012*	-0.011*	0.016	0.013	0.024*
1956	-0.005	-0.012*	-0.011*	0.016	0.012	0.024*
1957	-0.005	-0.012*	-0.011*	0.015	0.011	0.024*
1958	-0.005	-0.012*	-0.011*	0.015	0.011	0.024*
1959	-0.006	-0.012*	-0.011*	0.015	0.010	0.024*
1960	-0.006*	-0.012*	-0.011*	0.014	0.010	0.024*
1961	-0.006*	-0.012*	-0.011*	0.014	0.010	0.024*
1962	-0.006*	-0.012*	-0.011*	0.012	0.009	0.024*
1963	-0.006*	-0.012*	-0.011*	0.011	0.009	0.024*
1964	-0.006*	-0.012*	-0.011*	0.009	0.009	0.024*
1965	-0.006*	-0.012*	-0.011*	0.008	0.009	0.024*
1966	-0.006*	-0.012*	-0.011*	0.006	0.009	0.024*
1967	-0.006*	-0.012*	-0.011*	0.005	0.009	0.024*
1968	-0.007*	-0.012*	-0.011*	0.005	0.010	0.024*
1969	-0.007*	-0.012*	-0.011*	0.005	0.011	0.024*
1970	-0.007*	-0.012*	-0.011*	0.007	0.011	0.024*
1971	-0.007*	-0.012*	-0.011*	0.007	0.012	0.024*
1972	-0.007*	-0.012*	-0.011*	0.008	0.012	0.023*
1973	-0.007*	-0.012*	-0.011*	0.007	0.013	0.023*
1974	-0.007*	-0.012*	-0.011*	0.006	0.014	0.023*
1975	-0.007*	-0.012*	-0.011*	0.006	0.014	0.023*
1976	-0.007*	-0.012*	-0.011*	0.005	0.015	0.023*
1977	-0.007*	-0.012*	-0.011*	0.004	0.015	0.023*
1978	-0.007*	-0.012*	-0.011*	0.003	0.015	0.023*
1979	-0.007	-0.012*	-0.011*	0.002	0.015	0.023*
1980	-0.007	-0.012*	-0.011*	0.001	0.015	0.023*
1981	-0.007	-0.012*	-0.011*	-0.000	0.015	0.023*
1982	-0.007	-0.012*	-0.011*	-0.001	0.015	0.023*
1983	-0.007	-0.012*	-0.011*	-0.001	0.015	0.023*
1984	-0.007	-0.012*	-0.011*	-0.001	0.015	0.023*
1985	-0.007	-0.012*	-0.011*	-0.000	0.015	0.023*
1986	-0.007	-0.012*	-0.011*	-0.000	0.015	0.023*

* Indicates coefficient is significant at $P \leq 0.05$.

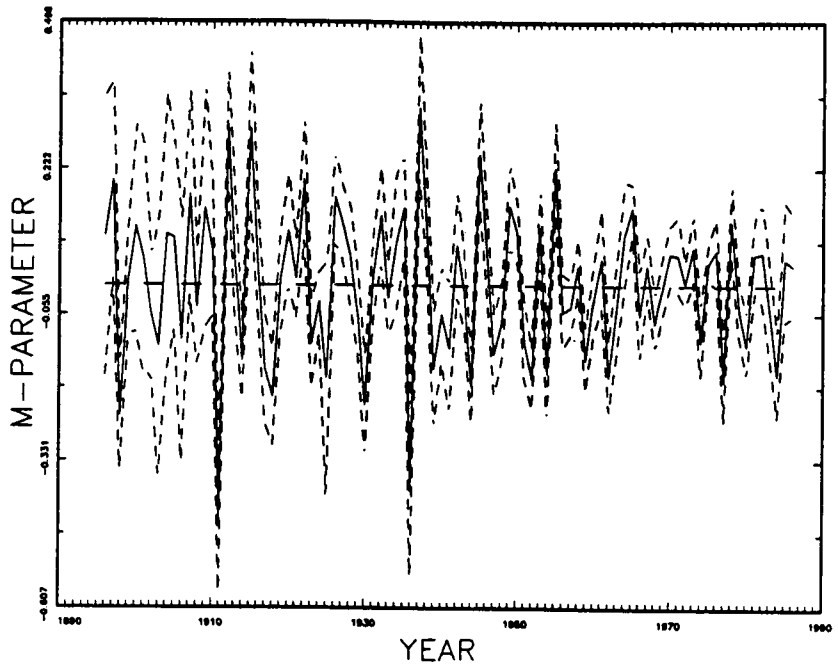


Figure A82. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 4.

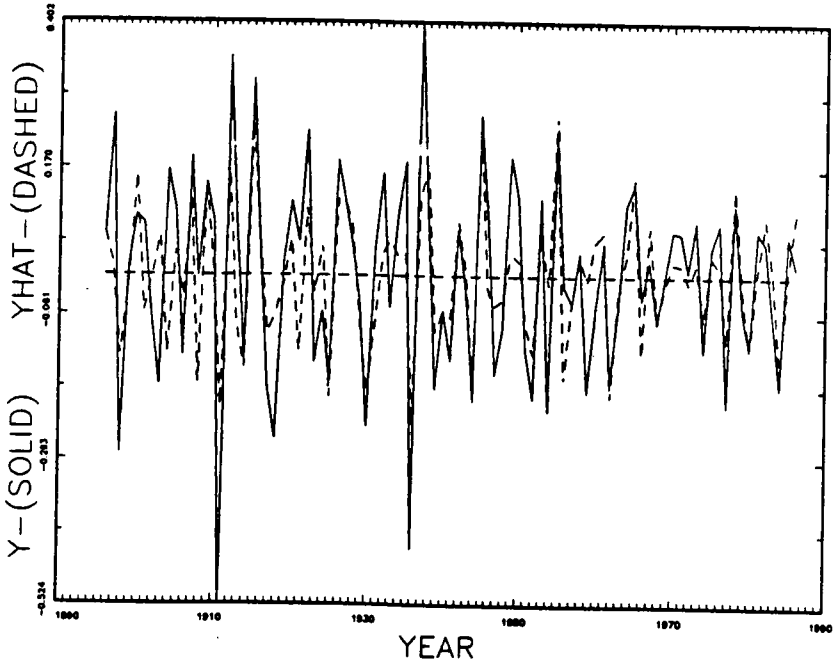
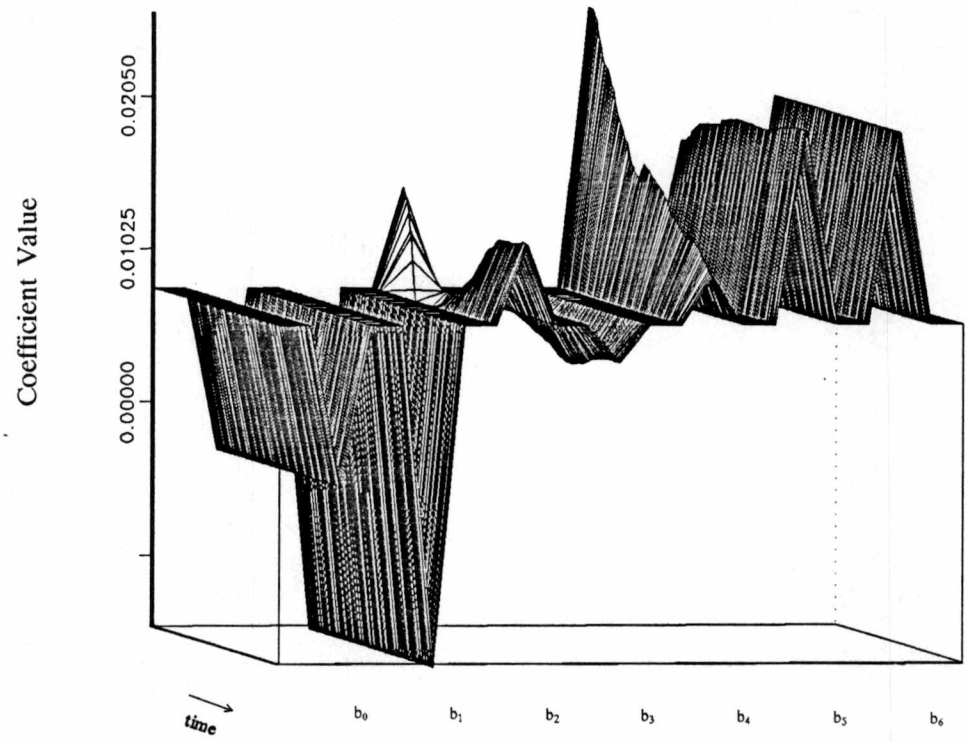


Figure A83. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 4.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = past April temperature
b_3 = past August temperature
b_4 = May rain
b_5 = June rain
b_6 = past August rain

Figure A84. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 4.

Table A28. Climate parameter estimates for Emory River chestnut oak, cluster 4.

YEAR	June temp. b_1	Past April temp. b_2	Past August temp. b_3	May rain b_4	June rain b_5	Past August rain b_6
1897	-0.015*	0.014	0.008	0.026	0.017*	0.020*
1898	-0.015*	0.014	0.008	0.026	0.017*	0.020*
1899	-0.015*	0.014	0.008	0.026	0.017*	0.020*
1900	-0.015*	0.013	0.008	0.026	0.018*	0.020*
1901	-0.015*	0.012	0.008	0.026	0.018*	0.020*
1902	-0.015*	0.011	0.008	0.026	0.018*	0.020*
1903	-0.015*	0.010	0.007	0.025	0.018*	0.020*
1904	-0.015*	0.008	0.007	0.024	0.018*	0.020*
1905	-0.015*	0.007	0.007	0.024	0.018*	0.020*
1906	-0.015*	0.006	0.007	0.023	0.018*	0.020*
1907	-0.015*	0.005	0.007	0.023*	0.019*	0.020*
1908	-0.015*	0.005	0.007	0.023*	0.019*	0.020*
1909	-0.015*	0.005	0.007	0.023*	0.019*	0.020*
1910	-0.015*	0.005	0.007	0.023*	0.019*	0.020*
1911	-0.015*	0.005	0.006	0.022*	0.019*	0.020*
1912	-0.015*	0.005	0.006	0.022*	0.019*	0.020*
1913	-0.015*	0.005	0.006	0.022*	0.019*	0.020*
1914	-0.015*	0.005	0.006	0.021*	0.019*	0.020*
1915	-0.015*	0.005	0.006	0.021*	0.019*	0.020*
1916	-0.015*	0.005	0.006	0.020*	0.019*	0.020*
1917	-0.015*	0.005	0.006	0.020*	0.019*	0.020*
1918	-0.015*	0.005	0.006	0.020*	0.019*	0.020*
1919	-0.015*	0.005	0.006	0.019*	0.019*	0.020*
1920	-0.015*	0.005	0.006	0.019*	0.019*	0.020*
1921	-0.015*	0.005	0.006	0.019*	0.019*	0.020*
1922	-0.015*	0.005	0.006	0.018*	0.019*	0.020*
1923	-0.015*	0.005	0.006	0.018*	0.019*	0.020*
1924	-0.015*	0.005	0.006	0.018*	0.019*	0.020*
1925	-0.015*	0.005	0.005	0.017*	0.020*	0.020*
1926	-0.015*	0.005	0.005	0.017*	0.020*	0.020*
1927	-0.015*	0.005	0.005	0.017*	0.020*	0.020*
1928	-0.015*	0.005	0.005	0.017*	0.020*	0.020*
1929	-0.015*	0.005	0.005	0.016*	0.020*	0.020*
1930	-0.015*	0.005	0.005	0.016*	0.020*	0.020*
1931	-0.015*	0.005	0.005	0.016*	0.020*	0.020*
1932	-0.015*	0.005	0.005	0.016*	0.020*	0.020*
1933	-0.015*	0.005	0.005	0.016*	0.020*	0.020*
1934	-0.015*	0.006	0.005	0.016*	0.020*	0.020*
1935	-0.015*	0.006	0.005	0.017*	0.020*	0.020*
1936	-0.015*	0.006	0.005	0.017*	0.020*	0.020*
1937	-0.015*	0.007	0.005	0.017*	0.020*	0.020*
1938	-0.015*	0.007	0.005	0.017*	0.020*	0.020*
1939	-0.015*	0.008	0.005	0.017*	0.020*	0.020*
1940	-0.015*	0.008	0.005	0.017*	0.020*	0.020*
1941	-0.015*	0.008	0.004	0.016*	0.020*	0.020*
1942	-0.015*	0.009*	0.004	0.016*	0.020*	0.020*
1943	-0.015*	0.009*	0.004	0.016*	0.020*	0.020*
1944	-0.015*	0.009*	0.004	0.016*	0.020*	0.020*
1945	-0.015*	0.009*	0.004	0.016*	0.020*	0.020*
1946	-0.015*	0.010*	0.004	0.016*	0.020*	0.020*
1947	-0.015*	0.010*	0.004	0.016*	0.020*	0.020*
1948	-0.015*	0.010*	0.004	0.016*	0.020*	0.020*
1949	-0.015*	0.010*	0.004	0.016*	0.020*	0.020*
1950	-0.015*	0.010*	0.004	0.015*	0.020*	0.020*

Table A28. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1951	-0.015*	0.010*	0.004	0.015*	0.020*	0.020*
1952	-0.015*	0.011*	0.004	0.015*	0.020*	0.020*
1953	-0.015*	0.011*	0.004	0.015*	0.020*	0.020*
1954	-0.015*	0.011*	0.004	0.015*	0.020*	0.020*
1955	-0.015*	0.011*	0.004	0.014*	0.020*	0.020*
1956	-0.015*	0.012*	0.004	0.014*	0.020*	0.020*
1957	-0.015*	0.012*	0.004	0.014*	0.020*	0.020*
1958	-0.015*	0.012*	0.004	0.014*	0.020*	0.020*
1959	-0.015*	0.012*	0.004	0.014*	0.020*	0.020*
1960	-0.015*	0.012*	0.004	0.014*	0.020*	0.020*
1961	-0.015*	0.012*	0.004	0.014*	0.020*	0.020*
1962	-0.015*	0.012*	0.004	0.013*	0.020*	0.020*
1963	-0.015*	0.012*	0.005	0.013*	0.020*	0.020*
1964	-0.015*	0.013*	0.005	0.013*	0.020*	0.020*
1965	-0.015*	0.013*	0.005	0.013*	0.020*	0.020*
1966	-0.015*	0.013*	0.005	0.013*	0.020*	0.020*
1967	-0.015*	0.013*	0.005	0.013*	0.020*	0.020*
1968	-0.015*	0.013*	0.005	0.013*	0.020*	0.020*
1969	-0.015*	0.013*	0.005	0.013*	0.020*	0.020*
1970	-0.015*	0.013*	0.005	0.013*	0.020*	0.020*
1971	-0.015*	0.013*	0.005	0.013*	0.020*	0.020*
1972	-0.015*	0.013*	0.005	0.013*	0.020*	0.020*
1973	-0.015*	0.013*	0.005	0.013*	0.020*	0.020*
1974	-0.015*	0.013*	0.005	0.012*	0.020*	0.020*
1975	-0.015*	0.013*	0.005	0.012*	0.020*	0.020*
1976	-0.015*	0.013*	0.005	0.012*	0.020*	0.020*
1977	-0.015*	0.013*	0.005	0.012*	0.020*	0.020*
1978	-0.015*	0.013*	0.005	0.012	0.020*	0.020*
1979	-0.015*	0.013*	0.005	0.012	0.020*	0.020*
1980	-0.015*	0.013*	0.005	0.012	0.020*	0.020*
1981	-0.015*	0.013*	0.005	0.011	0.020*	0.020*
1982	-0.015*	0.013*	0.005	0.011	0.020*	0.020*
1983	-0.015*	0.013*	0.005	0.011	0.020*	0.020*
1984	-0.015*	0.013*	0.005	0.011	0.020*	0.020*
1985	-0.015*	0.013*	0.005	0.011	0.020*	0.020*
1986	-0.015*	0.013*	0.005	0.011	0.020*	0.020*

* Indicates coefficient is significant at $P \leq 0.05$.

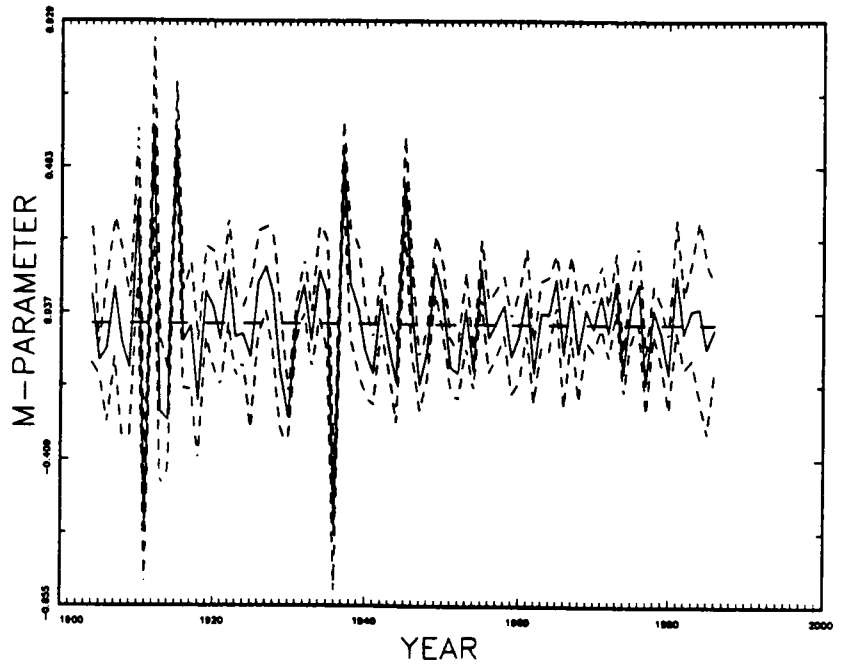


Figure A85. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 5.

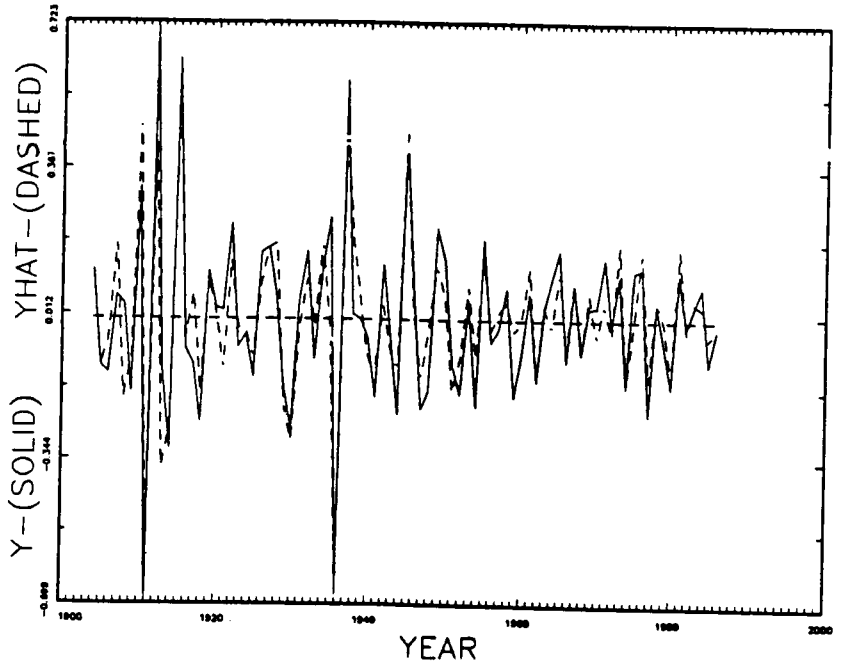
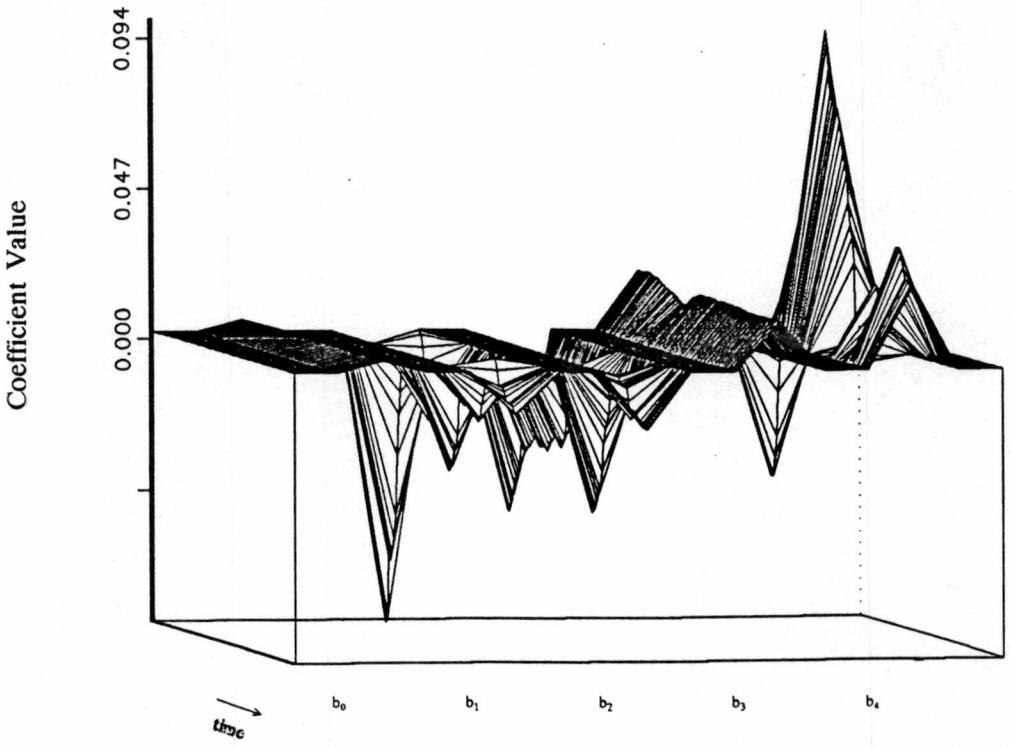


Figure A86. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 5.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = August temperature
b_3 = May rain
b_4 = June rain

Figure A87. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 5.

Table A29. Climate parameter estimates for Emory River chestnut oak, cluster 5.

YEAR	June temperature b_1	August temperature b_2	May rain b_3	June rain b_4
1904	-0.021	-0.054	0.021	-0.044*
1905	-0.022	-0.054	0.021	-0.043*
1906	-0.028	-0.051	0.021	-0.038
1907	-0.036	-0.049	0.021	-0.031
1908	-0.061*	-0.045	0.021	-0.017
1909	-0.071*	-0.042	0.021	-0.007
1910	-0.088*	-0.041	0.021	0.002
1911	-0.086*	-0.040	0.021	0.001
1912	-0.067*	-0.030	0.021	0.000
1913	-0.068*	-0.032	0.021	0.003
1914	-0.066*	-0.034	0.020	0.003
1915	-0.061*	-0.034	0.020	0.003
1916	-0.054*	-0.032	0.020	0.003
1917	-0.035	-0.032	0.019	0.002
1918	-0.022	-0.031	0.019	0.001
1919	-0.015	-0.029	0.019	0.001
1920	-0.004	-0.027	0.018	0.002
1921	-0.006	-0.029	0.018	0.008
1922	-0.008	-0.031	0.017	0.015
1923	-0.009	-0.031	0.017	0.019
1924	-0.010	-0.031	0.017	0.020
1925	-0.011	-0.031	0.016	0.034
1926	-0.007	-0.031*	0.016	0.036
1927	-0.004	-0.032*	0.015	0.037*
1928	0.000	-0.030	0.015	0.047*
1929	0.006	-0.028*	0.014	0.058*
1930	0.006	-0.028*	0.014	0.060*
1931	0.005	-0.027*	0.014	0.063*
1932	0.001	-0.026	0.014	0.067*
1933	-0.003	-0.027	0.015	0.067*
1934	-0.017	-0.029	0.015	0.073*
1935	-0.021	-0.029	0.017*	0.090*
1936	-0.019	-0.028	0.017*	0.100*
1937	-0.017	-0.026	0.017*	0.096*
1938	-0.019	-0.019	0.018*	0.088*
1939	-0.019	-0.013	0.018*	0.081*
1940	-0.017	-0.011	0.019*	0.079*
1941	-0.014	-0.008	0.019*	0.077*
1942	-0.013	-0.004	0.019*	0.077*
1943	-0.014	-0.004	0.019*	0.077*
1944	-0.018	-0.006	0.019*	0.072*
1945	-0.024	-0.010	0.019*	0.069*
1946	-0.032*	-0.012	0.019*	0.063*
1947	-0.035*	-0.010	0.019*	0.060*
1948	-0.033*	-0.013	0.019*	0.057*
1949	-0.033*	-0.017	0.019*	0.049*
1950	-0.028*	-0.019*	0.018*	0.042*
1951	-0.027*	-0.022*	0.018*	0.038*
1952	-0.023*	-0.028*	0.019*	0.030
1953	-0.009	-0.046*	0.019*	0.006
1954	-0.011	-0.046*	0.019*	0.006
1955	-0.012	-0.045*	0.019*	0.004
1956	-0.013	-0.042*	0.019*	0.001
1957	-0.012	-0.041*	0.018*	-0.000
1958	-0.012	-0.039*	0.018*	0.000

Table A29. Continued.

YEAR	b_1	b_2	b_3	b_4
1959	-0.012	-0.033	0.018*	0.002
1960	-0.010	-0.024	0.018*	0.007
1961	-0.012	-0.019	0.018*	0.013
1962	-0.012	-0.018	0.018*	0.015
1963	-0.013	-0.015	0.018*	0.019
1964	-0.017	-0.010	0.018*	0.025
1965	-0.016	-0.009	0.018*	0.025
1966	-0.011	-0.005	0.018*	0.019
1967	-0.008	-0.003	0.018*	0.016
1968	-0.005	-0.002	0.018*	0.014
1969	-0.004	-0.002	0.018*	0.014
1970	-0.001	-0.003	0.018*	0.015
1971	-0.001	-0.004	0.018*	0.020
1972	-0.000	-0.004	0.017*	0.023
1973	0.004	-0.004	0.018*	0.029
1974	0.004	-0.005	0.018*	0.030
1975	0.001	-0.008	0.018*	0.034
1976	-0.004	-0.014	0.018*	0.039*
1977	-0.004	-0.013	0.018*	0.039*
1978	-0.004	-0.012	0.018*	0.039*
1979	-0.005	-0.012	0.018*	0.037
1980	-0.007	-0.012	0.018*	0.033
1981	-0.009	-0.014	0.017	0.030
1982	-0.009	-0.015	0.017	0.029
1983	-0.008	-0.015	0.018	0.029
1984	-0.009	-0.015	0.018	0.028
1985	-0.011	-0.016	0.018	0.028
1986	-0.011	-0.016	0.018	0.028

* Indicates coefficient is significant at $P \leq 0.05$.

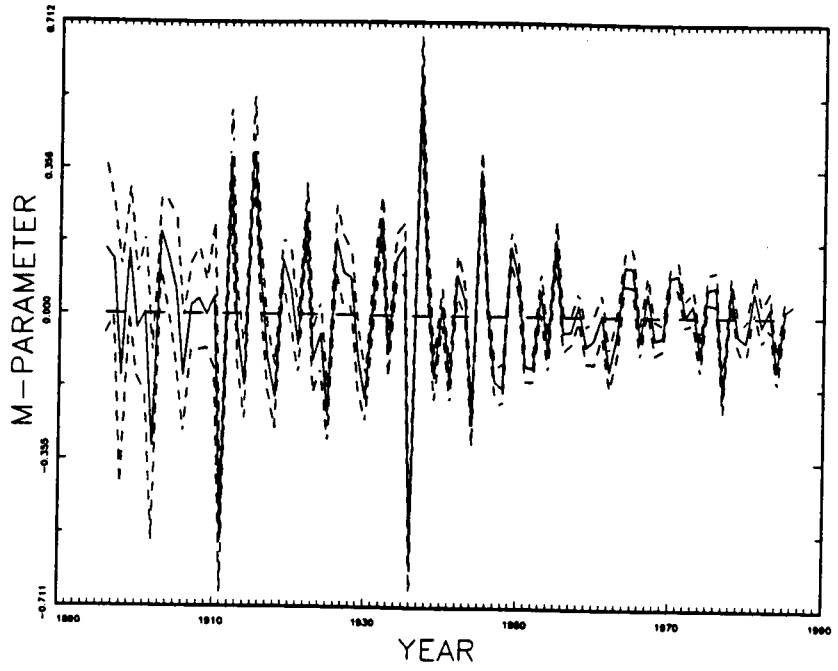


Figure A88. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 6.

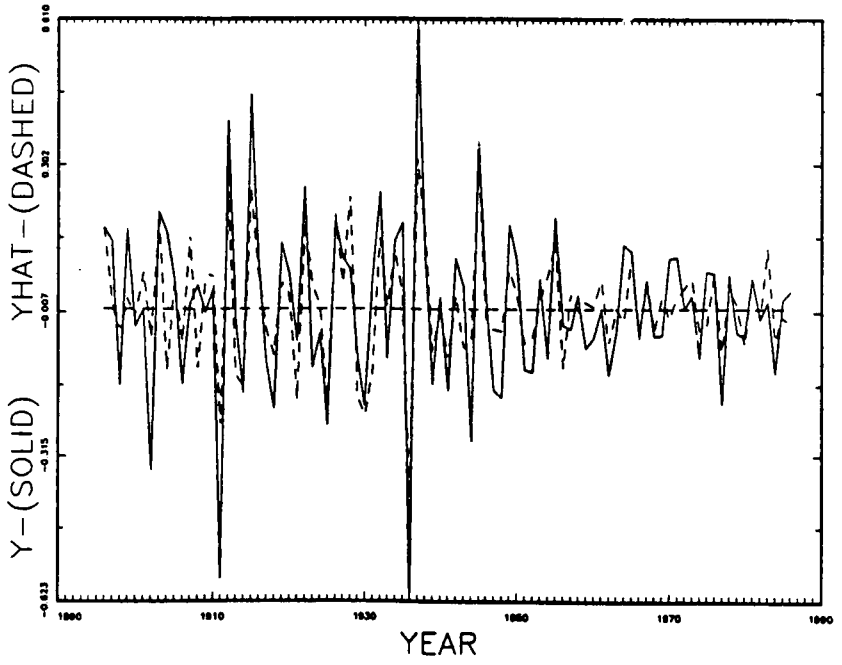
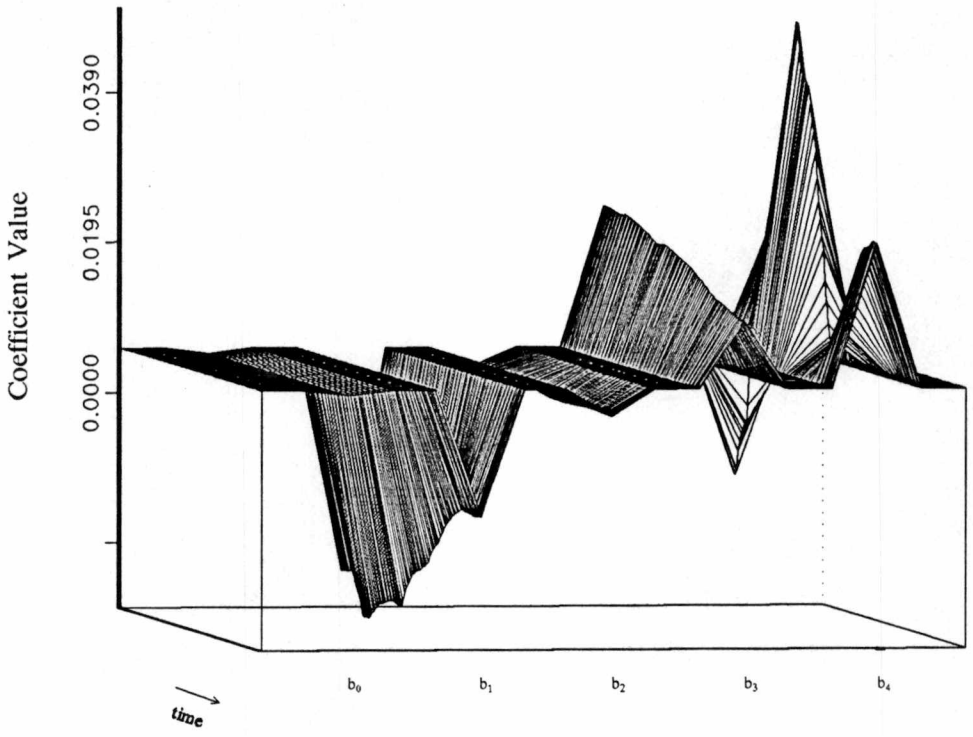


Figure A89. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 6.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = past December temperature
b_3 = May rain
b_4 = July rain

Figure A90. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 6.

Table A30. Climate parameter estimates for Emory River chestnut oak, cluster 6.

YEAR	June temperature b_1	Past December temperature b_2	May rain b_3	July rain b_4
1897	-0.023	0.003	0.024	-0.010
1898	-0.023	0.003	0.024	-0.008
1899	-0.023	0.003	0.024	-0.007
1900	-0.023	0.003	0.024	-0.005
1901	-0.023	0.003	0.024	-0.005
1902	-0.023	0.003	0.024	-0.004
1903	-0.023	0.003	0.024	-0.004
1904	-0.023	0.003	0.024	-0.002
1905	-0.024	0.003	0.024	0.002
1906	-0.025	0.003	0.023	0.004
1907	-0.025	0.004	0.023*	0.005
1908	-0.026*	0.004	0.023*	0.008
1909	-0.027*	0.004	0.023*	0.009
1910	-0.028*	0.004	0.024*	0.016
1911	-0.028*	0.004	0.024*	0.017
1912	-0.028*	0.004	0.023*	0.018
1913	-0.028*	0.004	0.023*	0.020
1914	-0.028*	0.004	0.023*	0.020
1915	-0.028*	0.004	0.023*	0.021
1916	-0.028*	0.004	0.023*	0.021
1917	-0.027*	0.004	0.023*	0.021
1918	-0.027*	0.004	0.023*	0.021
1919	-0.027*	0.004	0.023*	0.021
1920	-0.026*	0.004	0.023*	0.021
1921	-0.026*	0.004	0.022*	0.022
1922	-0.026*	0.004	0.022*	0.023
1923	-0.026*	0.004	0.022*	0.023
1924	-0.026*	0.004	0.022*	0.024
1925	-0.026*	0.004	0.022*	0.024
1926	-0.025*	0.004	0.022*	0.025
1927	-0.025*	0.004	0.022*	0.026*
1928	-0.025*	0.004	0.021*	0.029*
1929	-0.025*	0.003	0.021*	0.035*
1930	-0.025*	0.003	0.021*	0.038*
1931	-0.025*	0.003	0.021*	0.043*
1932	-0.025*	0.003	0.021*	0.045*
1933	-0.026*	0.003	0.021*	0.046*
1934	-0.026*	0.003	0.021*	0.048*
1935	-0.026*	0.003	0.021*	0.050*
1936	-0.025*	0.003	0.021*	0.050*
1937	-0.024*	0.003	0.021*	0.046*
1938	-0.023*	0.003	0.021*	0.044*
1939	-0.022*	0.003	0.021*	0.044*
1940	-0.022*	0.003	0.021*	0.043*
1941	-0.021*	0.002	0.021*	0.043*
1942	-0.021*	0.002	0.020*	0.042*
1943	-0.021*	0.002	0.020*	0.042*
1944	-0.021*	0.002	0.020*	0.040*
1945	-0.020*	0.002	0.020*	0.038*
1946	-0.020*	0.002	0.020*	0.037*
1947	-0.020*	0.002	0.020*	0.034*
1948	-0.020*	0.002	0.020*	0.031*
1949	-0.020*	0.002	0.020*	0.028*
1950	-0.019*	0.002	0.019*	0.025*

Table A30. Continued.

YEAR	b_1	b_2	b_3	b_4
1951	-0.019*	0.002	0.019*	0.023*
1952	-0.019*	0.002	0.019*	0.021*
1953	-0.018*	0.002	0.019*	0.017
1954	-0.018*	0.002	0.019*	0.015
1955	-0.017*	0.002	0.018*	0.012
1956	-0.017*	0.002	0.018*	0.010
1957	-0.016*	0.002	0.018*	0.010
1958	-0.016*	0.002	0.018*	0.010
1959	-0.016*	0.002	0.018*	0.010
1960	-0.015*	0.002	0.018*	0.010
1961	-0.014*	0.002	0.017*	0.010
1962	-0.014*	0.002	0.017*	0.011
1963	-0.013*	0.002	0.017*	0.010
1964	-0.013*	0.002	0.017*	0.011
1965	-0.013*	0.002	0.017*	0.011
1966	-0.012*	0.002	0.016*	0.011
1967	-0.012*	0.002	0.016*	0.011
1968	-0.012*	0.002	0.016*	0.011
1969	-0.012*	0.002	0.016*	0.012
1970	-0.011*	0.002	0.016*	0.013
1971	-0.011*	0.002	0.016*	0.014
1972	-0.011*	0.002	0.016*	0.016
1973	-0.011*	0.002	0.016*	0.018
1974	-0.010	0.002	0.015*	0.020*
1975	-0.011	0.002	0.015*	0.021*
1976	-0.011	0.002	0.015*	0.022*
1977	-0.011	0.002	0.015*	0.023*
1978	-0.011	0.002	0.015*	0.023*
1979	-0.011	0.002	0.015*	0.023*
1980	-0.011	0.002	0.015*	0.023*
1981	-0.011	0.002	0.015*	0.024*
1982	-0.011	0.002	0.014*	0.024
1983	-0.011	0.002	0.014*	0.024
1984	-0.011	0.002	0.014*	0.024
1985	-0.011	0.002	0.014*	0.024
1986	-0.011	0.002	0.014*	0.024

* Indicates coefficient is significant at $P \leq 0.05$.

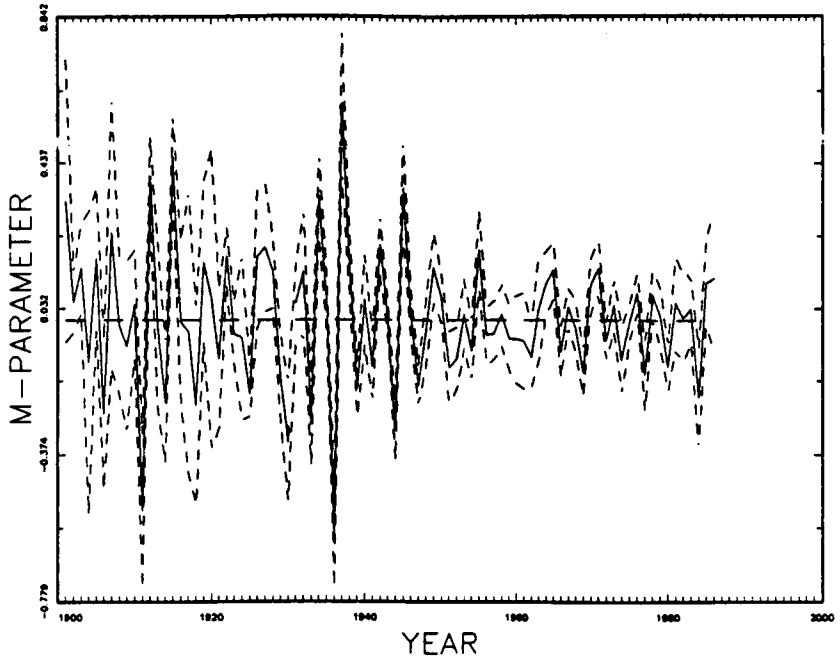


Figure A91. Graph of M-parameter and associated 95% confidence interval over time, Emory River chestnut oak, cluster 7.

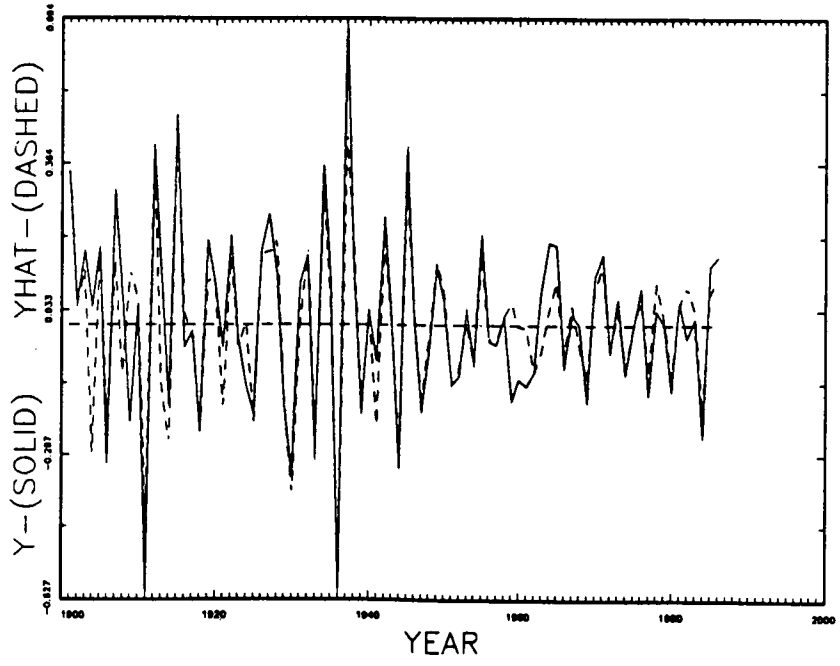
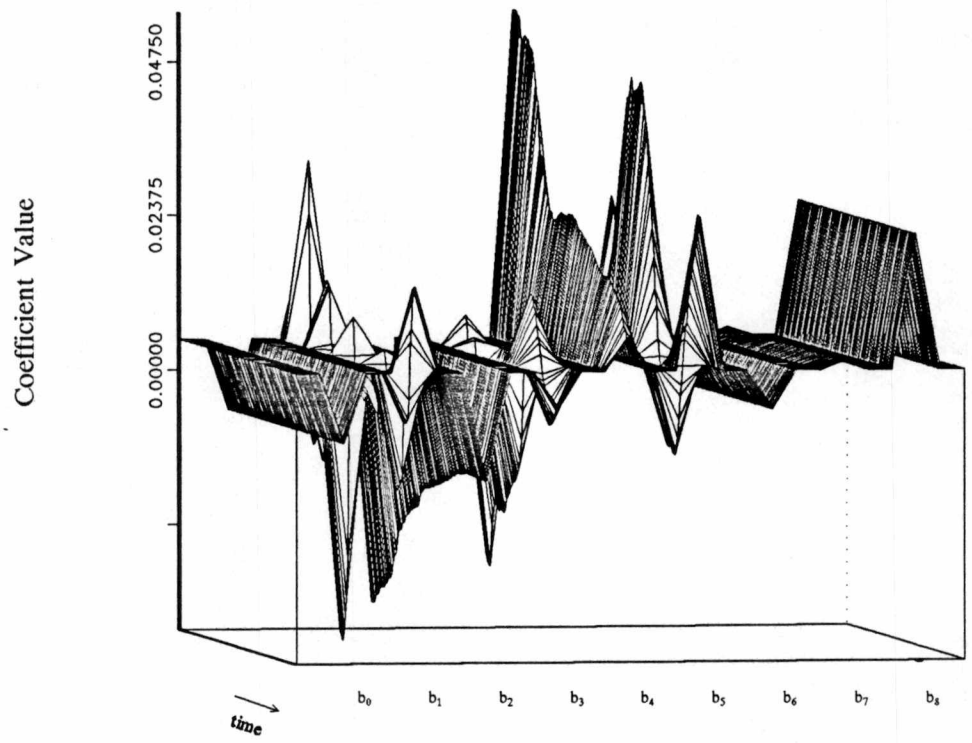


Figure A92. Graph of predicted and actual standardized growth, Emory River chestnut oak, cluster 7.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = September temperature
b_4 = May rain
b_5 = June rain
b_6 = July rain
b_7 = August rain
b_8 = past August rain

Figure A93. Three dimensional graph of changes in parameter coefficients over time, Emory River chestnut oak, cluster 7.

Table A31. Climate parameter estimates for Emory River chestnut oak, cluster 7.

YEAR	May temp. b_1	June temp. b_2	September temp. b_3	May rain b_4	June rain b_5	July rain b_6	August rain b_7	Past August rain b_8
1901	0.002	-0.036*	-0.005	0.055	0.008	-0.001	0.006	0.025*
1902	0.001	-0.036*	-0.005	0.055	0.008	-0.001	0.006	0.025*
1903	0.002	-0.036*	-0.005	0.055	0.008	-0.001	0.006	0.025*
1904	0.020	-0.035*	-0.013	0.054	0.011	-0.001	0.006	0.025*
1905	0.023	-0.035*	-0.015	0.054	0.012	-0.001	0.006	0.025*
1906	0.024	-0.034*	-0.015	0.054	0.010	-0.001	0.006	0.025*
1907	0.032	-0.033*	-0.014	0.051*	0.002	-0.001	0.006	0.025*
1908	0.024	-0.033*	-0.014	0.051*	0.000	-0.001	0.006	0.025*
1909	-0.002	-0.033*	-0.015	0.051*	0.005	-0.001	0.006	0.025*
1910	-0.010	-0.033*	-0.016	0.052*	0.007	-0.001	0.006	0.025*
1911	-0.011	-0.033*	-0.014	0.051*	0.006	-0.001	0.006	0.025*
1912	-0.011	-0.032*	-0.014	0.051*	0.006	-0.001	0.006	0.025*
1913	-0.008	-0.032*	-0.005	0.050*	0.008	-0.001	0.006	0.025*
1914	-0.007	-0.032*	-0.000	0.050*	0.009	-0.001	0.006	0.025*
1915	-0.008	-0.031*	0.001	0.050*	0.009	-0.001	0.006	0.025*
1916	-0.010	-0.031*	0.002	0.048*	0.010	-0.001	0.006	0.025*
1917	-0.013	-0.029*	0.007	0.045*	0.013	-0.001	0.006	0.025*
1918	-0.013	-0.028*	0.009	0.043*	0.014	-0.001	0.006	0.025*
1919	-0.009	-0.027*	0.008	0.042*	0.015	-0.001	0.006	0.025*
1920	0.011	-0.024*	0.002	0.035*	0.023	-0.001	0.006	0.025*
1921	0.015	-0.024*	-0.003	0.034*	0.027	-0.001	0.006	0.025*
1922	0.014	-0.024*	-0.002	0.033*	0.027	-0.001	0.006	0.025*
1923	0.014	-0.023*	-0.001	0.033*	0.026	-0.001	0.006	0.025*
1924	0.005	-0.022*	0.006	0.029*	0.022	-0.001	0.006	0.025*
1925	0.004	-0.022*	0.006	0.029*	0.022	-0.001	0.006	0.025*
1926	-0.004	-0.021*	0.001	0.028*	0.021	-0.001	0.006	0.025*
1927	-0.015	-0.021*	-0.003	0.026*	0.021	-0.001	0.006	0.025*
1928	-0.018	-0.021*	-0.005	0.026*	0.024	-0.001	0.006	0.025*
1929	-0.024	-0.020*	-0.007	0.025*	0.027	-0.001	0.006	0.025*
1930	-0.039*	-0.020*	-0.014	0.025*	0.033	-0.001	0.006	0.025*
1931	-0.039*	-0.020*	-0.017	0.025*	0.035	-0.001	0.006	0.025*
1932	-0.040*	-0.019*	-0.025	0.025*	0.042*	-0.001	0.006	0.025*
1933	-0.038*	-0.019*	-0.027*	0.025*	0.044*	-0.001	0.006	0.025*
1934	-0.036	-0.019*	-0.028*	0.025*	0.044*	-0.001	0.006	0.025*
1935	-0.033	-0.019*	-0.028*	0.026*	0.045*	-0.001	0.006	0.025*
1936	-0.027	-0.018*	-0.028*	0.026*	0.047*	-0.001	0.006	0.025*
1937	-0.004	-0.017*	-0.022*	0.026*	0.045*	-0.001	0.006	0.025*
1938	0.001	-0.017*	-0.020*	0.026*	0.045*	-0.001	0.006	0.025*
1939	0.004	-0.017*	-0.019*	0.026*	0.045*	-0.001	0.006	0.025*
1940	0.010	-0.016*	-0.016*	0.026*	0.045*	-0.001	0.006	0.025*
1941	0.004	-0.016*	-0.019*	0.026*	0.046*	-0.001	0.006	0.025*
1942	0.002	-0.016*	-0.019*	0.026*	0.046*	-0.001	0.006	0.025*
1943	0.001	-0.016*	-0.019*	0.026*	0.046*	-0.001	0.006	0.025*
1944	-0.002	-0.016*	-0.019*	0.026*	0.046*	-0.001	0.006	0.025*
1945	-0.001	-0.015*	-0.019*	0.026*	0.042*	-0.001	0.006	0.025*
1946	-0.001	-0.015*	-0.019*	0.026*	0.041*	-0.001	0.006	0.025*
1947	-0.001	-0.015*	-0.019*	0.025*	0.039*	-0.001	0.006	0.025*
1948	-0.002	-0.015*	-0.017	0.025*	0.034*	-0.001	0.006	0.025*
1949	-0.002	-0.015*	-0.017	0.024*	0.031*	-0.001	0.006	0.025*
1950	-0.001	-0.015*	-0.016	0.024*	0.029*	-0.001	0.006	0.025*
1951	0.000	-0.015*	-0.015	0.024*	0.024	-0.001	0.006	0.025*
1952	0.002	-0.015*	-0.015	0.023*	0.020	-0.001	0.006	0.025*
1953	0.002	-0.014*	-0.014	0.023*	0.015	-0.001	0.006	0.025*
1954	0.003	-0.014*	-0.014	0.023*	0.013	-0.001	0.006	0.025*

Table A31. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
1955	0.001	-0.014*	-0.014	0.022*	0.007	-0.001	0.006	0.025*
1956	-0.000	-0.014*	-0.013	0.022*	0.005	-0.001	0.006	0.025*
1957	-0.002	-0.014*	-0.012	0.022*	0.003	-0.001	0.006	0.025*
1958	-0.004	-0.013*	-0.011	0.022*	-0.001	-0.001	0.006	0.025*
1959	0.003	-0.013*	-0.007	0.021*	-0.004	-0.001	0.006	0.025*
1960	0.002	-0.013*	-0.003	0.021*	-0.006	-0.001	0.006	0.025*
1961	-0.001	-0.013*	0.004	0.020*	-0.008	-0.001	0.006	0.025*
1962	-0.001	-0.013*	0.006	0.020*	-0.008	-0.001	0.006	0.025*
1963	0.007	-0.012*	0.013	0.019*	-0.008	-0.001	0.006	0.025*
1964	0.005	-0.012*	0.014	0.019*	-0.007	-0.001	0.006	0.025*
1965	0.001	-0.012*	0.015	0.019*	-0.008	-0.001	0.006	0.025*
1966	-0.001	-0.012*	0.015	0.018*	-0.009	-0.001	0.006	0.025*
1967	-0.003	-0.012*	0.015	0.018*	-0.009	-0.001	0.006	0.025*
1968	-0.008	-0.012*	0.014	0.018*	-0.009	-0.001	0.006	0.025*
1969	-0.010	-0.012*	0.013	0.018*	-0.007	-0.001	0.006	0.025*
1970	-0.013	-0.012*	0.011	0.018*	-0.004	-0.001	0.006	0.025*
1971	-0.014	-0.012*	0.009	0.018*	-0.000	-0.001	0.006	0.025*
1972	-0.014	-0.012*	0.008	0.018*	0.002	-0.001	0.006	0.025*
1973	-0.014	-0.012*	0.006	0.017*	0.004	-0.001	0.006	0.025*
1974	-0.013	-0.012*	0.004	0.017*	0.009	-0.001	0.006	0.025*
1975	-0.013*	-0.012*	0.003	0.016*	0.010	-0.001	0.006	0.025*
1976	-0.011	-0.012*	0.002	0.016	0.011	-0.001	0.006	0.025*
1977	-0.004	-0.012*	-0.001	0.015	0.015	-0.001	0.006	0.025*
1978	-0.003	-0.012*	-0.002	0.015	0.016	-0.001	0.006	0.025*
1979	-0.003	-0.012*	-0.004	0.015	0.019	-0.001	0.006	0.025*
1980	-0.003	-0.012*	-0.004	0.014	0.020	-0.001	0.006	0.025*
1981	0.000	-0.012	-0.003	0.013	0.024	-0.001	0.006	0.025*
1982	0.009	-0.012	-0.003	0.011	0.025	-0.001	0.006	0.025*
1983	0.011	-0.012	-0.003	0.011	0.026	-0.001	0.006	0.025*
1984	0.017	-0.012	-0.001	0.010	0.028	-0.001	0.006	0.025*
1985	0.018	-0.012	-0.001	0.010	0.028	-0.001	0.006	0.025*
1986	0.018	-0.012	-0.001	0.010	0.028	-0.001	0.006	0.025*

* Indicates coefficient is significant at $P \leq 0.05$.

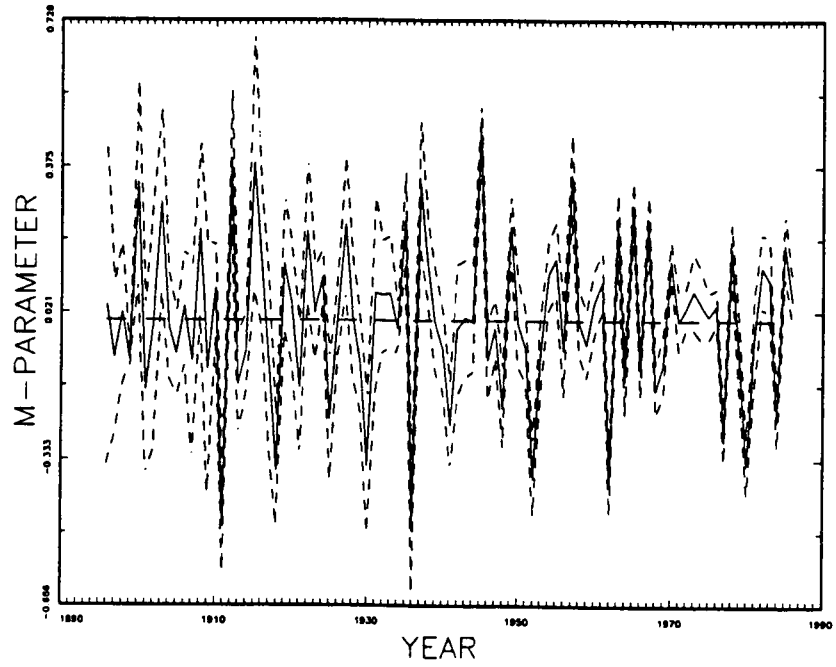


Figure A94. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes chestnut oak, cluster 1.

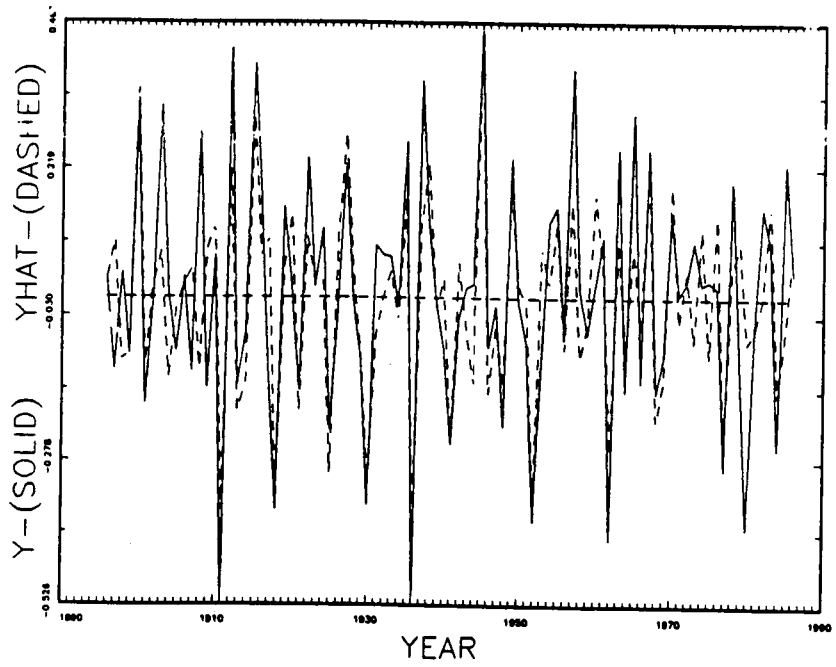
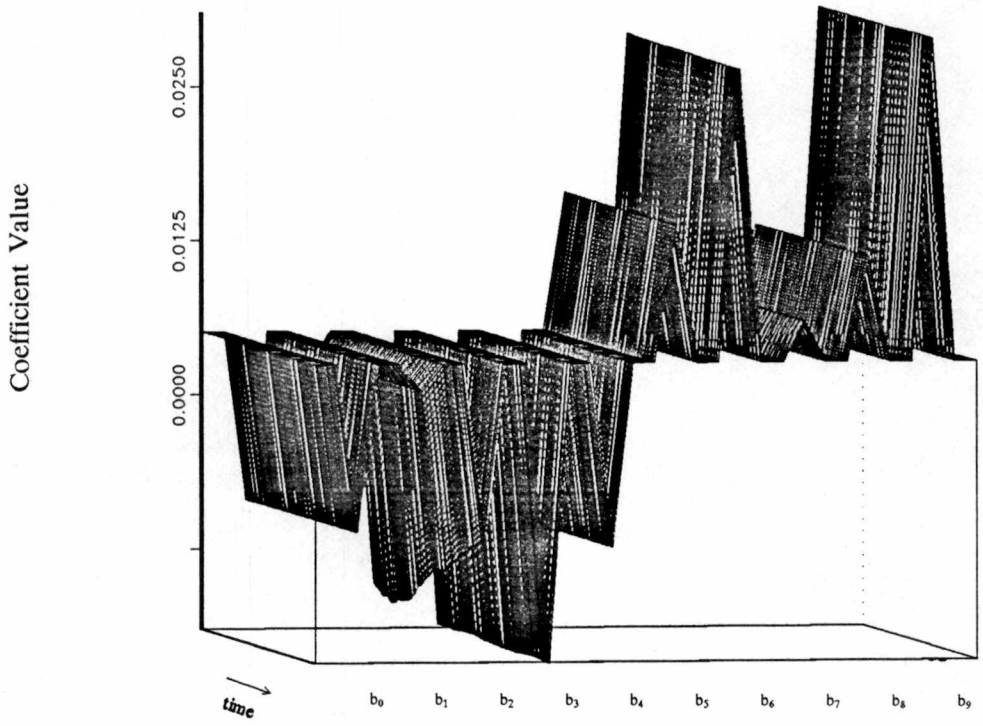


Figure A95. Graph of predicted and actual standardized growth, Land Between the Lakes chestnut oak, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = April temperature
b_2 = May temperature
b_3 = June temperature
b_4 = August temperature
b_5 = May rain
b_6 = June rain
b_7 = past February rain
b_8 = past June rain
b_9 = past August rain

Figure A96. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes chestnut oak, cluster 1.

Table A32. Climate parameter estimates for LBL chestnut oak, cluster 1.

YEAR	April temp. b_1	May temp. b_2	June temp. b_3	August temp. b_4	May rain b_5	June rain b_6	February rain b_7	Past June rain b_8	Past August rain b_9
1897	0.003	-0.015	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1898	0.003	-0.016	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1899	0.003	-0.016	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1900	0.003	-0.016	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1901	0.003	-0.016	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1902	0.003	-0.016	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1903	0.003	-0.016	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1904	0.003	-0.016	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1905	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1906	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1907	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1908	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1909	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1910	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1911	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1912	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1913	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1914	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1915	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1916	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1917	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1918	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1919	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1920	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1921	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1922	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1923	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1924	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.009	0.014	0.031*
1925	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1926	0.003	-0.016*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1927	0.003	-0.015*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1928	0.003	-0.015*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1929	0.003	-0.015*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1930	0.003	-0.015*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1931	0.003	-0.015*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1932	0.003	-0.015*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1933	0.003	-0.014*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1934	0.003	-0.014*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1935	0.003	-0.014*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1936	0.003	-0.014*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1937	0.003	-0.014*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1938	0.003	-0.014*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1939	0.003	-0.014*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1940	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1941	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1942	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1943	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1944	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1945	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1946	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1947	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1948	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1949	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1950	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1951	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*

Table A32. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9
1952	0.003	-0.013*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1953	0.003	-0.012*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1954	0.003	-0.012*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1955	0.003	-0.012*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1956	0.003	-0.012*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1957	0.003	-0.012*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1958	0.003	-0.012*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1959	0.003	-0.012*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1960	0.003	-0.012*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1961	0.003	-0.012*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1962	0.003	-0.012*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1963	0.003	-0.011*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1964	0.003	-0.011*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1965	0.003	-0.011*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1966	0.003	-0.011*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1967	0.003	-0.011*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1968	0.003	-0.011*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1969	0.003	-0.011*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1970	0.003	-0.011*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1971	0.003	-0.011*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1972	0.003	-0.010*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1973	0.003	-0.010*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1974	0.003	-0.010*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1975	0.003	-0.010*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1976	0.003	-0.010*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1977	0.003	-0.010*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1978	0.003	-0.010*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1979	0.003	-0.010*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1980	0.003	-0.010*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1981	0.003	-0.009*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1982	0.003	-0.009*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1983	0.003	-0.009*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1984	0.003	-0.009*	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1985	0.003	-0.009	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*
1986	0.003	-0.009	-0.019*	-0.010*	0.016*	0.029*	0.008	0.014	0.031*

* Indicates coefficient is signficant at $P \leq 0.05$.

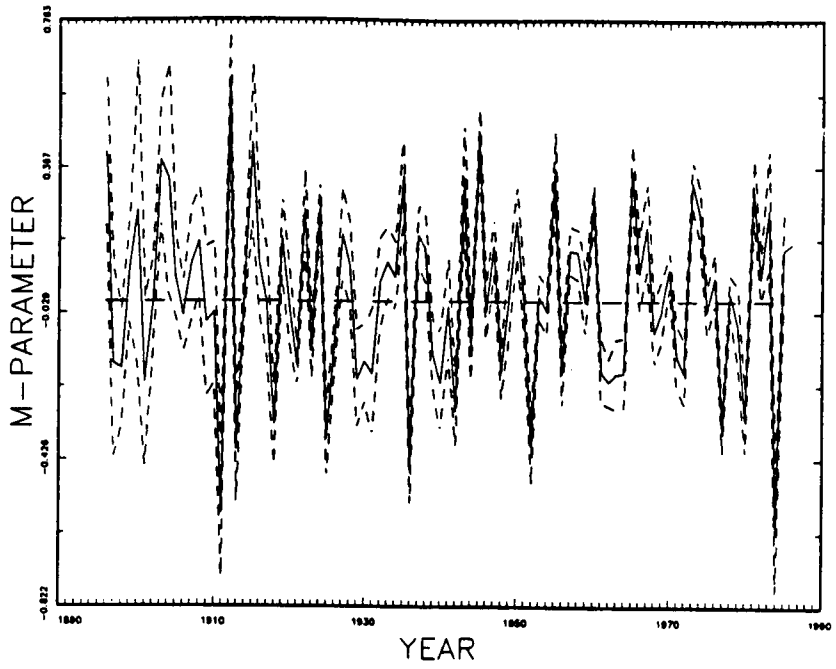


Figure A97. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes chestnut oak, cluster 2.

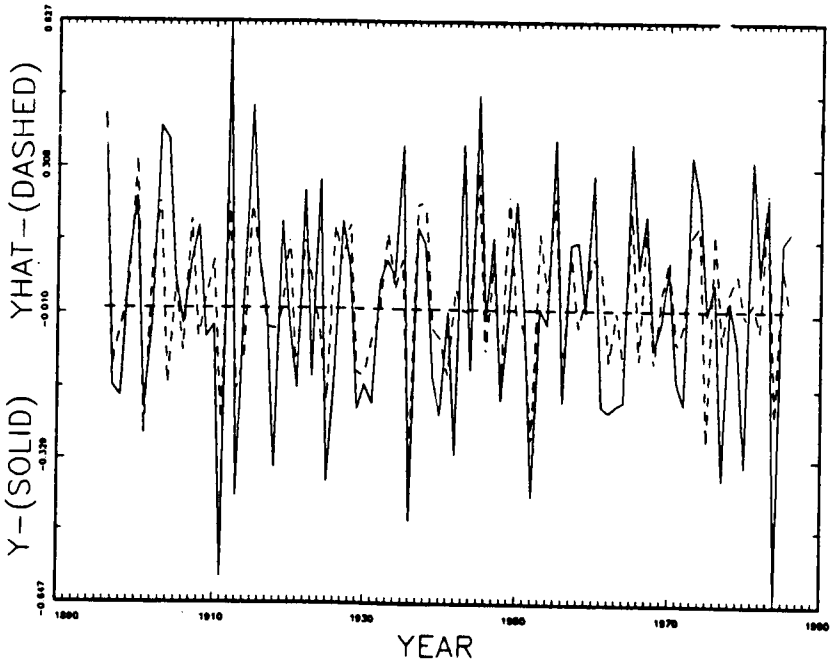
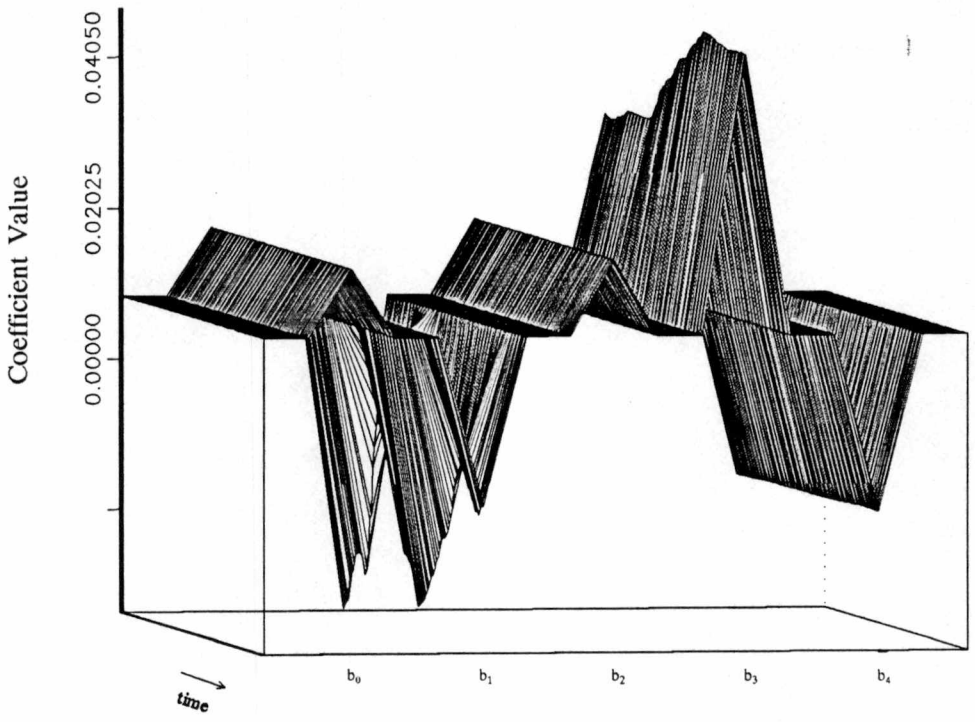


Figure A98. Graph of predicted and actual standardized growth, Land Between the Lakes chestnut oak, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = May rain
b_3 = June rain
b_4 = October rain

Figure A99. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes chestnut oak, cluster 2.

Table A33. Climate parameter estimates for LBL chestnut oak, cluster 2.

YEAR	June temperature b_1	May rain b_2	June rain b_3	October rain b_4
1897	-0.033	0.019*	0.032	-0.016
1898	-0.033	0.019*	0.032	-0.016
1899	-0.032	0.019*	0.032	-0.016
1900	-0.029	0.019*	0.032	-0.016
1901	-0.029	0.019*	0.032	-0.016
1902	-0.028	0.019*	0.032	-0.016
1903	-0.027	0.019*	0.032	-0.016
1904	-0.026	0.019*	0.033	-0.016
1905	-0.026	0.019*	0.033	-0.016
1906	-0.026	0.019*	0.033	-0.016
1907	-0.026	0.019*	0.033	-0.016
1908	-0.026	0.019*	0.033	-0.016
1909	-0.027	0.019*	0.033	-0.016
1910	-0.028	0.019*	0.033*	-0.016
1911	-0.027	0.019*	0.034*	-0.016
1912	-0.025	0.019*	0.034*	-0.016
1913	-0.021	0.019*	0.034*	-0.016
1914	-0.020	0.019*	0.034*	-0.016
1915	-0.014	0.019*	0.034*	-0.016
1916	-0.011	0.019*	0.034*	-0.016
1917	-0.008	0.019*	0.034*	-0.016
1918	-0.005	0.019*	0.034*	-0.016
1919	-0.003	0.019*	0.034*	-0.016
1920	-0.002	0.019*	0.034*	-0.016
1921	-0.001	0.019*	0.034*	-0.016
1922	0.001	0.019*	0.034*	-0.016
1923	0.001	0.019*	0.034*	-0.016
1924	0.001	0.019*	0.034*	-0.016
1925	0.002	0.019*	0.034*	-0.016
1926	0.001	0.019*	0.034*	-0.016
1927	-0.002	0.019*	0.035*	-0.016
1928	-0.005	0.019*	0.035*	-0.016
1929	-0.008	0.019*	0.036*	-0.016
1930	-0.011	0.019*	0.036*	-0.016
1931	-0.016	0.019*	0.037*	-0.016
1932	-0.019	0.019*	0.038*	-0.016
1933	-0.021	0.019*	0.038*	-0.016
1934	-0.022	0.019*	0.039*	-0.016
1935	-0.024	0.019*	0.039*	-0.016
1936	-0.024	0.019*	0.039*	-0.016
1937	-0.024	0.019*	0.040*	-0.016
1938	-0.025	0.019*	0.040*	-0.016
1939	-0.025	0.019*	0.040*	-0.016
1940	-0.026	0.019*	0.041*	-0.016
1941	-0.027	0.019*	0.041*	-0.016
1942	-0.027	0.019*	0.042*	-0.016
1943	-0.029*	0.019*	0.042*	-0.016
1944	-0.030*	0.019*	0.043*	-0.016
1945	-0.030*	0.019*	0.043*	-0.016
1946	-0.030*	0.019*	0.043*	-0.016
1947	-0.030*	0.019*	0.043*	-0.016
1948	-0.029*	0.019*	0.043*	-0.016
1949	-0.029*	0.019*	0.044*	-0.016
1950	-0.028*	0.019*	0.044*	-0.016
1951	-0.027*	0.019*	0.045*	-0.016

Table A33. Continued.

YEAR	b_1	b_2	b_3	b_4
1952	-0.026*	0.019*	0.045*	-0.016
1953	-0.026*	0.019*	0.045*	-0.016
1954	-0.026*	0.019*	0.045*	-0.016
1955	-0.025*	0.019*	0.046*	-0.016
1956	-0.023	0.019*	0.046*	-0.016
1957	-0.023	0.019*	0.046*	-0.016
1958	-0.022	0.019*	0.047*	-0.016
1959	-0.020	0.019*	0.047*	-0.016
1960	-0.020	0.019*	0.047*	-0.016
1961	-0.020	0.019*	0.047*	-0.016
1962	-0.020	0.019*	0.047*	-0.016
1963	-0.019	0.019*	0.047*	-0.016
1964	-0.018	0.019*	0.047*	-0.016
1965	-0.017	0.019*	0.047*	-0.016
1966	-0.016	0.019*	0.047*	-0.016
1967	-0.014	0.019*	0.047*	-0.015
1968	-0.012	0.019*	0.046*	-0.015
1969	-0.011	0.019*	0.046*	-0.015
1970	-0.011	0.019*	0.046*	-0.015
1971	-0.010	0.019*	0.046*	-0.015
1972	-0.009	0.019*	0.046*	-0.015
1973	-0.010	0.019*	0.046*	-0.015
1974	-0.010	0.019*	0.046*	-0.015
1975	-0.011	0.019*	0.046*	-0.015
1976	-0.012	0.019*	0.046*	-0.015
1977	-0.013	0.019*	0.046*	-0.015
1978	-0.013	0.019*	0.046*	-0.015
1979	-0.014	0.019*	0.046*	-0.015
1980	-0.014	0.019*	0.046*	-0.015
1981	-0.015	0.019*	0.046*	-0.015
1982	-0.015	0.019*	0.046*	-0.015
1983	-0.016	0.019*	0.046*	-0.015
1984	-0.015	0.019*	0.046*	-0.015
1985	-0.014	0.019*	0.046*	-0.015
1986	-0.014	0.019*	0.046*	-0.015

* Indicates coefficient is significant at $P \leq 0.05$.

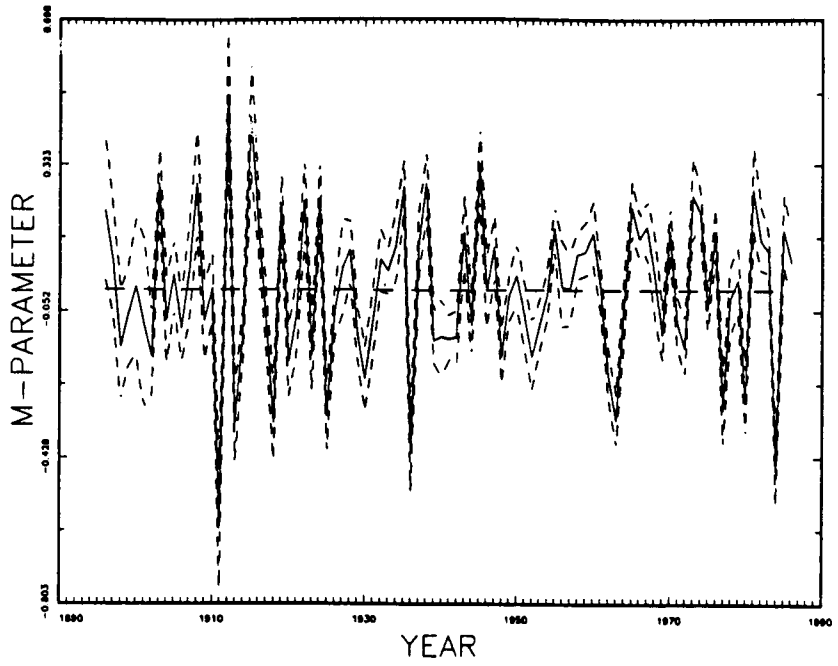


Figure A100. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes chestnut oak, cluster 3.

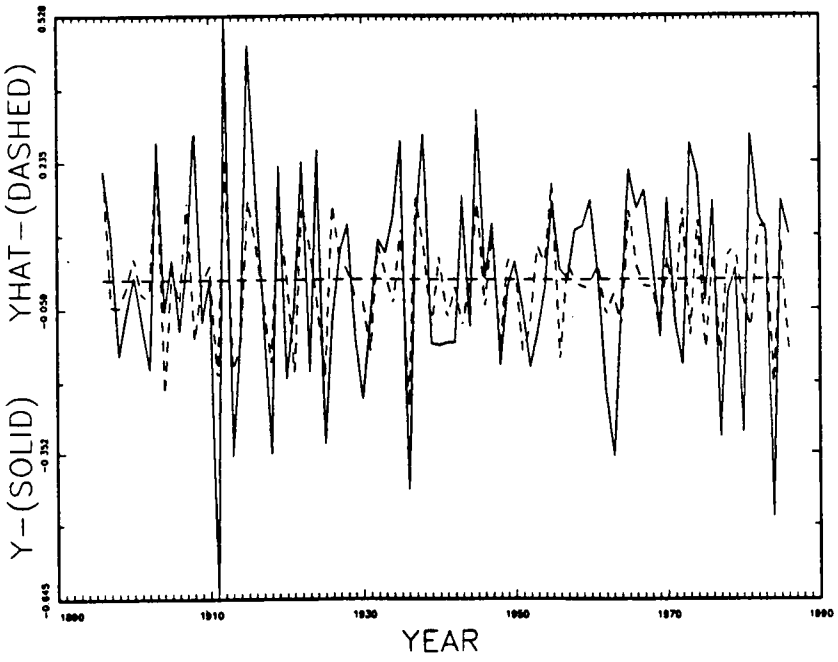


Figure A101. Graph of predicted and actual standardized growth, Land Between the Lakes chestnut oak, cluster 3.

Table A34. Climate parameter estimates for LBL chestnut oak, cluster 3.

YEAR	June temperature b_1	Past December temperature b_2	May rain b_3	October rain b_4
1897	-0.027*	0.008*	0.010	-0.003
1898	-0.027*	0.008*	0.010	-0.003
1899	-0.027*	0.008*	0.010	-0.003
1900	-0.027*	0.008*	0.010	-0.003
1901	-0.027*	0.008*	0.010	-0.003
1902	-0.027*	0.008*	0.010	-0.003
1903	-0.027*	0.008*	0.010	-0.003
1904	-0.027*	0.008*	0.010	-0.003
1905	-0.027*	0.008*	0.010	-0.003
1906	-0.027*	0.008*	0.010	-0.003
1907	-0.027*	0.008*	0.010	-0.003
1908	-0.027*	0.008*	0.010	-0.003
1909	-0.027*	0.008*	0.010	-0.003
1910	-0.027*	0.008*	0.010	-0.003
1911	-0.027*	0.008*	0.010	-0.003
1912	-0.027*	0.008*	0.010	-0.003
1913	-0.027*	0.008*	0.010	-0.003
1914	-0.027*	0.008*	0.010	-0.003
1915	-0.027*	0.008*	0.010	-0.003
1916	-0.027*	0.008*	0.010	-0.003
1917	-0.027*	0.008*	0.010	-0.003
1918	-0.027*	0.008*	0.010	-0.003
1919	-0.027*	0.008*	0.010	-0.003
1920	-0.027*	0.008*	0.010	-0.003
1921	-0.027*	0.008*	0.010	-0.003
1922	-0.027*	0.008*	0.010	-0.003
1923	-0.027*	0.008*	0.010	-0.003
1924	-0.027*	0.008*	0.010	-0.003
1925	-0.027*	0.008*	0.010	-0.003
1926	-0.027*	0.008*	0.010	-0.003
1927	-0.027*	0.008*	0.010	-0.003
1928	-0.027*	0.008*	0.010	-0.003
1929	-0.027*	0.008*	0.010	-0.003
1930	-0.027*	0.008*	0.010	-0.003
1931	-0.027*	0.008*	0.010	-0.003
1932	-0.027*	0.008*	0.010	-0.003
1933	-0.027*	0.008*	0.010	-0.003
1934	-0.027*	0.007*	0.010	-0.003
1935	-0.027*	0.007*	0.010	-0.003
1936	-0.027*	0.007*	0.010	-0.003
1937	-0.027*	0.007*	0.010	-0.003
1938	-0.027*	0.007*	0.010	-0.003
1939	-0.027*	0.007*	0.010	-0.003
1940	-0.027*	0.007*	0.010	-0.003
1941	-0.027*	0.007*	0.010	-0.003
1942	-0.027*	0.007*	0.010	-0.003
1943	-0.027*	0.007*	0.010	-0.003
1944	-0.027*	0.007*	0.010	-0.003
1945	-0.027*	0.007*	0.010	-0.003
1946	-0.027*	0.007*	0.010	-0.003
1947	-0.027*	0.007*	0.010	-0.003
1948	-0.027*	0.007*	0.010	-0.003
1949	-0.027*	0.007*	0.010	-0.003
1950	-0.027*	0.007*	0.010	-0.003

Table A34. Continued.

YEAR	b_1	b_2	b_3	b_4
1951	-0.027*	0.007*	0.010	-0.003
1952	-0.027*	0.007*	0.010	-0.003
1953	-0.027*	0.007*	0.010	-0.003
1954	-0.027*	0.007*	0.010	-0.003
1955	-0.027*	0.007*	0.010	-0.003
1956	-0.027*	0.007*	0.010	-0.003
1957	-0.027*	0.007*	0.010	-0.003
1958	-0.027*	0.007*	0.010	-0.003
1959	-0.027*	0.007*	0.010	-0.003
1960	-0.027*	0.007*	0.010	-0.002
1961	-0.027*	0.007*	0.010	-0.002
1962	-0.027*	0.007*	0.010	-0.002
1963	-0.027*	0.007*	0.010	-0.002
1964	-0.027*	0.007*	0.010	-0.002
1965	-0.027*	0.007*	0.010	-0.002
1966	-0.027*	0.007*	0.010	-0.002
1967	-0.027*	0.007*	0.010	-0.002
1968	-0.027*	0.007*	0.010	-0.002
1969	-0.027*	0.007*	0.010	-0.002
1970	-0.027*	0.007*	0.010	-0.002
1971	-0.027*	0.007*	0.010	-0.002
1972	-0.027*	0.007*	0.010	-0.002
1973	-0.027*	0.007*	0.010	-0.002
1974	-0.027*	0.007*	0.010	-0.002
1975	-0.027*	0.007*	0.010	-0.002
1976	-0.027*	0.007*	0.010	-0.002
1977	-0.027*	0.007*	0.010	-0.002
1978	-0.027*	0.007*	0.010	-0.002
1979	-0.027*	0.007*	0.010	-0.002
1980	-0.027*	0.007*	0.010	-0.002
1981	-0.027*	0.007*	0.010	-0.002
1982	-0.027*	0.007*	0.010	-0.002
1983	-0.027*	0.007*	0.010	-0.002
1984	-0.027*	0.007*	0.010	-0.002
1985	-0.027*	0.007*	0.010	-0.002
1986	-0.027*	0.007*	0.010	-0.002

* Indicates coefficient is significant at $P \leq 0.05$.

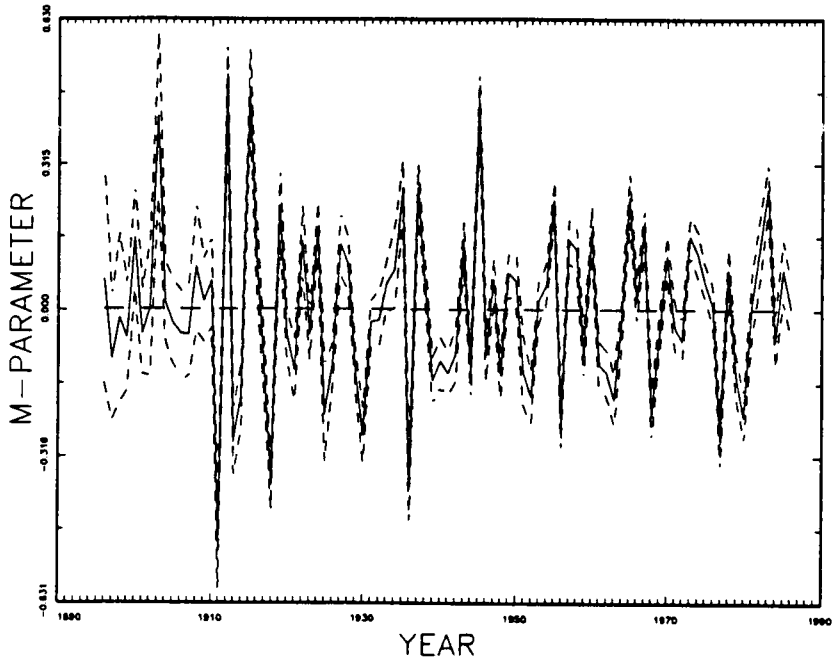


Figure A103. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes chestnut oak, cluster 4.

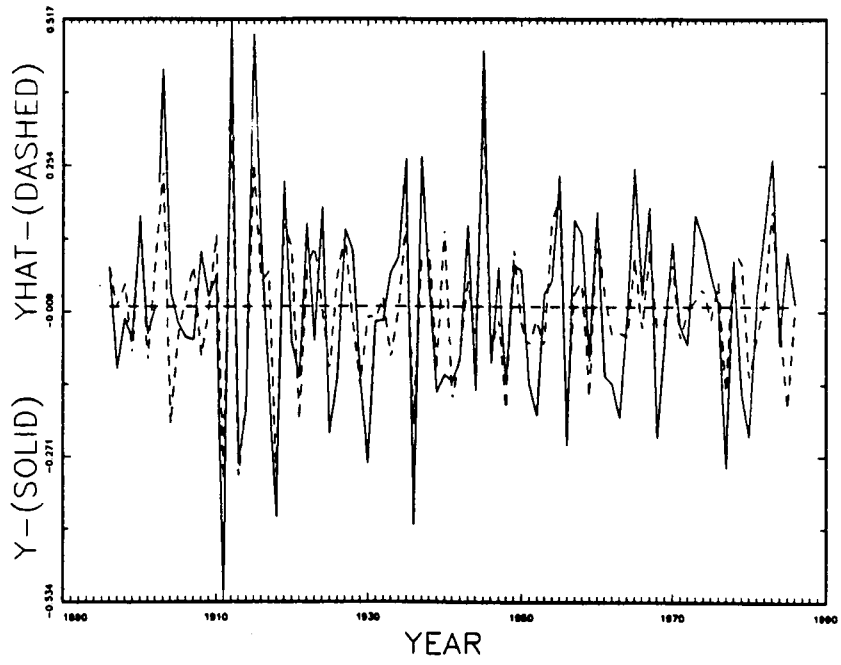
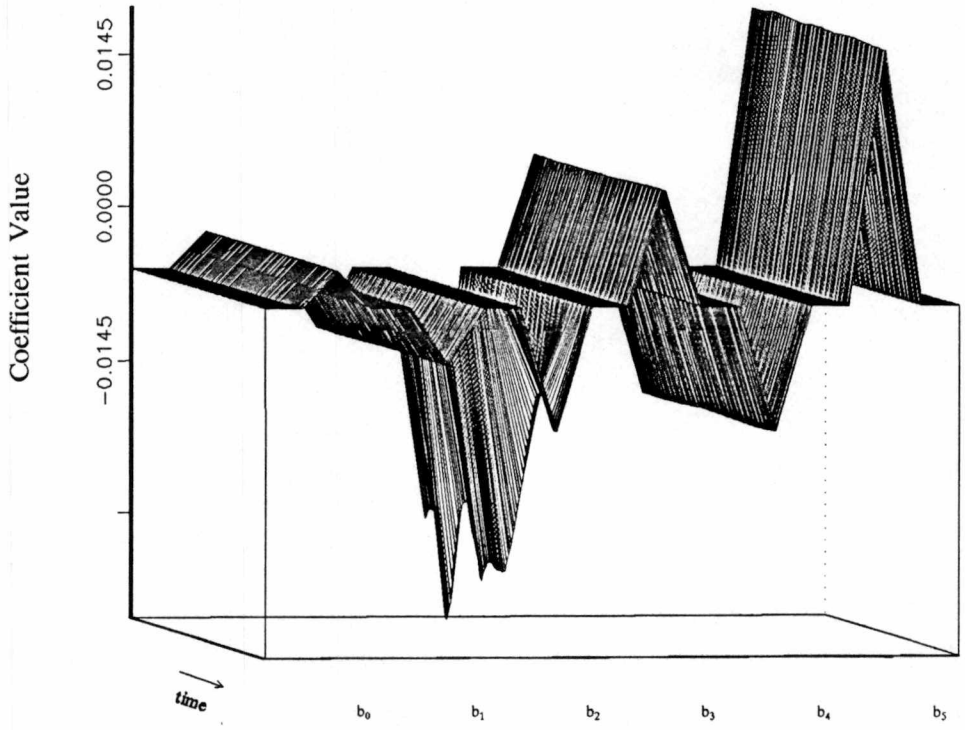


Figure A104. Graph of predicted and actual standardized growth, Land Between the Lakes chestnut oak, cluster 4.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = past March temperature
b_4 = past July rain
b_5 = past December rain

Figure A105. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes chestnut oak, cluster 4.

Table A35. Climate parameter estimates for LBL chestnut oak, cluster 4.

YEAR	May temp. b_1	June temp. b_2	Past March temp. b_3	Past July rain b_4	Past December rain b_5
1897	-0.011*	-0.029	0.005	-0.018*	0.019*
1898	-0.011*	-0.029	0.005	-0.018*	0.019*
1899	-0.011*	-0.029	0.005	-0.018*	0.019*
1900	-0.011*	-0.029	0.005	-0.018*	0.019*
1901	-0.011*	-0.029	0.005	-0.018*	0.019*
1902	-0.011*	-0.029	0.005	-0.018*	0.019*
1903	-0.011*	-0.028	0.005	-0.018*	0.019*
1904	-0.011*	-0.029	0.005	-0.018*	0.019*
1905	-0.011*	-0.030	0.005	-0.018*	0.019*
1906	-0.011*	-0.030*	0.005	-0.018*	0.019*
1907	-0.011*	-0.032*	0.005	-0.018*	0.019*
1908	-0.011*	-0.035*	0.005	-0.018*	0.019*
1909	-0.011*	-0.037*	0.005	-0.018*	0.019*
1910	-0.011*	-0.038*	0.005	-0.018*	0.019*
1911	-0.011*	-0.039*	0.005	-0.018*	0.019*
1912	-0.011*	-0.038*	0.005	-0.018*	0.019*
1913	-0.011*	-0.037*	0.005	-0.018*	0.019*
1914	-0.011*	-0.037*	0.005	-0.018*	0.019*
1915	-0.011*	-0.035*	0.005	-0.018*	0.019*
1916	-0.011*	-0.033*	0.005	-0.018*	0.019*
1917	-0.011*	-0.032*	0.005	-0.018*	0.019*
1918	-0.011*	-0.031*	0.005	-0.018*	0.019*
1919	-0.011*	-0.029*	0.005	-0.018*	0.019*
1920	-0.011*	-0.028*	0.005	-0.018*	0.019*
1921	-0.011*	-0.028*	0.005	-0.018*	0.019*
1922	-0.011*	-0.027*	0.005	-0.018*	0.019*
1923	-0.011*	-0.027*	0.005	-0.018*	0.019*
1924	-0.011*	-0.027*	0.005	-0.018*	0.019*
1925	-0.011*	-0.027*	0.005	-0.018*	0.019*
1926	-0.011*	-0.027*	0.005	-0.018*	0.019*
1927	-0.011*	-0.029*	0.005	-0.018*	0.019*
1928	-0.011*	-0.029*	0.005	-0.018*	0.019*
1929	-0.011*	-0.030*	0.005	-0.018*	0.019*
1930	-0.011*	-0.031*	0.005	-0.018*	0.019*
1931	-0.011*	-0.031*	0.005	-0.018*	0.019*
1932	-0.011*	-0.032*	0.005	-0.018*	0.019*
1933	-0.011*	-0.032*	0.005	-0.018*	0.019*
1934	-0.011*	-0.034*	0.005	-0.018*	0.019*
1935	-0.011*	-0.034*	0.005	-0.018*	0.019*
1936	-0.011*	-0.033*	0.005	-0.018*	0.019*
1937	-0.011*	-0.033*	0.005	-0.018*	0.019*
1938	-0.011*	-0.032*	0.005	-0.018*	0.019*
1939	-0.011*	-0.032*	0.005	-0.018*	0.019*
1940	-0.011*	-0.032*	0.005	-0.018*	0.019*
1941	-0.011*	-0.032*	0.005	-0.018*	0.019*
1942	-0.011*	-0.032*	0.005	-0.018*	0.019*
1943	-0.011*	-0.032*	0.005	-0.018*	0.019*
1944	-0.011*	-0.032*	0.005	-0.018*	0.019*
1945	-0.011*	-0.032*	0.005	-0.018*	0.019*
1946	-0.011*	-0.032*	0.005	-0.018*	0.019*
1947	-0.011*	-0.032*	0.005	-0.018*	0.019*
1948	-0.011*	-0.032*	0.005	-0.018*	0.019*
1949	-0.011*	-0.033*	0.005	-0.018*	0.019*
1950	-0.011*	-0.032*	0.005	-0.018*	0.018*
1951	-0.011*	-0.032*	0.005	-0.018*	0.018*

Table A35. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5
1952	-0.011*	-0.031*	0.005	-0.018*	0.018*
1953	-0.011*	-0.031*	0.005	-0.018*	0.018*
1954	-0.011*	-0.030*	0.005	-0.018*	0.018*
1955	-0.011*	-0.030*	0.005	-0.018*	0.019*
1956	-0.011*	-0.029*	0.005	-0.018*	0.019*
1957	-0.011*	-0.028*	0.005	-0.018*	0.019*
1958	-0.011*	-0.027*	0.005	-0.018*	0.019*
1959	-0.011*	-0.026*	0.005	-0.018*	0.019*
1960	-0.011*	-0.025*	0.005*	-0.018*	0.019*
1961	-0.011*	-0.025*	0.005*	-0.018*	0.019*
1962	-0.011*	-0.024*	0.005*	-0.018*	0.019*
1963	-0.011*	-0.023*	0.005*	-0.018*	0.019*
1964	-0.011*	-0.022*	0.005*	-0.018*	0.019*
1965	-0.011*	-0.021*	0.005	-0.018*	0.019*
1966	-0.011*	-0.020*	0.005*	-0.018*	0.019*
1967	-0.011*	-0.019*	0.005	-0.018*	0.019*
1968	-0.011*	-0.018*	0.005	-0.018*	0.019*
1969	-0.011*	-0.017*	0.005	-0.018*	0.018*
1970	-0.011*	-0.016*	0.005	-0.018*	0.018*
1971	-0.011*	-0.015	0.005	-0.018*	0.018*
1972	-0.011*	-0.015	0.005	-0.018*	0.018*
1973	-0.011*	-0.015	0.005	-0.018*	0.018*
1974	-0.011*	-0.014	0.005	-0.018*	0.018*
1975	-0.011*	-0.014	0.005	-0.018*	0.018*
1976	-0.011*	-0.015	0.005	-0.018*	0.018*
1977	-0.011*	-0.015	0.005	-0.018*	0.018*
1978	-0.011*	-0.015	0.005	-0.018*	0.018*
1979	-0.011*	-0.015	0.005	-0.018*	0.018*
1980	-0.011*	-0.016	0.005	-0.018*	0.018*
1981	-0.011*	-0.017	0.005	-0.018*	0.018*
1982	-0.011*	-0.017	0.005	-0.018*	0.018*
1983	-0.011*	-0.017	0.005	-0.018*	0.018*
1984	-0.011*	-0.018	0.005	-0.018*	0.018*
1985	-0.011*	-0.018	0.005	-0.018*	0.018*
1986	-0.011*	-0.018	0.005	-0.018*	0.018*

* Indicates coefficient is significant at $P \leq 0.05$.

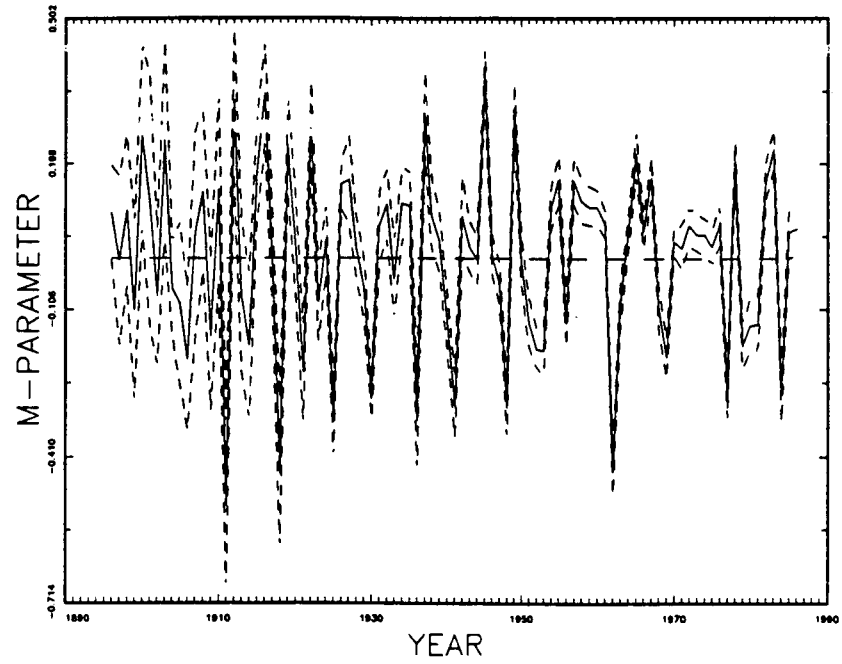


Figure A106. Graph of M-parameter and associated 95% confidence interval over time, Wayne County chestnut oak, cluster 1.

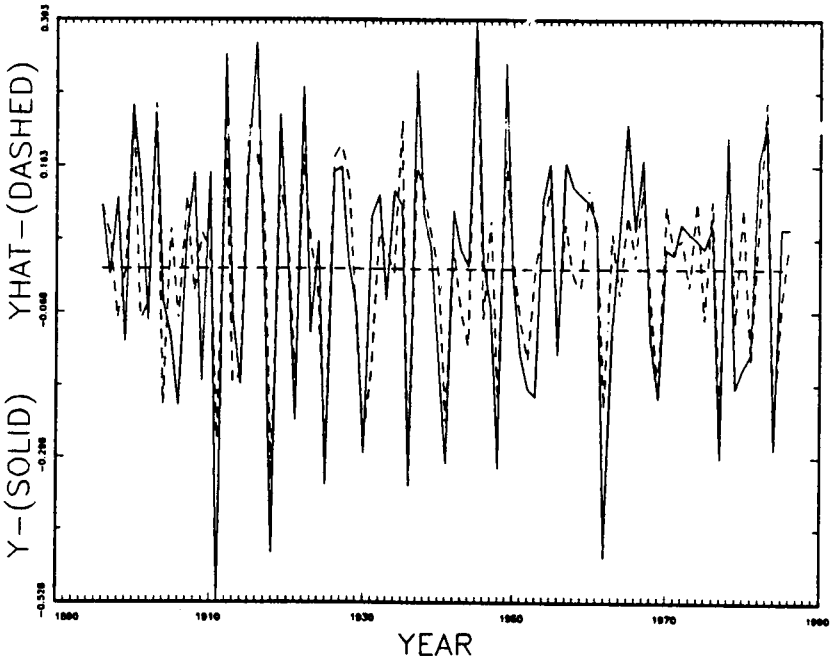
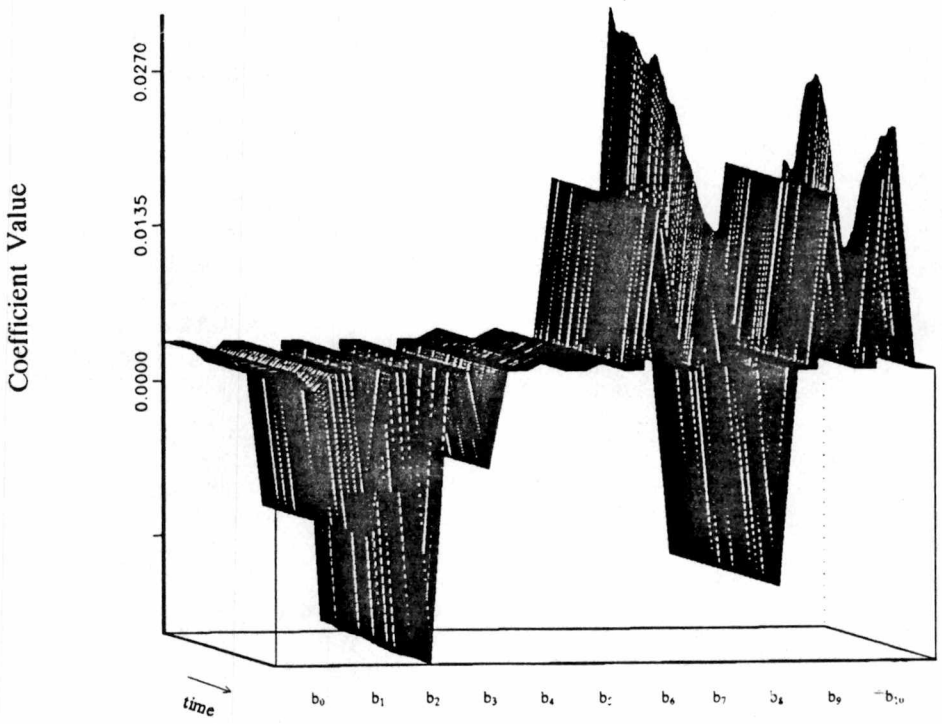


Figure A107. Graph of predicted and actual standardized growth, Wayne County chestnut oak, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = October temperature
b_4 = past March temperature
b_5 = past December temperature
b_6 = May rain
b_7 = June rain
b_8 = September rain
b_9 = past June rain
b_{10} = past August rain

Figure A108. Three dimensional graph of changes in parameter coefficients over time, Wayne County chestnut oak, cluster 1.

Table A36. Climate parameter estimates for Wayne County chestnut oak, cluster 1.

YEAR	May temp. b_1	June temp. b_2	October temp. b_3	Past March temp. b_4	Past December temp. b_5	May rain b_6	June rain b_7	September rain b_8	Past June rain b_9	Past August rain b_{10}
1897	-0.011*	-0.021*	-0.005	0.004	0.004	0.017*	0.032	-0.015*	0.018*	0.019
1898	-0.011*	-0.021*	-0.005	0.004	0.004	0.017*	0.032	-0.015*	0.018*	0.019
1899	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.031	-0.015*	0.018*	0.018
1900	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.031	-0.015*	0.018*	0.018
1901	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.018
1902	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.018
1903	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.018
1904	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.018
1905	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.019
1906	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.019
1907	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.020
1908	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.021
1909	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.022
1910	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.023
1911	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.024
1912	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.024
1913	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030	-0.015*	0.018*	0.025
1914	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030*	-0.015*	0.018*	0.025
1915	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030*	-0.015*	0.018*	0.026
1916	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030*	-0.015*	0.018*	0.026
1917	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.030*	-0.015*	0.018*	0.026
1918	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.026
1919	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.026
1920	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.026
1921	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.027*
1922	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.027*
1923	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.027*
1924	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.028*	-0.015*	0.018*	0.027*
1925	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.028*	-0.015*	0.018*	0.026*
1926	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.028*	-0.015*	0.018*	0.026*
1927	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.028*	-0.015*	0.018*	0.026*
1928	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.028*	-0.015*	0.018*	0.025*

Table A36. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}
1929	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.025*
1930	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.024*
1931	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.023*
1932	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.022
1933	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.021
1934	-0.011*	-0.021*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.020
1935	-0.011*	-0.022*	-0.005	0.004*	0.004	0.017*	0.029*	-0.015*	0.018*	0.019
1936	-0.011*	-0.022*	-0.005	0.004*	0.004	0.017*	0.028*	-0.015*	0.018*	0.018
1937	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.028*	-0.015*	0.018*	0.017
1938	-0.011*	-0.022*	-0.005	0.004*	0.004	0.017*	0.028*	-0.015*	0.018*	0.016
1939	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.027*	-0.015*	0.018*	0.016
1940	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.027*	-0.015*	0.018*	0.015
1941	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.027*	-0.015*	0.018*	0.014
1942	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.026*	-0.015*	0.018*	0.013
1943	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.026*	-0.015*	0.018*	0.013
1944	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.025*	-0.015*	0.018*	0.013
1945	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.025*	-0.015*	0.018*	0.013
1946	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.025*	-0.015*	0.018*	0.013
1947	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.025*	-0.015*	0.018*	0.013
1948	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.025*	-0.015*	0.018*	0.013
1949	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.025*	-0.015*	0.018*	0.013
1950	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.024*	-0.015*	0.018*	0.014
1951	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.024*	-0.015*	0.018*	0.014
1952	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.024*	-0.015*	0.018*	0.014
1953	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.023*	-0.015*	0.018*	0.015
1954	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.023*	-0.015*	0.018*	0.015*
1955	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.022*	-0.015*	0.018*	0.016*
1956	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.022*	-0.015*	0.018*	0.017*
1957	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.021*	-0.015*	0.018*	0.017*
1958	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.021*	-0.015*	0.018*	0.018*
1959	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.021*	-0.015*	0.018*	0.019*
1960	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.021*	-0.015*	0.018*	0.019*
1961	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.020*	-0.015*	0.018*	0.019*
1962	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.020*	-0.015*	0.018*	0.020*
1963	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.020*	-0.015*	0.018*	0.020*
1964	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.019*	-0.015*	0.018*	0.020*

Table A36. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}
1965	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.019*	-0.015*	0.018*	0.021*
1966	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.019*	-0.015*	0.018*	0.021*
1967	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.018*	-0.015*	0.018*	0.021*
1968	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.018*	-0.015*	0.018*	0.021*
1969	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.017*	-0.015*	0.018*	0.021*
1970	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.017*	-0.015*	0.018*	0.022*
1971	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.017*	-0.015*	0.018*	0.022*
1972	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.017*	-0.015*	0.018*	0.022*
1973	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.016*	-0.015*	0.018*	0.023*
1974	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.016*	-0.015*	0.018*	0.023*
1975	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.016	-0.015*	0.018*	0.023*
1976	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.016	-0.015*	0.018*	0.023*
1977	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.016	-0.015*	0.018*	0.023*
1978	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.016	-0.015*	0.018*	0.023*
1979	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.016	-0.015*	0.018*	0.023*
1980	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.015	-0.015*	0.018*	0.024*
1981	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.015	-0.015*	0.018*	0.024*
1982	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.015	-0.015*	0.018*	0.024*
1983	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.015	-0.015*	0.018*	0.024*
1984	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.016	-0.015*	0.018*	0.024*
1985	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.016	-0.015*	0.018*	0.024*
1986	-0.011*	-0.022*	-0.005	0.004*	0.004*	0.017*	0.016	-0.015*	0.018*	0.024*

* Indicates coefficient is significant at $P \leq 0.05$.

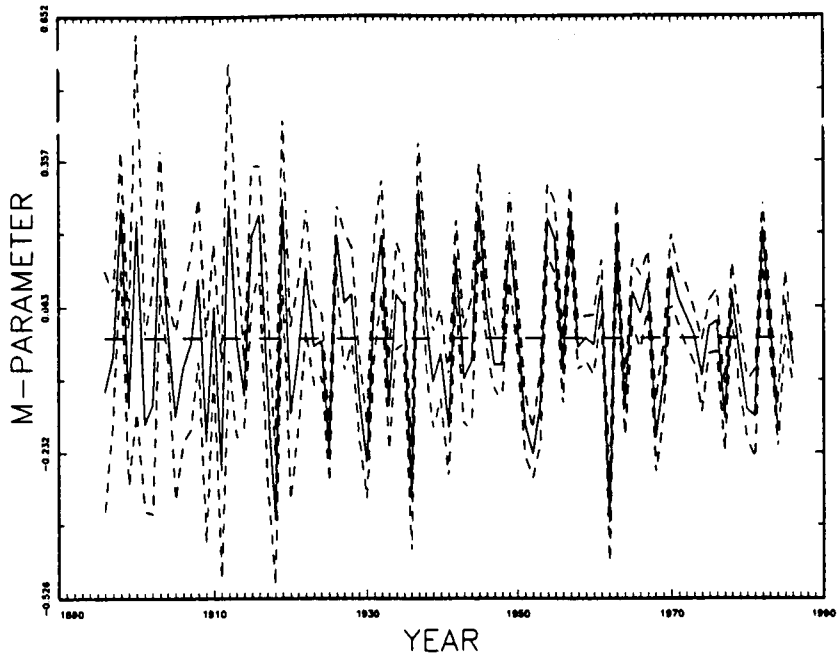


Figure A109. Graph of M-parameter and associated 95% confidence interval over time, Wayne County chestnut oak, cluster 2.

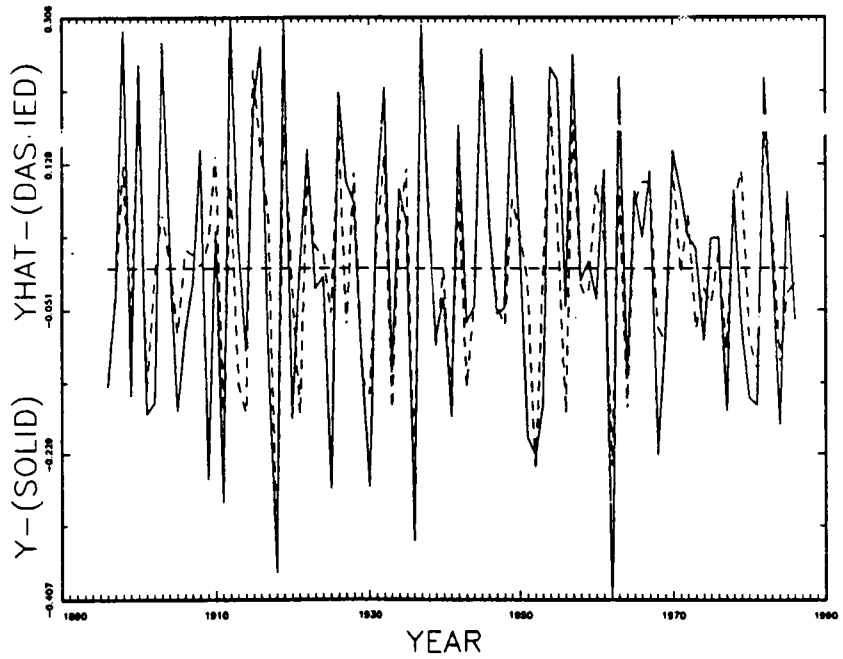
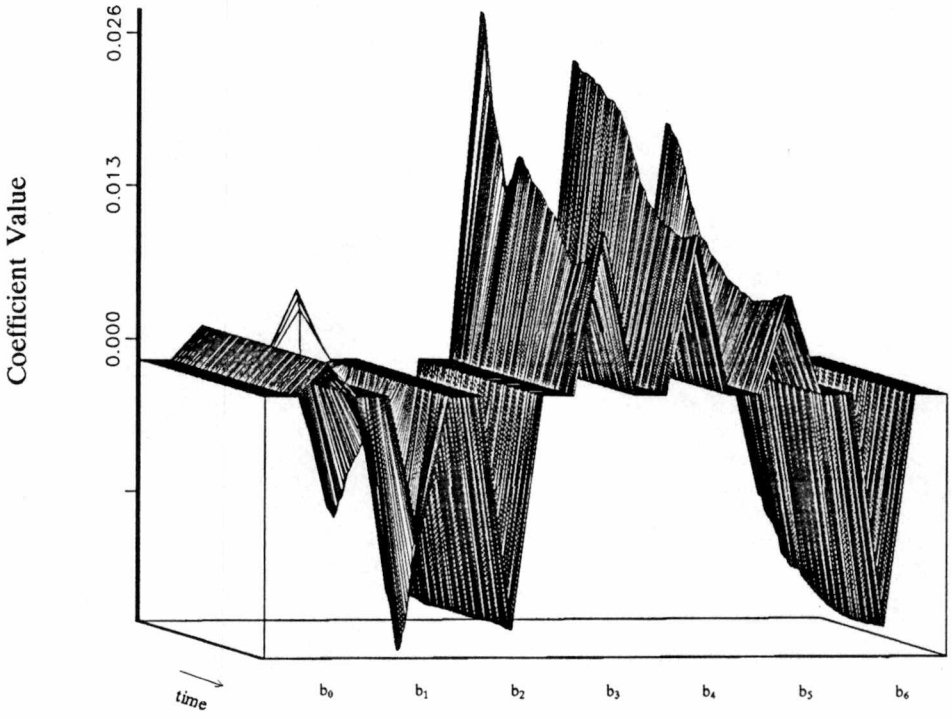


Figure A110. Graph of predicted and actual standardized growth, Wayne County chestnut oak, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = January rain
b_4 = June rain
b_5 = past February rain
b_6 = past March rain

Figure A111. Three dimensional graph of changes in parameter coefficients over time, Wayne County chestnut oak, cluster 2.

Table A37. Climate parameter estimates for Wayne County chestnut oak, cluster 2.

YEAR	May temp. b_1	June temp. b_2	January rain b_3	June rain b_4	Past February rain b_5	Past March rain b_6
1897	0.004	-0.021*	0.028	0.023	0.018	-0.014
1898	0.004	-0.021*	0.027	0.023	0.018	-0.014
1899	0.003	-0.021*	0.027	0.023	0.018	-0.014
1900	-0.003	-0.021*	0.023	0.023	0.017	-0.015
1901	-0.004	-0.021*	0.022	0.023	0.017	-0.015
1902	-0.005	-0.021*	0.020	0.023	0.017	-0.015
1903	-0.005	-0.021*	0.020	0.023	0.017	-0.015*
1904	-0.005	-0.021*	0.020	0.023	0.017	-0.015*
1905	-0.004	-0.021*	0.019	0.023	0.017	-0.015*
1906	-0.004	-0.021*	0.019	0.023	0.016	-0.016*
1907	-0.003	-0.021*	0.018	0.023	0.016	-0.016*
1908	-0.004	-0.021*	0.018	0.023	0.015	-0.016*
1909	-0.005	-0.021*	0.017	0.022	0.015	-0.016*
1910	-0.006	-0.021*	0.017	0.022	0.015	-0.016*
1911	-0.007	-0.021*	0.016	0.022	0.014	-0.017*
1912	-0.009	-0.021*	0.014	0.022*	0.013	-0.018*
1913	-0.010	-0.021*	0.013	0.022*	0.012	-0.018*
1914	-0.010	-0.021*	0.013	0.022*	0.012	-0.018*
1915	-0.010	-0.021*	0.013	0.022*	0.012	-0.018*
1916	-0.011	-0.021*	0.014	0.022*	0.012	-0.018*
1917	-0.012	-0.021*	0.014	0.022*	0.011	-0.018*
1918	-0.013	-0.021*	0.014	0.021*	0.011	-0.019*
1919	-0.013	-0.022*	0.015*	0.021*	0.010	-0.019*
1920	-0.014	-0.022*	0.015*	0.021*	0.010	-0.019*
1921	-0.014	-0.022*	0.016*	0.021*	0.010	-0.019*
1922	-0.014	-0.022*	0.016*	0.021*	0.009	-0.019*
1923	-0.014	-0.022*	0.016*	0.021*	0.009	-0.019*
1924	-0.014	-0.022*	0.016*	0.021*	0.009	-0.019*
1925	-0.014	-0.022*	0.016*	0.021*	0.009	-0.019*
1926	-0.014	-0.022*	0.016*	0.021*	0.009	-0.019*
1927	-0.013	-0.022*	0.016*	0.021*	0.008	-0.019*
1928	-0.013	-0.022*	0.015*	0.020*	0.008	-0.019*
1929	-0.012	-0.022*	0.015*	0.020*	0.008	-0.020*
1930	-0.012	-0.022*	0.015*	0.020*	0.008	-0.020*
1931	-0.011	-0.022*	0.015*	0.020*	0.008	-0.020*
1932	-0.011	-0.022*	0.015*	0.019*	0.008	-0.020*
1933	-0.010	-0.022*	0.014*	0.019*	0.008	-0.020*
1934	-0.010	-0.022*	0.014*	0.019*	0.008	-0.020*
1935	-0.010	-0.022*	0.014*	0.019*	0.007	-0.020*
1936	-0.010	-0.022*	0.014*	0.018*	0.007	-0.020*
1937	-0.009	-0.022*	0.014*	0.018*	0.007	-0.020*
1938	-0.009	-0.022*	0.014*	0.017*	0.007	-0.020*
1939	-0.009	-0.022*	0.014*	0.017*	0.007	-0.021*
1940	-0.009	-0.022*	0.014*	0.017*	0.007	-0.021*
1941	-0.008	-0.022*	0.013*	0.016*	0.006	-0.021*
1942	-0.008	-0.022*	0.013*	0.016*	0.006	-0.021*
1943	-0.008	-0.022*	0.013*	0.016*	0.006	-0.021*
1944	-0.007	-0.022*	0.013*	0.015*	0.006	-0.021*
1945	-0.007	-0.022*	0.013*	0.015*	0.006	-0.021*
1946	-0.007	-0.022*	0.013*	0.014*	0.006	-0.021*
1947	-0.007	-0.022*	0.012*	0.014*	0.006	-0.021*
1948	-0.007	-0.022*	0.012*	0.014*	0.006	-0.021*
1949	-0.007	-0.022*	0.012*	0.014*	0.006	-0.021*

Table A37. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1950	-0.007	-0.022*	0.012*	0.013*	0.006	-0.021*
1951	-0.008	-0.022*	0.012*	0.013*	0.006	-0.021*
1952	-0.008	-0.022*	0.011*	0.013*	0.006	-0.021*
1953	-0.009	-0.022*	0.011*	0.013*	0.006	-0.021*
1954	-0.009	-0.022*	0.010*	0.013*	0.006	-0.021*
1955	-0.011*	-0.022*	0.010*	0.013*	0.006	-0.021*
1956	-0.012*	-0.022*	0.010*	0.012*	0.005	-0.022*
1957	-0.013*	-0.022*	0.010*	0.012*	0.005	-0.022*
1958	-0.014*	-0.022*	0.010*	0.012*	0.005	-0.022*
1959	-0.014*	-0.022*	0.009*	0.012	0.005	-0.022*
1960	-0.016*	-0.022*	0.009*	0.012	0.005	-0.022*
1961	-0.018*	-0.022*	0.009*	0.012	0.005	-0.022*
1962	-0.019*	-0.022*	0.009*	0.012	0.005	-0.022*
1963	-0.020*	-0.022*	0.009*	0.012	0.005	-0.022*
1964	-0.020*	-0.022*	0.009	0.012	0.005	-0.022*
1965	-0.020*	-0.022*	0.009	0.012	0.005	-0.022*
1966	-0.021*	-0.022*	0.009	0.012	0.006	-0.022*
1967	-0.022*	-0.022*	0.009	0.012	0.006	-0.022*
1968	-0.022*	-0.021*	0.009	0.012	0.006	-0.022*
1969	-0.023*	-0.021*	0.009	0.011	0.006	-0.022*
1970	-0.024*	-0.021*	0.009	0.011	0.006	-0.022*
1971	-0.024*	-0.021*	0.009	0.011	0.006	-0.022*
1972	-0.024*	-0.021*	0.009	0.011	0.006	-0.022*
1973	-0.023*	-0.021*	0.009	0.011	0.006	-0.022*
1974	-0.022*	-0.021*	0.009	0.011	0.006	-0.022*
1975	-0.022*	-0.022*	0.010	0.011	0.006	-0.022*
1976	-0.021*	-0.022*	0.010	0.011	0.006	-0.022*
1977	-0.020*	-0.022*	0.010	0.011	0.006	-0.022*
1978	-0.019*	-0.022*	0.010*	0.011	0.006	-0.022*
1979	-0.018*	-0.022*	0.011*	0.011	0.006	-0.022*
1980	-0.017*	-0.022*	0.011*	0.011	0.006	-0.022*
1981	-0.015*	-0.022*	0.012*	0.011	0.006	-0.022*
1982	-0.015*	-0.022*	0.012*	0.012	0.006	-0.022*
1983	-0.014*	-0.022*	0.012*	0.012	0.007	-0.022*
1984	-0.014*	-0.022*	0.012*	0.012	0.007	-0.022*
1985	-0.014*	-0.022*	0.012*	0.012	0.007	-0.021*
1986	-0.014*	-0.022*	0.012*	0.012	0.007	-0.021*

* Indicates coefficient is significant at $P \leq 0.05$.

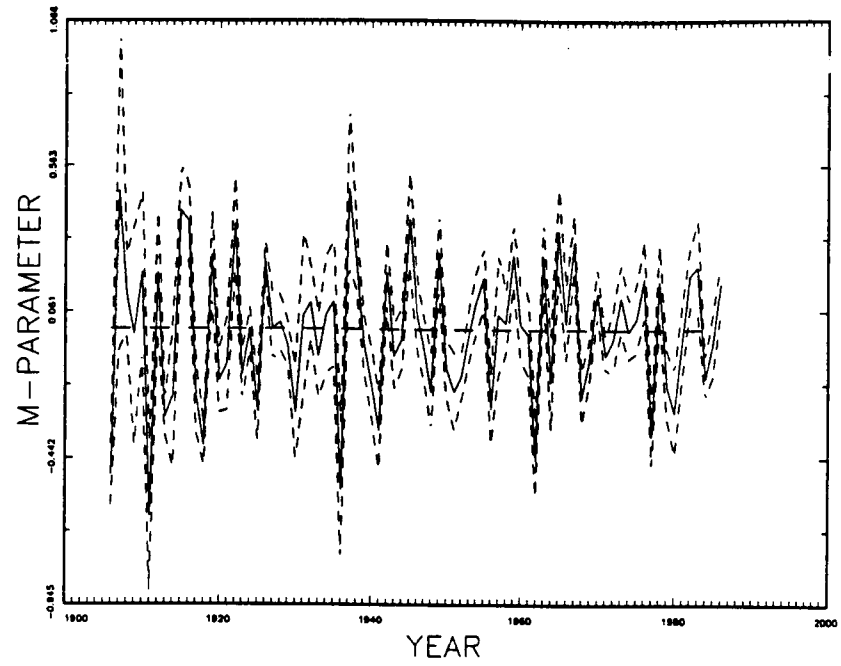


Figure A112. Graph of M-parameter and associated 95% confidence interval over time, Wayne County chestnut oak, cluster 3.

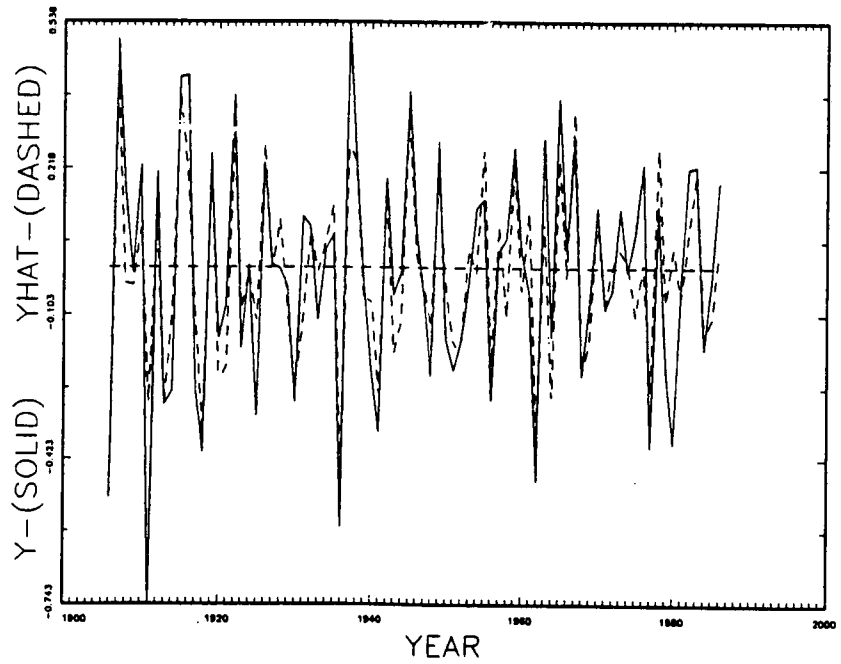
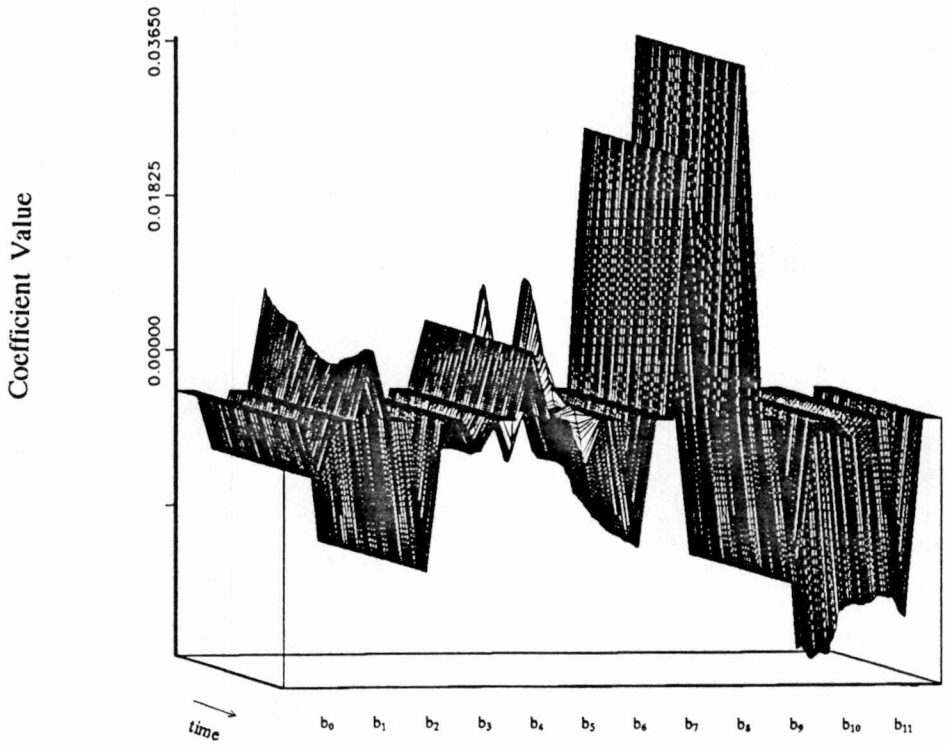


Figure A113. Graph of predicted and actual standardized growth, Wayne County chestnut oak, cluster 3.



Where:

b_0 = the intercept (non-varying)
b_1 = March temperature
b_2 = June temperature
b_3 = September temperature
b_4 = past January temperature
b_5 = past February temperature
b_6 = April rain
b_7 = May rain
b_8 = June rain
b_9 = September rain
b_{10} = past January rain
b_{11} = past March rain

Figure A114. Three dimensional graph of changes in parameter coefficients over time, Wayne County chestnut oak, cluster 3.

Table A38. Climate parameter estimates for Wayne County chestnut oak, cluster 3.

YEAR	March temp. b_1	June temp. b_2	September temp. b_3	Past January temp. b_4	Past February temp. b_5	April rain b_6	May rain b_7	June rain b_8	September rain b_9	Past January rain b_{10}	Past March rain b_{11}
1906	0.007	-0.023*	-0.015	0.003	0.001	-0.012	0.026*	0.037*	-0.024*	-0.007	-0.036*
1907	0.006	-0.023*	-0.015	0.003	0.007	-0.012	0.026*	0.037*	-0.024*	-0.007	-0.035*
1908	0.006	-0.023*	-0.015	0.003	0.007	-0.012	0.026*	0.037*	-0.024*	-0.007	-0.035*
1909	0.006	-0.023*	-0.015	0.003	0.008	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1910	0.006	-0.023*	-0.015	0.003	0.008	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1911	0.006	-0.023*	-0.015*	0.003	0.005	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1912	0.005	-0.023*	-0.015*	0.003	0.003	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.036*
1913	0.005	-0.023*	-0.015*	0.003	0.003	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.036*
1914	0.005	-0.023*	-0.015*	0.003	0.001	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.036*
1915	0.005	-0.023*	-0.015*	0.003	-0.000	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.036*
1916	0.005	-0.023*	-0.014*	0.003	-0.002	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.036*
1917	0.005	-0.023*	-0.014*	0.003	-0.003	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.036*
1918	0.005	-0.023*	-0.014*	0.003	-0.004	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.036*
1919	0.005	-0.023*	-0.014*	0.003	-0.006	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.036*
1920	0.005	-0.023*	-0.014*	0.003	-0.007	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.036*
1921	0.004	-0.023*	-0.014*	0.003	-0.009	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.036*
1922	0.004	-0.023*	-0.014*	0.003	-0.011	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1923	0.004	-0.023*	-0.014*	0.003	-0.011	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1924	0.004	-0.023*	-0.014*	0.003	-0.012	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1925	0.004	-0.023*	-0.014*	0.003	-0.012	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1926	0.004	-0.023*	-0.014*	0.003	-0.012	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1927	0.004	-0.023*	-0.014*	0.003	-0.012	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1928	0.004	-0.023*	-0.014*	0.003	-0.012	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1929	0.004	-0.023*	-0.014*	0.003	-0.012	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1930	0.004	-0.023*	-0.014*	0.003	-0.010	-0.013	0.026*	0.037*	-0.024*	-0.007	-0.035*
1931	0.003	-0.023*	-0.013*	0.003	-0.007	-0.014	0.026*	0.037*	-0.024*	-0.007	-0.034*
1932	0.003	-0.023*	-0.013*	0.003	-0.006	-0.014	0.026*	0.037*	-0.024*	-0.007	-0.034*
1933	0.003	-0.023*	-0.013*	0.003	-0.005	-0.014	0.026*	0.037*	-0.024*	-0.007	-0.033*
1934	0.003	-0.023*	-0.013*	0.003	-0.002	-0.014	0.026*	0.037*	-0.024*	-0.007	-0.033*
1935	0.003	-0.023*	-0.012*	0.003	0.000	-0.015	0.026*	0.037*	-0.024*	-0.007	-0.032*
1936	0.002	-0.023*	-0.012*	0.003	0.003	-0.015	0.026*	0.037*	-0.024*	-0.007	-0.031*
1937	0.002	-0.023*	-0.011	0.003	0.009	-0.016	0.026*	0.037*	-0.024*	-0.007	-0.030*
1938	0.002	-0.023*	-0.011	0.003	0.009	-0.016	0.026*	0.037*	-0.024*	-0.007	-0.030*

Table A38. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}	b_{11}
1939	0.002	-0.023*	-0.011	0.003	0.010	-0.016	0.026*	0.037*	-0.024*	-0.007	-0.030*
1940	0.002	-0.023*	-0.011	0.003	0.010	-0.016*	0.026*	0.037*	-0.024*	-0.007	-0.030*
1941	0.002	-0.023*	-0.011	0.003	0.010	-0.016*	0.026*	0.037*	-0.024*	-0.007	-0.029*
1942	0.002	-0.023*	-0.011	0.003	0.010	-0.016*	0.026*	0.037*	-0.024*	-0.007	-0.029*
1943	0.001	-0.023*	-0.011	0.003	0.009	-0.016*	0.026*	0.037*	-0.024*	-0.007	-0.029*
1944	0.001	-0.023*	-0.010	0.003	0.009	-0.016*	0.026*	0.037*	-0.024*	-0.007	-0.029*
1945	0.001	-0.023*	-0.010	0.003	0.008	-0.017*	0.026*	0.037*	-0.024*	-0.007	-0.029*
1946	0.001	-0.023*	-0.010	0.003	0.007	-0.017*	0.026*	0.037*	-0.024*	-0.007	-0.029*
1947	0.001	-0.023*	-0.010	0.003	0.007	-0.017*	0.026*	0.037*	-0.024*	-0.007	-0.029*
1948	0.001	-0.023*	-0.010	0.003	0.006	-0.017*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1949	0.001	-0.023*	-0.010	0.003	0.004	-0.017*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1950	0.001	-0.023*	-0.010	0.003	0.004	-0.017*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1951	0.001	-0.023*	-0.010	0.003	0.003	-0.018*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1952	0.001	-0.023*	-0.010	0.003	0.002	-0.018*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1953	0.001	-0.023*	-0.010	0.003	0.002	-0.018*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1954	0.001	-0.023*	-0.010	0.003	0.001	-0.018*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1955	0.001	-0.023*	-0.010	0.003	0.001	-0.018*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1956	0.001	-0.023*	-0.010	0.003	0.000	-0.018*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1957	0.001	-0.023*	-0.009	0.003	-0.001	-0.018*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1958	0.001	-0.023*	-0.009	0.003	-0.001	-0.018*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1959	0.001	-0.023*	-0.009	0.003	-0.001	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1960	0.001	-0.023*	-0.009	0.003	-0.002	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1961	0.001	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1962	0.001	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1963	0.001	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1964	0.001	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1965	0.002	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1966	0.002	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1967	0.002	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1968	0.002	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1969	0.002	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1970	0.002	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1971	0.002	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1972	0.002	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1973	0.002	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1974	0.002	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*

Table A38. Continued.

1975	0.003	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.026*
1976	0.003	-0.023*	-0.009	0.003	-0.004	-0.020*	0.026*	0.037*	-0.024*	-0.007	-0.026*
1977	0.003	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.026*
1978	0.003	-0.023*	-0.009	0.003	-0.004	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1979	0.003	-0.023*	-0.009	0.003	-0.005	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1980	0.003	-0.023*	-0.009	0.003	-0.006	-0.019*	0.026*	0.037*	-0.024*	-0.007	-0.027*
1981	0.003	-0.023*	-0.009	0.003	-0.007	-0.020*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1982	0.003	-0.023*	-0.009	0.003	-0.007	-0.020*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1983	0.003	-0.023*	-0.009	0.003	-0.009	-0.020*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1984	0.003	-0.023*	-0.008	0.003	-0.009	-0.020*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1985	0.003	-0.023*	-0.008	0.003	-0.010	-0.020*	0.026*	0.037*	-0.024*	-0.007	-0.028*
1986	0.003	-0.023*	-0.008	0.003	-0.010	-0.020*	0.026*	0.037*	-0.024*	-0.007	-0.028*

* Indicates coefficient is significant at $P \leq 0.05$.

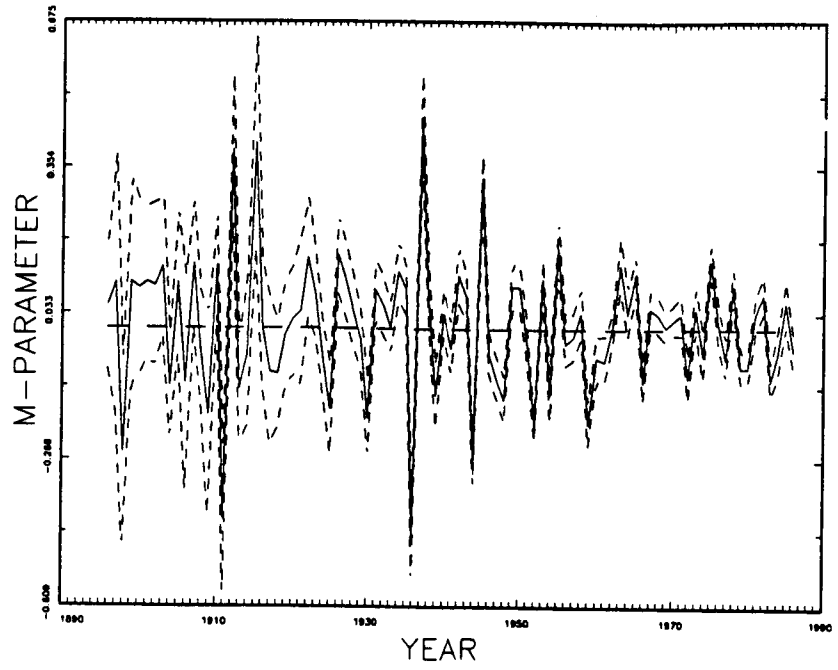


Figure A115. Graph of M-parameter and associated 95% confidence interval over time, Emory River northern red oak, cluster 1.

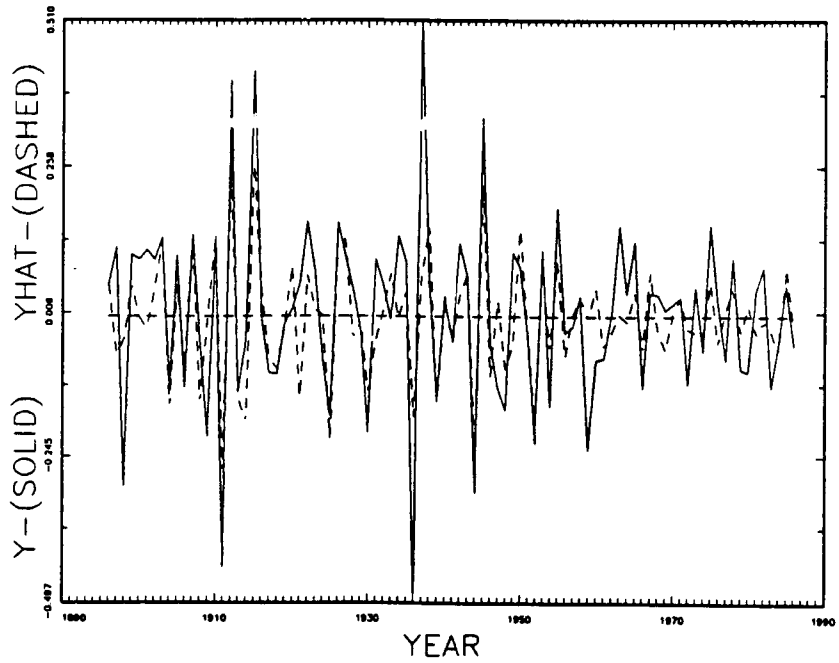
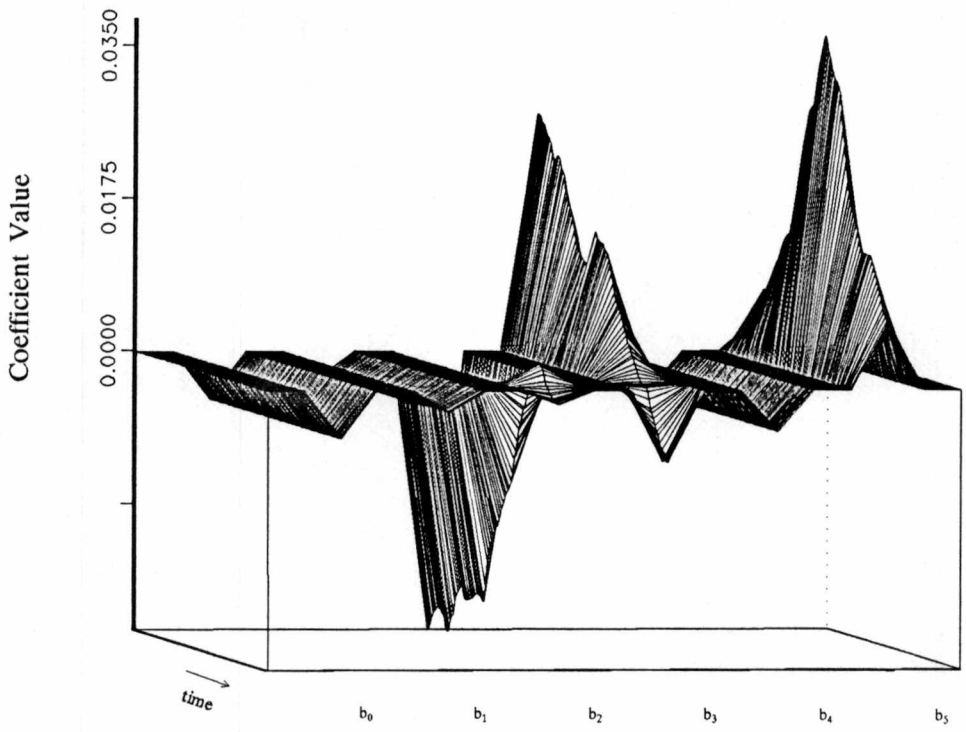


Figure A116. Graph of predicted and actual standardized growth, Emory River northern red oak, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = February temperature
b_2 = June temperature
b_3 = May rain
b_4 = past June rain
b_5 = past August rain

Figure A117. Three dimensional graph of changes in parameter coefficients over time, Emory River northern red oak, cluster 1.

Table A39. Climate parameter estimates for Emory River northern red oak, cluster 1.

YEAR	February temperature b_1	June temperature b_2	May rain b_3	Past June rain b_4	Past August rain b_5
1897	-0.003	-0.032	0.027	-0.005	0.004
1898	-0.003	-0.031	0.027	-0.005	0.004
1899	-0.003	-0.031	0.026	-0.005	0.005
1900	-0.003	-0.030	0.026	-0.005	0.006
1901	-0.003	-0.030	0.025	-0.005	0.007
1902	-0.003	-0.029	0.025	-0.005	0.007
1903	-0.003	-0.029	0.025	-0.005	0.007
1904	-0.003	-0.029	0.024	-0.005	0.007
1905	-0.003	-0.029	0.024	-0.005	0.007
1906	-0.003	-0.030	0.023	-0.005	0.008
1907	-0.003	-0.030	0.022	-0.005	0.008
1908	-0.003	-0.030	0.022	-0.005	0.008
1909	-0.003	-0.031	0.023	-0.005	0.010
1910	-0.003	-0.031	0.023	-0.005	0.010
1911	-0.003	-0.031	0.022	-0.005	0.011
1912	-0.003	-0.030	0.022	-0.005	0.011
1913	-0.003	-0.030	0.021	-0.005	0.012
1914	-0.003	-0.029	0.021	-0.005	0.012
1915	-0.003	-0.028	0.019	-0.005	0.013
1916	-0.003	-0.027	0.019	-0.005	0.014
1917	-0.003	-0.027	0.018	-0.005	0.014
1918	-0.003	-0.026	0.017	-0.005	0.014
1919	-0.003	-0.026	0.017	-0.005	0.014
1920	-0.003	-0.026	0.016	-0.005	0.015
1921	-0.003	-0.027*	0.015	-0.005	0.015
1922	-0.003	-0.027*	0.014	-0.005	0.016
1923	-0.003	-0.027*	0.013	-0.005	0.016
1924	-0.003	-0.027*	0.013	-0.005	0.017
1925	-0.003	-0.027*	0.013	-0.005	0.019
1926	-0.003	-0.027*	0.012	-0.005	0.020
1927	-0.003	-0.027*	0.012	-0.005	0.021
1928	-0.003	-0.027*	0.012	-0.005	0.023
1929	-0.003	-0.026*	0.012	-0.005	0.025*
1930	-0.003	-0.026*	0.011	-0.005	0.027*
1931	-0.003	-0.026*	0.011	-0.005	0.028*
1932	-0.003	-0.026*	0.011	-0.005	0.029*
1933	-0.003	-0.026*	0.012	-0.005	0.029*
1934	-0.003	-0.027*	0.013	-0.005	0.030*
1935	-0.003	-0.027*	0.014	-0.005	0.030*
1936	-0.003	-0.025*	0.016	-0.005	0.031*
1937	-0.003	-0.022*	0.015	-0.005	0.032*
1938	-0.003	-0.021*	0.015	-0.005	0.033*
1939	-0.003	-0.020*	0.014	-0.005	0.035*
1940	-0.003	-0.020*	0.014	-0.005	0.036*
1941	-0.003	-0.019*	0.014	-0.005	0.036*
1942	-0.003	-0.018*	0.014	-0.005	0.037*
1943	-0.003	-0.018*	0.014	-0.005	0.038*
1944	-0.003	-0.018*	0.013	-0.005	0.038*
1945	-0.003	-0.017*	0.013	-0.005	0.037*
1946	-0.003	-0.016*	0.012	-0.005	0.036*
1947	-0.003	-0.016*	0.011	-0.005	0.035*
1948	-0.003	-0.015*	0.010	-0.005	0.034*
1949	-0.003	-0.014*	0.009	-0.005	0.034*

Table A39. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5
1950	-0.003	-0.014*	0.008	-0.005	0.033*
1951	-0.003	-0.013*	0.008	-0.005	0.033*
1952	-0.003	-0.013*	0.008	-0.005	0.033*
1953	-0.003	-0.012*	0.007	-0.005	0.032*
1954	-0.003	-0.011	0.007	-0.005	0.030*
1955	-0.003	-0.010	0.006	-0.005	0.028*
1956	-0.003	-0.009	0.005	-0.005	0.026*
1957	-0.003	-0.007	0.005	-0.005	0.025*
1958	-0.003	-0.006	0.004	-0.005	0.022*
1959	-0.003	-0.005	0.004	-0.005	0.021*
1960	-0.003	-0.004	0.003	-0.005	0.020*
1961	-0.003	-0.004	0.003	-0.005	0.019*
1962	-0.003	-0.003	0.002	-0.005	0.019*
1963	-0.003	-0.002	0.002	-0.005	0.018*
1964	-0.003	-0.002	0.001	-0.005	0.018*
1965	-0.003	-0.001	0.001	-0.005	0.017*
1966	-0.003	-0.000	0.000	-0.005	0.016*
1967	-0.003	0.000	-0.000	-0.005	0.015*
1968	-0.003	0.001	-0.000	-0.005	0.015*
1969	-0.003	0.001	-0.000	-0.005	0.015*
1970	-0.003	0.001	-0.000	-0.005	0.015*
1971	-0.003	0.002	-0.001	-0.005	0.015*
1972	-0.003	0.002	-0.001	-0.005	0.015*
1973	-0.003	0.002	-0.002	-0.005	0.015*
1974	-0.003	0.002	-0.003	-0.005	0.015*
1975	-0.003	0.001	-0.003	-0.005	0.014
1976	-0.003	0.000	-0.004	-0.005	0.013
1977	-0.003	-0.000	-0.005	-0.005	0.013
1978	-0.003	-0.000	-0.005	-0.005	0.012
1979	-0.003	-0.001	-0.006	-0.005	0.011
1980	-0.003	-0.001	-0.006	-0.005	0.011
1981	-0.003	-0.001	-0.007	-0.005	0.010
1982	-0.003	-0.001	-0.008	-0.005	0.009
1983	-0.003	-0.001	-0.008	-0.005	0.009
1984	-0.003	-0.002	-0.008	-0.005	0.008
1985	-0.003	-0.002	-0.008	-0.005	0.008
1986	-0.003	-0.002	-0.008	-0.005	0.008

* Indicates coefficient is significant at $P \leq 0.05$.

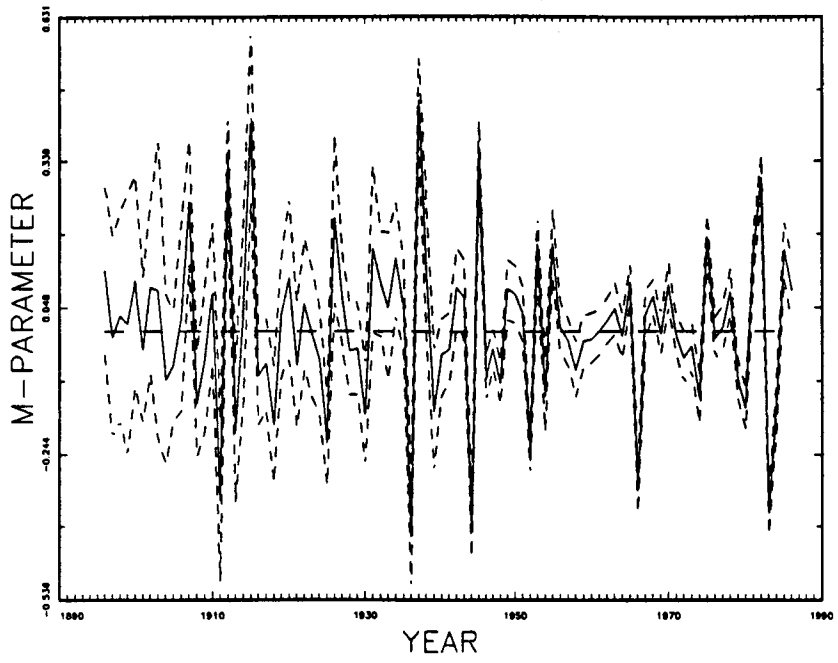


Figure A118. Graph of M-parameter and associated 95% confidence interval over time, Emory River northern red oak, cluster 2.

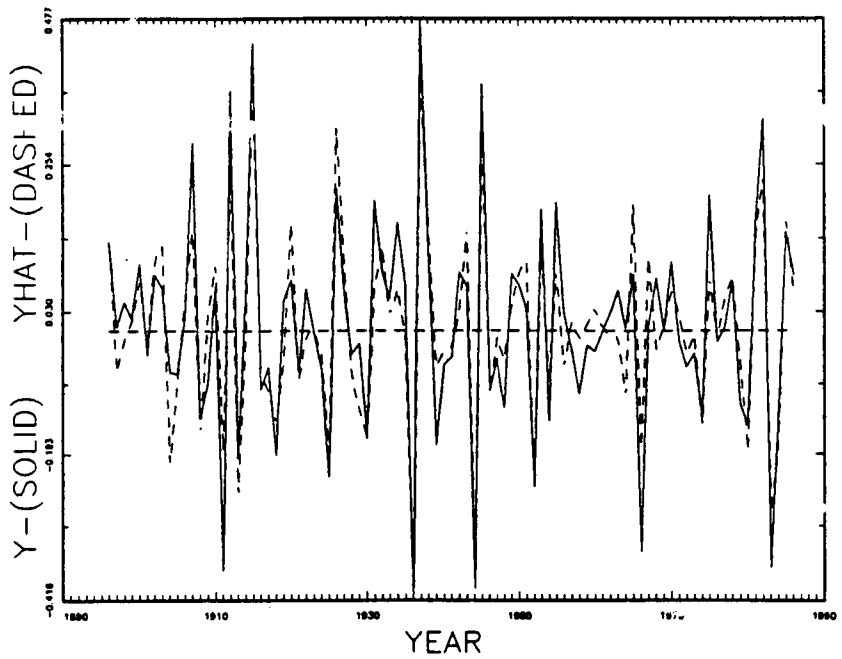
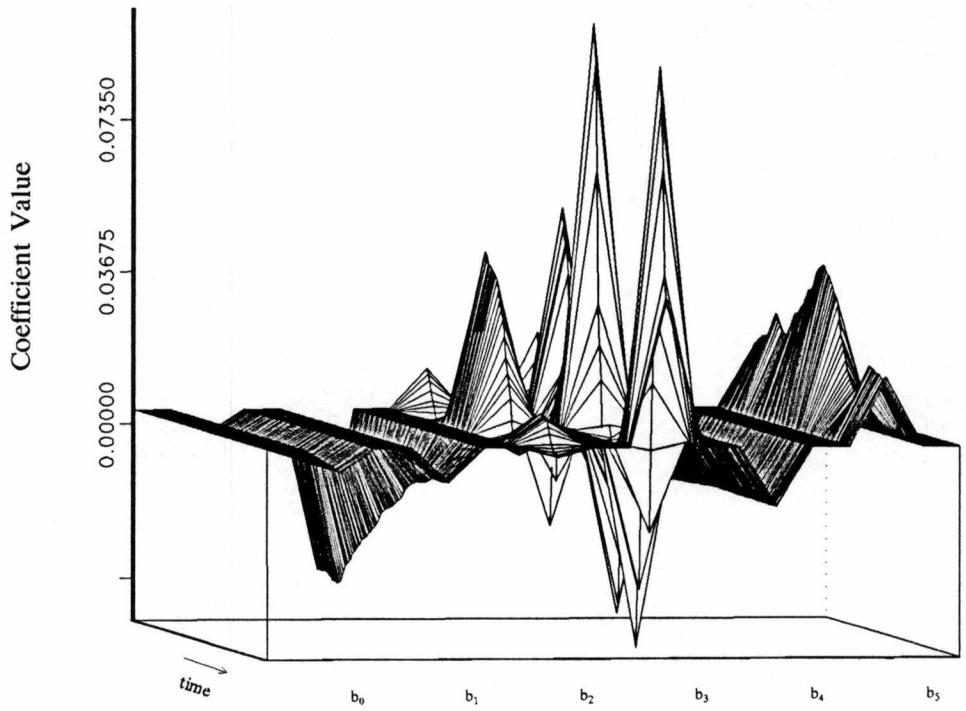


Figure A119. Graph of predicted and actual standardized growth, Emory River northern red oak, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = June rain
b_3 = August rain
b_4 = past May rain
b_5 = past August rain

Figure A120. Three dimensional graph of changes in parameter coefficients over time, Emory River northern red oak, cluster 2.

Table A40. Climate parameter estimates for Emory River northern red oak, cluster 2.

YEAR	June temperature b_1	June rain b_2	August rain b_3	Past May rain b_4	Past August rain b_5
1897	-0.035	0.012	0.022	-0.012	0.019
1898	-0.035	0.010	0.016	-0.012	0.019
1899	-0.035	0.008	0.010	-0.012	0.020
1900	-0.035*	0.006	0.007	-0.012	0.020
1901	-0.035*	0.005	0.008	-0.012	0.021
1902	-0.035*	0.003	0.005	-0.012	0.021
1903	-0.035*	-0.002	-0.010	-0.012	0.021
1904	-0.035*	-0.001	-0.012	-0.012	0.021
1905	-0.035*	-0.000	-0.014	-0.012	0.022
1906	-0.036*	0.000	-0.024	-0.012	0.022
1907	-0.036*	-0.000	-0.010	-0.012	0.023
1908	-0.036*	-0.001	-0.003	-0.012	0.023
1909	-0.036*	0.000	-0.008	-0.012	0.025
1910	-0.037*	0.001	-0.013	-0.012	0.026
1911	-0.036*	0.000	0.012	-0.012	0.027
1912	-0.036*	-0.000	0.021	-0.012	0.027
1913	-0.035*	-0.000	0.049	-0.012	0.026
1914	-0.034*	-0.001	0.054	-0.012	0.025
1915	-0.032*	-0.001	0.050	-0.012	0.024
1916	-0.032*	-0.001	0.045	-0.012	0.023
1917	-0.031*	-0.001	0.045	-0.012	0.023
1918	-0.030*	-0.001	0.038	-0.012	0.023
1919	-0.030*	-0.000	0.017	-0.012	0.023
1920	-0.029*	0.002	0.007	-0.011	0.025
1921	-0.028*	0.004	0.005	-0.011	0.026
1922	-0.027*	0.005	0.015	-0.011	0.027
1923	-0.027*	0.006	0.021	-0.011	0.028
1924	-0.026*	0.007	0.019	-0.011	0.029
1925	-0.026*	0.007	0.014	-0.011	0.029
1926	-0.025*	0.008	0.023	-0.011	0.029
1927	-0.024*	0.008	0.017	-0.011	0.030
1928	-0.024*	0.007	0.008	-0.011	0.031
1929	-0.024*	0.010	0.019	-0.011	0.031
1930	-0.023*	0.014	0.034	-0.011	0.032
1931	-0.022*	0.025	0.046	-0.011	0.033
1932	-0.022*	0.030	0.048	-0.011	0.034
1933	-0.021*	0.040*	0.051	-0.011*	0.035*
1934	-0.021*	0.041*	0.070	-0.011*	0.035*
1935	-0.021*	0.044*	0.085	-0.011*	0.036*
1936	-0.020*	0.045*	0.100*	-0.011*	0.036*
1937	-0.020*	0.045*	0.091*	-0.011*	0.037*
1938	-0.018*	0.042*	0.065	-0.011*	0.039*
1939	-0.017*	0.043*	0.033	-0.011*	0.041*
1940	-0.017*	0.042*	0.023	-0.011*	0.041*
1941	-0.016*	0.041*	0.015	-0.011*	0.042*
1942	-0.016*	0.041*	0.002	-0.010*	0.042*
1943	-0.015*	0.040*	-0.011	-0.010*	0.042*
1944	-0.015*	0.039*	-0.012	-0.010*	0.042*
1945	-0.015*	0.037*	-0.004	-0.010*	0.041*
1946	-0.015*	0.035*	0.003	-0.010*	0.041*
1947	-0.014*	0.033*	0.005	-0.010*	0.040*
1948	-0.014*	0.030*	0.002	-0.010*	0.039*
1949	-0.014*	0.026*	-0.007	-0.010*	0.038*

Table A40. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5
1950	-0.013*	0.021*	-0.015	-0.010*	0.037*
1951	-0.013*	0.018	-0.032	-0.010*	0.036*
1952	-0.012*	0.015	-0.040*	-0.010*	0.036*
1953	-0.012*	0.012	-0.037	-0.010*	0.034*
1954	-0.011*	0.007	-0.026	-0.010*	0.031*
1955	-0.010*	0.001	-0.016	-0.010*	0.027*
1956	-0.009*	0.000	-0.016	-0.010*	0.025*
1957	-0.009*	0.001	-0.018	-0.010*	0.024*
1958	-0.009	-0.000	-0.013	-0.011*	0.021*
1959	-0.008	-0.001	-0.005	-0.011*	0.019*
1960	-0.008	-0.001	-0.009	-0.011*	0.018*
1961	-0.008	-0.001	-0.014	-0.011*	0.017*
1962	-0.007	0.000	-0.011	-0.011*	0.016*
1963	-0.007	0.002	-0.006	-0.011*	0.015*
1964	-0.007	0.004	-0.023	-0.011*	0.015*
1965	-0.007	0.006	-0.047*	-0.011*	0.015*
1966	-0.007	0.005	-0.032*	-0.011*	0.014*
1967	-0.006	0.006	-0.032*	-0.011*	0.014*
1968	-0.006	0.007	-0.013	-0.011*	0.015*
1969	-0.006	0.008	0.005	-0.011*	0.015*
1970	-0.006	0.009	0.009	-0.011*	0.016*
1971	-0.006	0.009	0.005	-0.011*	0.017*
1972	-0.006	0.010	-0.003	-0.011*	0.019*
1973	-0.005	0.010	-0.013	-0.011*	0.020*
1974	-0.005	0.010	-0.018	-0.011*	0.021*
1975	-0.005	0.010	0.002	-0.011*	0.021*
1976	-0.005	0.010	0.018	-0.011*	0.021*
1977	-0.005	0.010	0.035	-0.011*	0.021*
1978	-0.005	0.009	0.056*	-0.011*	0.020*
1979	-0.005	0.008	0.068*	-0.011*	0.020*
1980	-0.005	0.006	0.084*	-0.011*	0.020*
1981	-0.005	0.004	0.094*	-0.011*	0.020*
1982	-0.005	0.003	0.085*	-0.011*	0.020*
1983	-0.005	0.002	0.070*	-0.011*	0.019*
1984	-0.005	0.001	0.045*	-0.011*	0.020*
1985	-0.005	0.001	0.039	-0.011*	0.020
1986	-0.005	0.001	0.039	-0.011*	0.020

* Indicates coefficient is significant at $P \leq 0.05$.

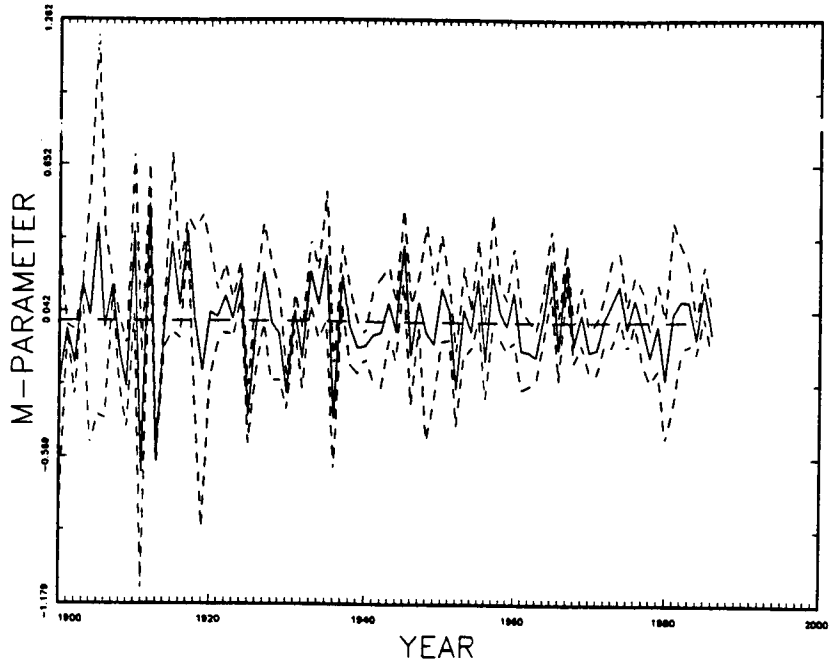


Figure A121. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes northern red oak, cluster 1.

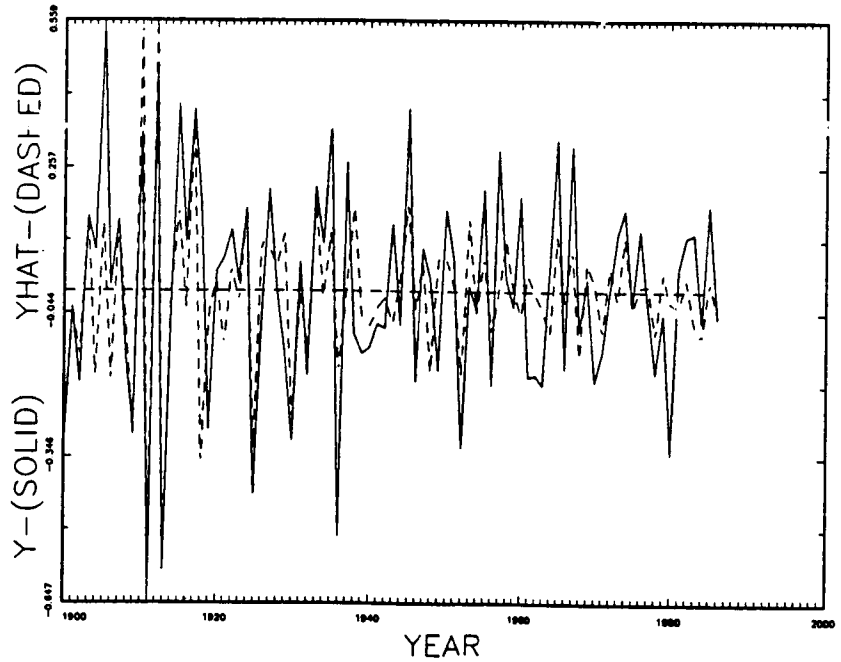
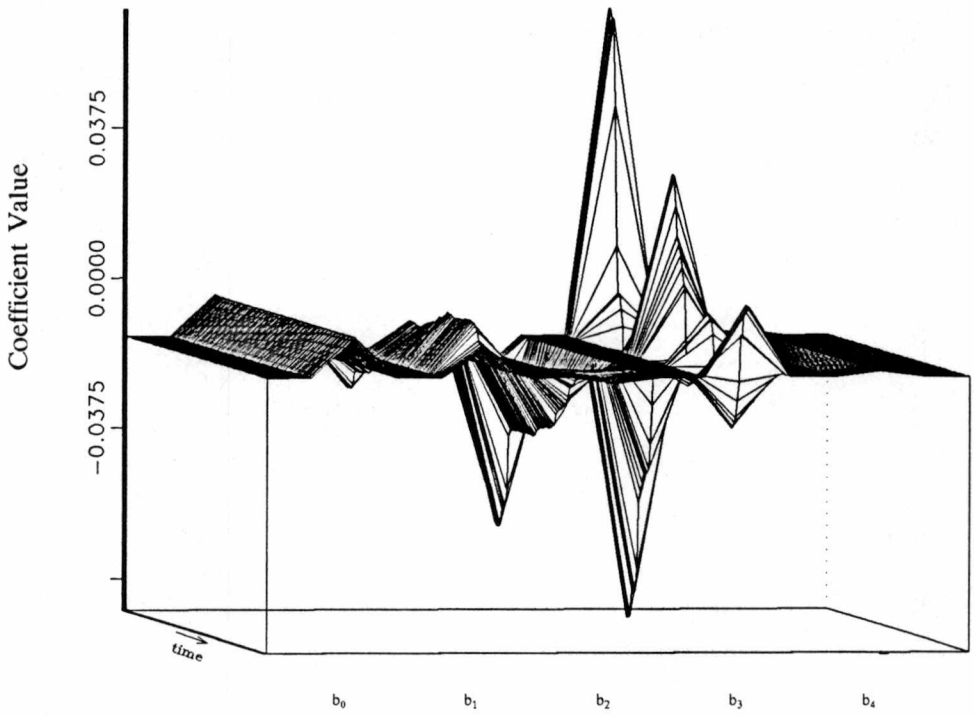


Figure A122. Graph of predicted and actual standardized growth, Land Between the Lakes northern red oak, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = February temperature
b_2 = June temperature
b_3 = past April temperature
b_4 = past October temperature

Figure A123. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes northern red oak, cluster 1.

Table A41. Climate parameter estimates for LBL northern red oak, cluster 1.

YEAR	February temperature b_1	June temperature b_2	Past April temperature b_3	Past October temperature b_4
1900	-0.027	-0.024*	0.067*	-0.013*
1901	-0.027	-0.024*	0.067*	-0.013*
1902	-0.027	-0.025*	0.065*	-0.013*
1903	-0.027	-0.025*	0.065*	-0.013*
1904	-0.026	-0.032*	0.043	-0.013*
1905	-0.023	-0.048*	0.008	-0.013*
1906	-0.023*	-0.052*	-0.003	-0.013*
1907	-0.023*	-0.052*	-0.004	-0.013*
1908	-0.023*	-0.052*	-0.007	-0.013*
1909	-0.023*	-0.052*	-0.011	-0.013*
1910	-0.022*	-0.055*	-0.033	-0.013*
1911	-0.022*	-0.060*	-0.079*	-0.013*
1912	-0.022*	-0.060*	-0.083*	-0.013*
1913	-0.022*	-0.060*	-0.083*	-0.013*
1914	-0.022*	-0.060*	-0.083*	-0.013*
1915	-0.021*	-0.056*	-0.076*	-0.013*
1916	-0.021*	-0.055*	-0.077*	-0.013*
1917	-0.021*	-0.055*	-0.077*	-0.013*
1918	-0.020*	-0.051*	-0.071*	-0.013*
1919	-0.016*	-0.038*	-0.054*	-0.013*
1920	-0.015*	-0.035*	-0.051*	-0.013*
1921	-0.015*	-0.036*	-0.049*	-0.013*
1922	-0.015*	-0.036*	-0.046*	-0.013*
1923	-0.015*	-0.036*	-0.046*	-0.013*
1924	-0.015*	-0.036*	-0.046*	-0.013*
1925	-0.015*	-0.035*	-0.045*	-0.013*
1926	-0.015*	-0.035*	-0.039*	-0.013*
1927	-0.015*	-0.036*	-0.029	-0.013*
1928	-0.014*	-0.036*	-0.016	-0.013*
1929	-0.014*	-0.035*	-0.018	-0.013*
1930	-0.014*	-0.035*	-0.017	-0.013*
1931	-0.014*	-0.035*	-0.016	-0.013*
1932	-0.013*	-0.035*	-0.014	-0.013*
1933	-0.013*	-0.035*	-0.012	-0.013*
1934	-0.012*	-0.035*	-0.008	-0.013*
1935	-0.009	-0.035*	0.003	-0.013*
1936	-0.007	-0.034*	0.008	-0.013*
1937	-0.007	-0.034*	0.013	-0.013*
1938	-0.006	-0.033*	0.024	-0.013*
1939	-0.006	-0.033*	0.030*	-0.013*
1940	-0.006	-0.033*	0.030*	-0.013*
1941	-0.006	-0.033*	0.023	-0.013*
1942	-0.006	-0.032*	0.015	-0.013*
1943	-0.007	-0.032*	0.013	-0.013*
1944	-0.007	-0.032*	0.011	-0.013*
1945	-0.007	-0.032*	0.008	-0.013*
1946	-0.007	-0.031*	0.004	-0.013*
1947	-0.007	-0.031*	0.003	-0.013*
1948	-0.006	-0.028*	-0.019	-0.013*
1949	-0.006	-0.028*	-0.021	-0.013*
1950	-0.005	-0.027*	-0.021	-0.013*
1951	-0.005	-0.027*	-0.020	-0.013*
1952	-0.005	-0.026*	-0.018	-0.013*
1953	-0.005	-0.025*	-0.014	-0.013*
1954	-0.005	-0.025*	-0.014	-0.013*

Table A41. Continued.

YEAR	b_1	b_2	b_3	b_4
1955	-0.004	-0.024*	-0.016	-0.013*
1956	-0.004	-0.023*	-0.018	-0.013*
1957	-0.003	-0.021*	-0.016	-0.013*
1958	-0.003	-0.020*	-0.013	-0.013*
1959	-0.003	-0.020	-0.012	-0.013*
1960	-0.002	-0.019	-0.007	-0.013*
1961	-0.002	-0.018	-0.002	-0.013*
1962	-0.001	-0.017	-0.003	-0.013*
1963	-0.001	-0.017	-0.003	-0.013*
1964	-0.001	-0.017	-0.007	-0.013*
1965	-0.002	-0.016	-0.015	-0.013*
1966	-0.002	-0.015	-0.022*	-0.013*
1967	-0.002	-0.015	-0.020	-0.013*
1968	-0.002	-0.015	-0.021	-0.013*
1969	-0.002	-0.015	-0.022	-0.013*
1970	-0.002	-0.015	-0.022	-0.013*
1971	-0.002	-0.015	-0.022	-0.013*
1972	-0.002	-0.015	-0.023	-0.013*
1973	-0.001	-0.016	-0.027	-0.013*
1974	-0.001	-0.016	-0.028	-0.013*
1975	-0.001	-0.016	-0.029	-0.013*
1976	-0.001	-0.016	-0.028	-0.013*
1977	-0.002	-0.016	-0.027	-0.013*
1978	-0.002	-0.016	-0.026	-0.013*
1979	-0.002	-0.016	-0.022	-0.013*
1980	-0.003	-0.016	-0.017	-0.013*
1981	-0.006	-0.016	-0.005	-0.013*
1982	-0.006	-0.016	-0.005	-0.013*
1983	-0.007	-0.016	0.002	-0.013*
1984	-0.007	-0.016	0.003	-0.013*
1985	-0.007	-0.016	0.003	-0.013*
1986	-0.007	-0.016	0.003	-0.013*

* Indicates coefficient is significant at $P \leq 0.05$.

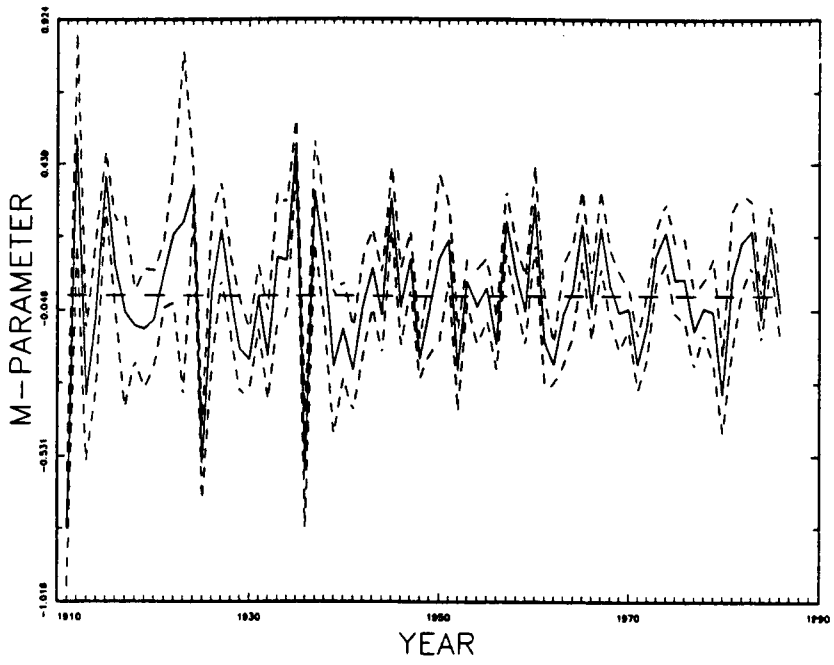


Figure A124. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes northern red oak, cluster 2.

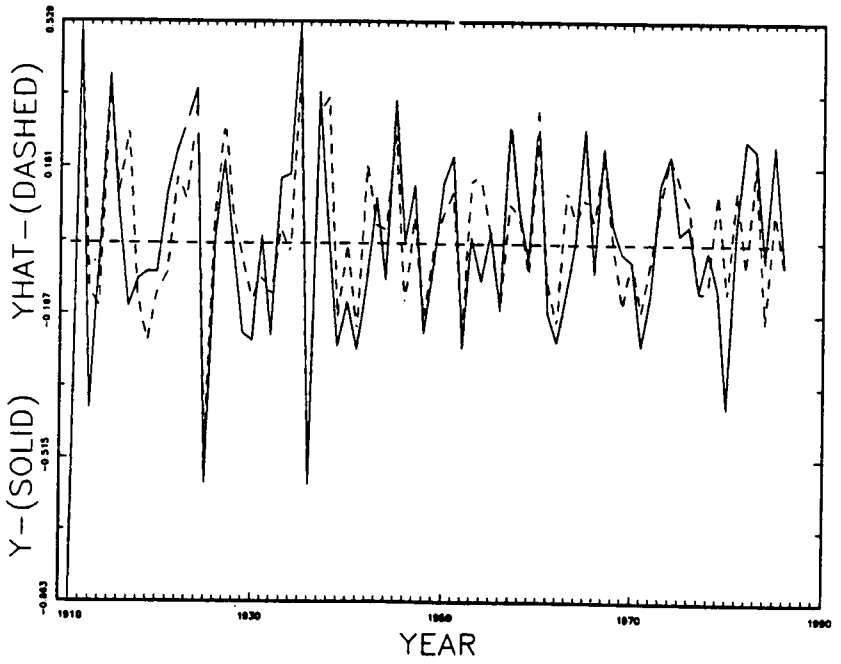
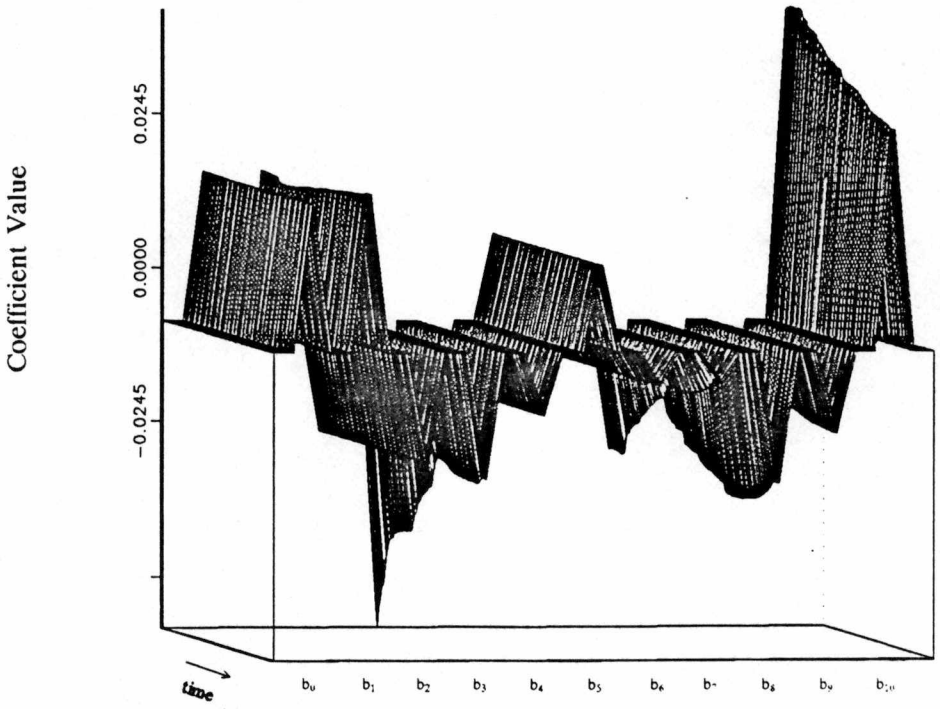


Figure A125. Graph of predicted and actual standardized growth, Land Between the Lakes northern red oak, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = April temperature
b_2 = May temperature
b_3 = June temperature
b_4 = September temperature
b_5 = past February temperature
b_6 = past September temperature
b_7 = past October temperature
b_8 = July rain
b_9 = past February rain
b_{10} = past August rain

Figure A126. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes northern red oak, cluster 2.

Table A42. Climate parameter estimates for LBL northern red oak, cluster 2.

YEAR	April temp. b_1	May temp. b_2	June temp. b_3	September temp. b_4	Past February temp. b_5	Past September temp. b_6	Past October temp. b_7	July rain b_8	Past February rain b_9	Past August rain b_{10}
1911	0.015	-0.026*	-0.057*	-0.019*	0.005	-0.014*	-0.029*	-0.024	-0.020	0.040*
1912	0.015	-0.026*	-0.054*	-0.019*	0.005	-0.014*	-0.029*	-0.024	-0.020	0.041*
1913	0.015	-0.026*	-0.052*	-0.019*	0.005	-0.014*	-0.029*	-0.024	-0.020	0.041*
1914	0.015	-0.026*	-0.050*	-0.019*	0.005	-0.014*	-0.029*	-0.025	-0.020	0.041*
1915	0.015	-0.026*	-0.050*	-0.019*	0.005	-0.014*	-0.029*	-0.025	-0.020	0.041*
1916	0.015	-0.026*	-0.049*	-0.019*	0.005	-0.014*	-0.029*	-0.025	-0.020	0.041*
1917	0.015	-0.026*	-0.045*	-0.019*	0.005	-0.014*	-0.029*	-0.025	-0.020	0.041*
1918	0.015	-0.026*	-0.044*	-0.019*	0.005	-0.014*	-0.029*	-0.025	-0.020	0.041*
1919	0.015	-0.026*	-0.043*	-0.019*	0.005	-0.014*	-0.029*	-0.025	-0.020	0.041*
1920	0.015	-0.026*	-0.042*	-0.019*	0.005	-0.014*	-0.029*	-0.025	-0.020	0.041*
1921	0.015	-0.026*	-0.042*	-0.019*	0.005	-0.014*	-0.029*	-0.026	-0.020	0.041*
1922	0.015	-0.026*	-0.042*	-0.019*	0.005	-0.014*	-0.029*	-0.026	-0.020	0.041*
1923	0.014*	-0.026*	-0.041*	-0.019*	0.005	-0.014*	-0.026*	-0.027*	-0.020*	0.040*
1924	0.014*	-0.026*	-0.041*	-0.019*	0.005	-0.014*	-0.026*	-0.028*	-0.020*	0.040*
1925	0.014*	-0.026*	-0.041*	-0.019*	0.005	-0.014*	-0.026*	-0.028*	-0.020*	0.040*
1926	0.014*	-0.026*	-0.041*	-0.019*	0.005	-0.014*	-0.025*	-0.028*	-0.020*	0.039*
1927	0.014*	-0.026*	-0.041*	-0.019*	0.005	-0.014*	-0.024*	-0.028*	-0.020*	0.039*
1928	0.014*	-0.026*	-0.041*	-0.019*	0.005	-0.014*	-0.024*	-0.028*	-0.020*	0.039*
1929	0.014*	-0.026*	-0.041*	-0.019*	0.005	-0.014*	-0.024*	-0.028*	-0.020*	0.038*
1930	0.014*	-0.026*	-0.040*	-0.019*	0.005	-0.014*	-0.024*	-0.028*	-0.020*	0.038*
1931	0.014*	-0.026*	-0.040*	-0.019*	0.005	-0.014*	-0.024*	-0.028*	-0.020*	0.038*
1932	0.014*	-0.026*	-0.040*	-0.019*	0.005	-0.014*	-0.023*	-0.029*	-0.020*	0.038*
1933	0.014*	-0.026*	-0.040*	-0.019*	0.005	-0.014*	-0.023*	-0.029*	-0.020*	0.037*
1934	0.014*	-0.026*	-0.040*	-0.019*	0.005	-0.014*	-0.022*	-0.030*	-0.020*	0.037*
1935	0.014*	-0.026*	-0.040*	-0.019*	0.005	-0.014*	-0.022*	-0.030*	-0.020*	0.037*
1936	0.014*	-0.026*	-0.039*	-0.019*	0.005	-0.014*	-0.022*	-0.030*	-0.020*	0.036*
1937	0.015*	-0.026*	-0.038*	-0.019*	0.005	-0.014*	-0.021*	-0.030*	-0.020*	0.036*
1938	0.015*	-0.026*	-0.037*	-0.019*	0.005	-0.014*	-0.021*	-0.030*	-0.020*	0.036*
1939	0.015*	-0.026*	-0.036*	-0.019*	0.005	-0.014*	-0.021*	-0.030*	-0.020*	0.035*
1940	0.015*	-0.026*	-0.035*	-0.019*	0.005	-0.014*	-0.020*	-0.030*	-0.019*	0.035*
1941	0.015*	-0.026*	-0.035*	-0.019*	0.005	-0.014*	-0.020*	-0.030*	-0.019*	0.035*
1942	0.015*	-0.026*	-0.034*	-0.019*	0.005	-0.014*	-0.020*	-0.031*	-0.019*	0.034*
1943	0.015*	-0.026*	-0.034*	-0.019*	0.005	-0.014*	-0.019*	-0.031*	-0.019*	0.034*

Table A42. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}
1944	0.015*	-0.026*	-0.033*	-0.019*	0.005	-0.014*	-0.019*	-0.031*	-0.019*	0.034*
1945	0.015*	-0.026*	-0.033*	-0.019*	0.005	-0.014*	-0.019*	-0.031*	-0.019*	0.034*
1946	0.015*	-0.026*	-0.033*	-0.019*	0.005	-0.014*	-0.019*	-0.031*	-0.019*	0.034*
1947	0.015*	-0.026*	-0.032*	-0.019*	0.005	-0.014*	-0.019*	-0.032*	-0.019*	0.034*
1948	0.015*	-0.026*	-0.032*	-0.019*	0.005	-0.014*	-0.018*	-0.032*	-0.019*	0.034*
1949	0.015*	-0.026*	-0.032*	-0.019*	0.005	-0.014*	-0.018*	-0.032*	-0.019*	0.033*
1950	0.015*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.017*	-0.033*	-0.019*	0.032*
1951	0.015*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.017*	-0.033*	-0.019*	0.032*
1952	0.015*	-0.026*	-0.027*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.032*
1953	0.015*	-0.026*	-0.027*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.032*
1954	0.015*	-0.026*	-0.027*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.032*
1955	0.015*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.032*
1956	0.016*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.031*
1957	0.016*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.031*
1958	0.016*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.031*
1959	0.016*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.031*
1960	0.016*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.031*
1961	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.031*
1962	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.020*	0.030*
1963	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.017*	-0.033*	-0.020*	0.030*
1964	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.017*	-0.033*	-0.021*	0.030*
1965	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.017*	-0.033*	-0.021*	0.029*
1966	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.021*	0.029*
1967	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.021*	0.029*
1968	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.021*	0.029*
1969	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.021*	0.028*
1970	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.021*	0.028*
1971	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.033*	-0.021*	0.028*
1972	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.032*	-0.021*	0.028*
1973	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.032*	-0.021*	0.028*
1974	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.016*	-0.032*	-0.021*	0.028*
1975	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.015*	-0.032*	-0.021*	0.028*
1976	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.015*	-0.032*	-0.021*	0.027*
1977	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.015*	-0.031*	-0.021*	0.027*
1978	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.015*	-0.031*	-0.021*	0.027*
1979	0.016*	-0.026*	-0.030*	-0.019*	0.005	-0.014*	-0.015*	-0.031*	-0.021*	0.027*

Table A42. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}
1980	0.016*	-0.026*	-0.030*	-0.019*	0.005	-0.014*	-0.014*	-0.030*	-0.021*	0.027*
1981	0.016*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.014	-0.030*	-0.021*	0.027*
1982	0.017*	-0.026*	-0.029*	-0.019*	0.005	-0.014*	-0.013	-0.029*	-0.021*	0.026*
1983	0.017*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.013	-0.029*	-0.021*	0.026*
1984	0.017*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.013	-0.029*	-0.021*	0.026*
1985	0.017*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.013	-0.029*	-0.021*	0.026*
1986	0.017*	-0.026*	-0.028*	-0.019*	0.005	-0.014*	-0.013	-0.029*	-0.021*	0.026*

* Indicates coefficient is significant at $P \leq 0.05$.

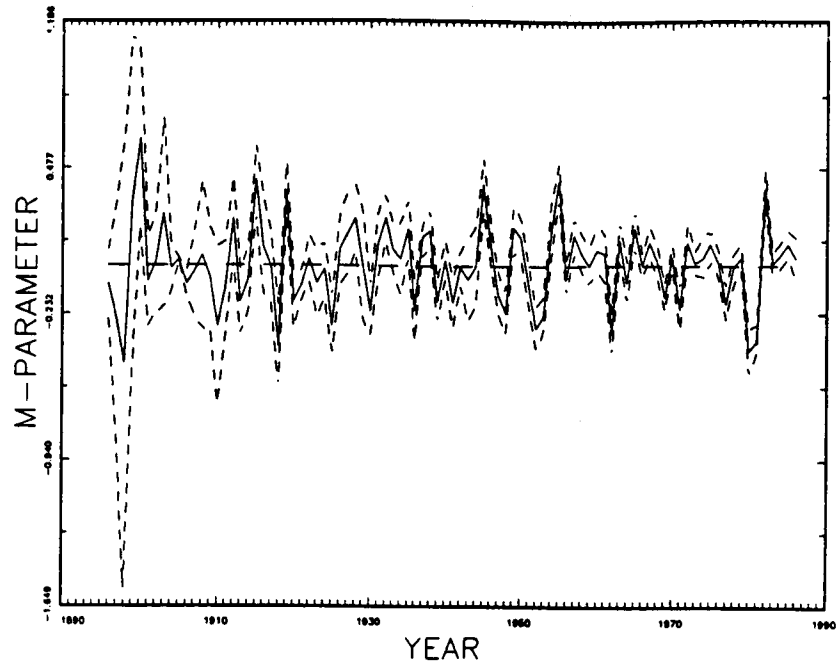


Figure A127. Graph of M-parameter and associated 95% confidence interval over time, Wayne County northern red oak, cluster 1.

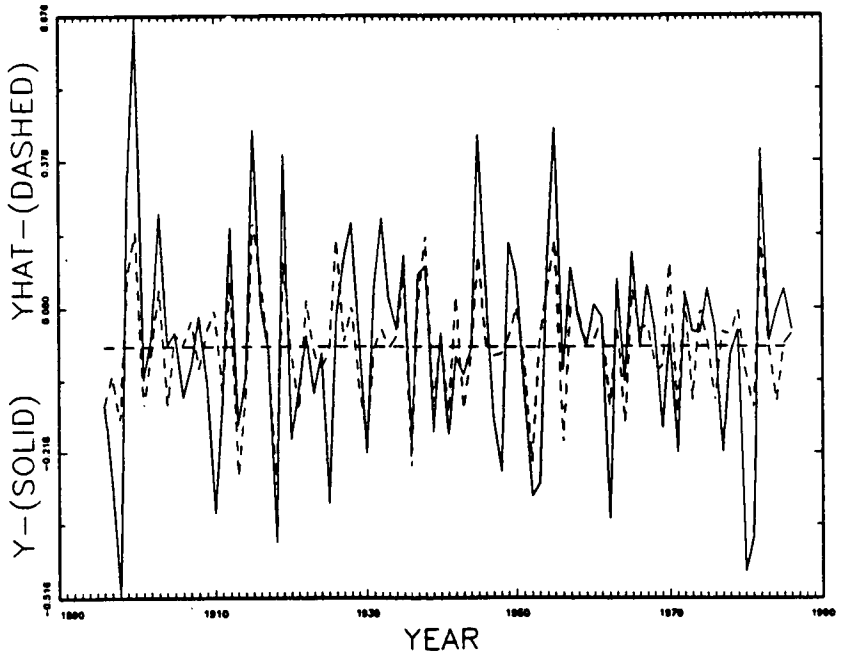
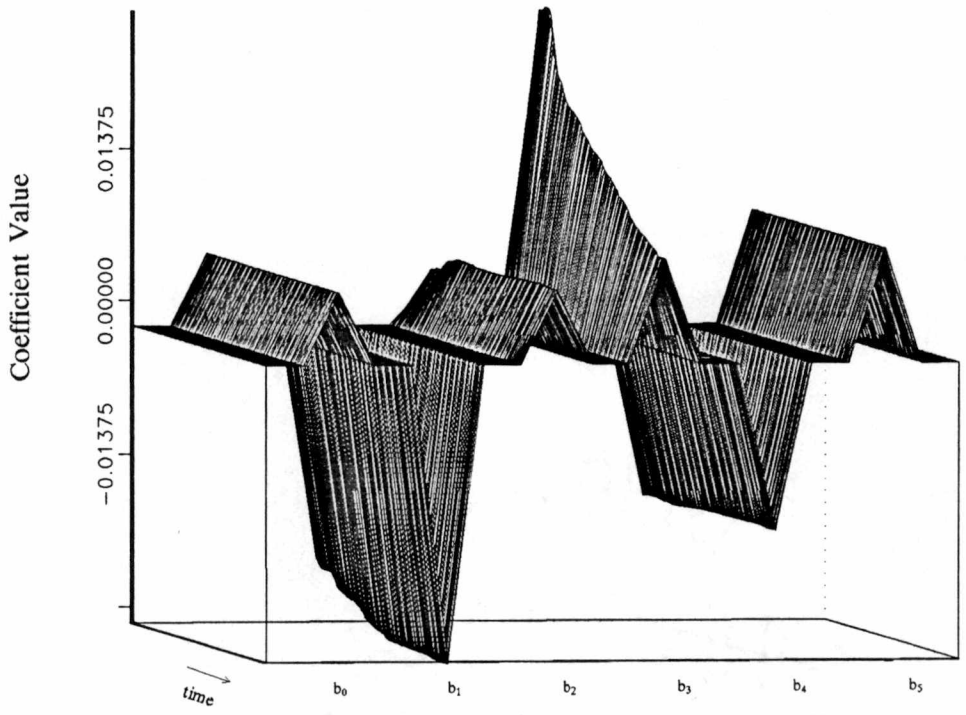


Figure A128. Graph of predicted and actual standardized growth, Wayne County northern red oak, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = past May temperature
b_3 = June rain
b_4 = past March rain
b_5 = past June rain

Figure A129. Three dimensional graph of changes in parameter coefficients over time, Wayne County northern red oak, cluster 1.

Table A43. Climate parameter estimates for Wayne County northern red oak, cluster 1.

YEAR	June temp. b_1	Past May temp. b_2	June rain b_3	Past March rain b_4	Past June rain b_5
1897	-0.023	0.001	0.022	-0.018*	0.008
1898	-0.024*	0.002	0.025	-0.018*	0.008
1899	-0.024*	0.003	0.026*	-0.018*	0.008
1900	-0.024*	0.003	0.026*	-0.018*	0.008
1901	-0.024*	0.003	0.026*	-0.018*	0.008
1902	-0.024*	0.003	0.026*	-0.017*	0.008
1903	-0.024*	0.003	0.026*	-0.017*	0.008
1904	-0.024*	0.003	0.026*	-0.017*	0.008
1905	-0.024*	0.003	0.026*	-0.017*	0.008
1906	-0.024*	0.003	0.026*	-0.017*	0.008
1907	-0.024*	0.003	0.026*	-0.018*	0.008
1908	-0.025*	0.003	0.024*	-0.018*	0.008
1909	-0.025*	0.003	0.024*	-0.018*	0.008
1910	-0.025*	0.004	0.022*	-0.018*	0.008
1911	-0.025*	0.004	0.021*	-0.018*	0.008
1912	-0.025*	0.004	0.021*	-0.018*	0.008
1913	-0.025*	0.004	0.020*	-0.018*	0.008
1914	-0.026*	0.004	0.020*	-0.018*	0.008
1915	-0.026*	0.004	0.020*	-0.018*	0.008
1916	-0.026*	0.004	0.019*	-0.018*	0.008
1917	-0.026*	0.004	0.019*	-0.018*	0.008
1918	-0.026*	0.004	0.018	-0.018*	0.008
1919	-0.026*	0.004	0.018	-0.018*	0.008
1920	-0.026*	0.004	0.018	-0.018*	0.008
1921	-0.026*	0.004	0.018	-0.018*	0.008
1922	-0.026*	0.004	0.018	-0.018*	0.008
1923	-0.026*	0.004	0.018	-0.018*	0.008
1924	-0.026*	0.004	0.018	-0.018*	0.008
1925	-0.026*	0.004	0.018	-0.018*	0.008
1926	-0.027*	0.004	0.017	-0.018*	0.008
1927	-0.027*	0.004	0.017	-0.018*	0.008
1928	-0.027*	0.004	0.017	-0.017*	0.008
1929	-0.027*	0.004	0.016	-0.017*	0.008
1930	-0.027*	0.004	0.016	-0.017*	0.008
1931	-0.027*	0.004	0.016	-0.017*	0.008
1932	-0.028*	0.004	0.016	-0.017*	0.008
1933	-0.028*	0.004	0.016	-0.017*	0.008
1934	-0.028*	0.004	0.015	-0.017*	0.008
1935	-0.028*	0.004	0.015	-0.017*	0.008
1936	-0.028*	0.004	0.015	-0.017*	0.008
1937	-0.028*	0.004	0.015	-0.017*	0.008
1938	-0.028*	0.004	0.015	-0.017*	0.008
1939	-0.028*	0.004	0.015	-0.017*	0.008
1940	-0.028*	0.004	0.014	-0.017*	0.008
1941	-0.028*	0.004	0.014	-0.017*	0.008
1942	-0.028*	0.004	0.014	-0.017*	0.008
1943	-0.028*	0.004	0.014	-0.017*	0.008
1944	-0.029*	0.004	0.013	-0.017*	0.008
1945	-0.029*	0.004	0.013	-0.017*	0.008
1946	-0.029*	0.004	0.013	-0.017*	0.008
1947	-0.029*	0.004	0.013	-0.017*	0.008
1948	-0.029*	0.004	0.013	-0.017*	0.008
1949	-0.029*	0.004	0.013	-0.017*	0.008

Table A43. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5
1950	-0.029*	0.004	0.012	-0.017*	0.008
1951	-0.029*	0.004	0.012	-0.017*	0.008
1952	-0.029*	0.004	0.012	-0.017*	0.008
1953	-0.029*	0.004	0.012	-0.017*	0.008
1954	-0.029*	0.004	0.012	-0.017*	0.008
1955	-0.029*	0.004	0.011	-0.017*	0.008
1956	-0.029*	0.004	0.011	-0.017*	0.008
1957	-0.029*	0.004	0.011	-0.017*	0.008
1958	-0.029*	0.004	0.011	-0.017*	0.008
1959	-0.029*	0.004	0.011	-0.017*	0.008
1960	-0.029*	0.004	0.010	-0.017*	0.008
1961	-0.029*	0.004	0.010	-0.017*	0.008
1962	-0.029*	0.004	0.010	-0.017*	0.008
1963	-0.029*	0.004	0.010	-0.017*	0.008
1964	-0.029*	0.004	0.009	-0.017*	0.008
1965	-0.029*	0.004	0.009	-0.017*	0.008
1966	-0.029*	0.004	0.009	-0.017*	0.008
1967	-0.029*	0.004	0.009	-0.017*	0.008
1968	-0.029*	0.004	0.009	-0.017*	0.008
1969	-0.029*	0.004	0.009	-0.017*	0.008
1970	-0.029*	0.004	0.009	-0.017*	0.008
1971	-0.029*	0.004	0.009	-0.017*	0.008
1972	-0.029*	0.004	0.008	-0.017*	0.008
1973	-0.029*	0.004	0.008	-0.017*	0.008
1974	-0.029*	0.004	0.008	-0.017*	0.008
1975	-0.029*	0.004	0.008	-0.017*	0.008
1976	-0.029*	0.004	0.008	-0.017*	0.008
1977	-0.029*	0.004	0.008	-0.017*	0.008
1978	-0.029*	0.004	0.008	-0.017*	0.008
1979	-0.029*	0.004	0.007	-0.017*	0.008
1980	-0.029*	0.004	0.007	-0.017*	0.008
1981	-0.029*	0.004	0.007	-0.017*	0.008
1982	-0.029*	0.004	0.007	-0.017*	0.008
1983	-0.029*	0.004	0.007	-0.017*	0.008
1984	-0.029*	0.004	0.007	-0.017*	0.008
1985	-0.029*	0.004	0.007	-0.017*	0.008
1986	-0.029*	0.004	0.007	-0.017*	0.008

* Indicates coefficient is significant at $P \leq 0.05$.

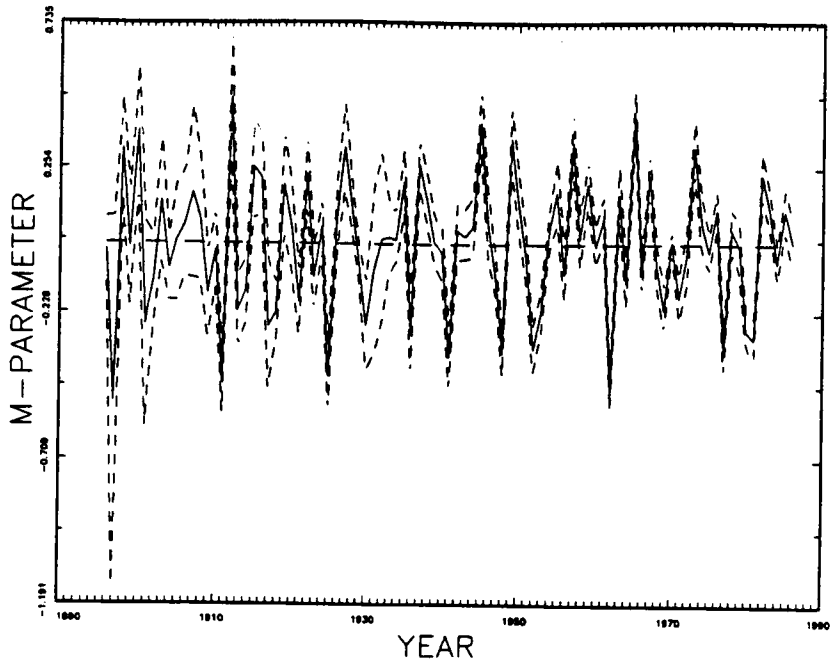


Figure A130. Graph of M-parameter and associated 95% confidence interval over time, Wayne County northern red oak, cluster 2.

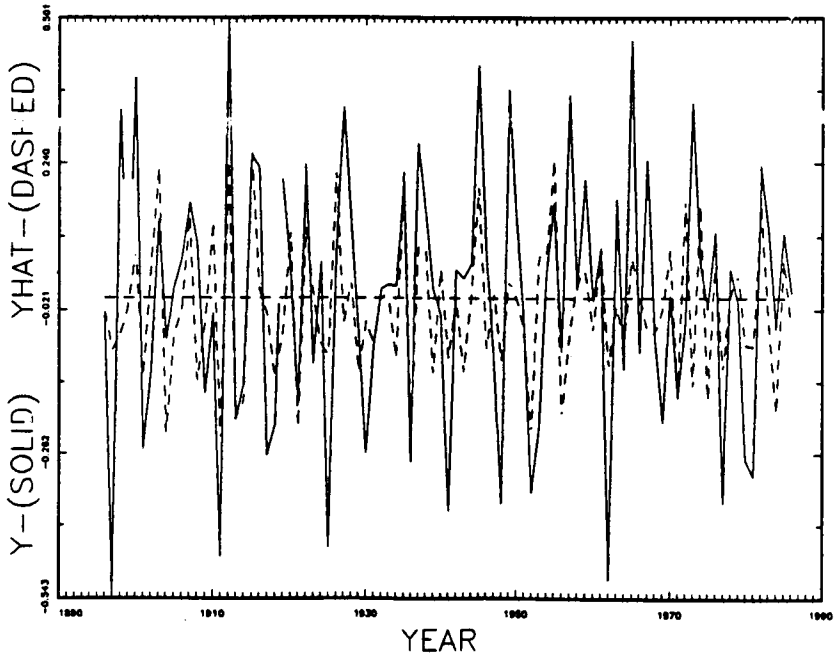
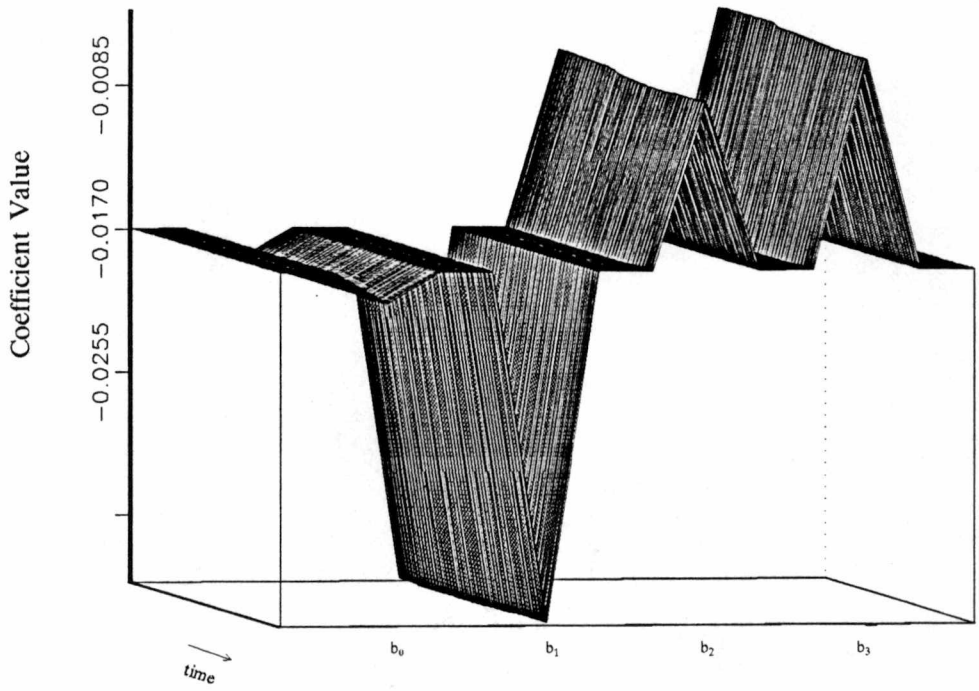


Figure A131. Graph of predicted and actual standardized growth, Wayne County northern red oak, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = past May rain
b_3 = past June rain

Figure A132. Three dimensional graph of changes in parameter coefficients over time, Wayne County northern red oak, cluster 2.

Table A44. Climate parameter estimates by year for Wayne County northern red oak, cluster 2.

YEAR	June temperature b_1	Past May rain b_2	Past June rain b_3
1897	-0.038*	-0.007	-0.004
1898	-0.038*	-0.007	-0.004
1899	-0.038*	-0.006	-0.004
1900	-0.038*	-0.006	-0.004
1901	-0.038*	-0.006	-0.004
1902	-0.038*	-0.006	-0.004
1903	-0.038*	-0.006	-0.004
1904	-0.038*	-0.006	-0.004
1905	-0.038*	-0.006	-0.004
1906	-0.038*	-0.007	-0.004
1907	-0.038*	-0.007	-0.004
1908	-0.038*	-0.007	-0.004
1909	-0.038*	-0.007	-0.004
1910	-0.038*	-0.007	-0.004
1911	-0.038*	-0.007	-0.004
1912	-0.038*	-0.007	-0.004
1913	-0.038*	-0.007	-0.004
1914	-0.038*	-0.007	-0.004
1915	-0.038*	-0.007	-0.004
1916	-0.038*	-0.007	-0.004
1917	-0.038*	-0.007	-0.004
1918	-0.038*	-0.007	-0.004
1919	-0.038*	-0.007	-0.004
1920	-0.038*	-0.007	-0.004
1921	-0.038*	-0.007	-0.004
1922	-0.038*	-0.007	-0.004
1923	-0.038*	-0.007	-0.004
1924	-0.038*	-0.007	-0.004
1925	-0.038*	-0.007	-0.004
1926	-0.038*	-0.007	-0.004
1927	-0.038*	-0.007	-0.004
1928	-0.038*	-0.007	-0.004
1929	-0.038*	-0.007	-0.004
1930	-0.038*	-0.007	-0.004
1931	-0.038*	-0.007	-0.004
1932	-0.038*	-0.007	-0.004
1933	-0.038*	-0.007	-0.004
1934	-0.038*	-0.007	-0.004
1935	-0.038*	-0.007	-0.004
1936	-0.038*	-0.007	-0.004
1937	-0.038*	-0.007	-0.004
1938	-0.038*	-0.007	-0.004
1939	-0.038*	-0.007	-0.004
1940	-0.038*	-0.007	-0.004
1941	-0.038*	-0.007	-0.004
1942	-0.038*	-0.007	-0.004
1943	-0.038*	-0.007	-0.004
1944	-0.038*	-0.007	-0.004
1945	-0.038*	-0.007	-0.004
1946	-0.038*	-0.007	-0.004
1947	-0.038*	-0.007	-0.004
1948	-0.038*	-0.007	-0.004
1949	-0.038*	-0.007	-0.004

Table A44. Continued.

YEAR	b_1	b_2	b_3
1950	-0.038*	-0.007	-0.004
1951	-0.038*	-0.007	-0.004
1952	-0.038*	-0.007	-0.004
1953	-0.038*	-0.007	-0.004
1954	-0.038*	-0.007	-0.004
1955	-0.038*	-0.007	-0.004
1956	-0.038*	-0.007	-0.004
1957	-0.038*	-0.007	-0.004
1958	-0.038*	-0.007	-0.004
1959	-0.038*	-0.007	-0.004
1960	-0.038*	-0.007	-0.004
1961	-0.038*	-0.007	-0.004
1962	-0.038*	-0.007	-0.004
1963	-0.038*	-0.007	-0.004
1964	-0.038*	-0.007	-0.004
1965	-0.038*	-0.007	-0.004
1966	-0.038*	-0.007	-0.004
1967	-0.038*	-0.007	-0.004
1968	-0.038*	-0.007	-0.004
1969	-0.038*	-0.007	-0.005
1970	-0.038*	-0.007	-0.005
1971	-0.038*	-0.007	-0.005
1972	-0.038*	-0.007	-0.005
1973	-0.038*	-0.007	-0.005
1974	-0.038*	-0.007	-0.005
1975	-0.038*	-0.007	-0.005
1976	-0.038*	-0.007	-0.005
1977	-0.038*	-0.007	-0.005
1978	-0.038*	-0.007	-0.005
1979	-0.038*	-0.007	-0.005
1980	-0.038*	-0.007	-0.005
1981	-0.038*	-0.007	-0.005
1982	-0.038*	-0.007	-0.005
1983	-0.038*	-0.007	-0.005
1984	-0.038*	-0.007	-0.005
1985	-0.038*	-0.007	-0.005
1986	-0.038*	-0.007	-0.005

* Indicates coefficient is significant at $P \leq 0.05$.

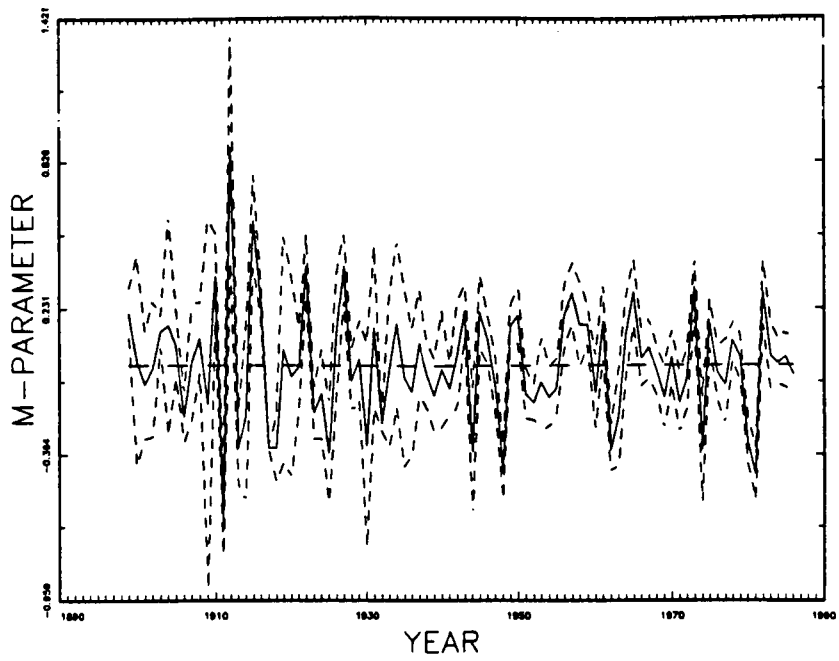


Figure A133. Graph of M-parameter and associated 95% confidence interval over time, Wayne County northern red oak, cluster 3.

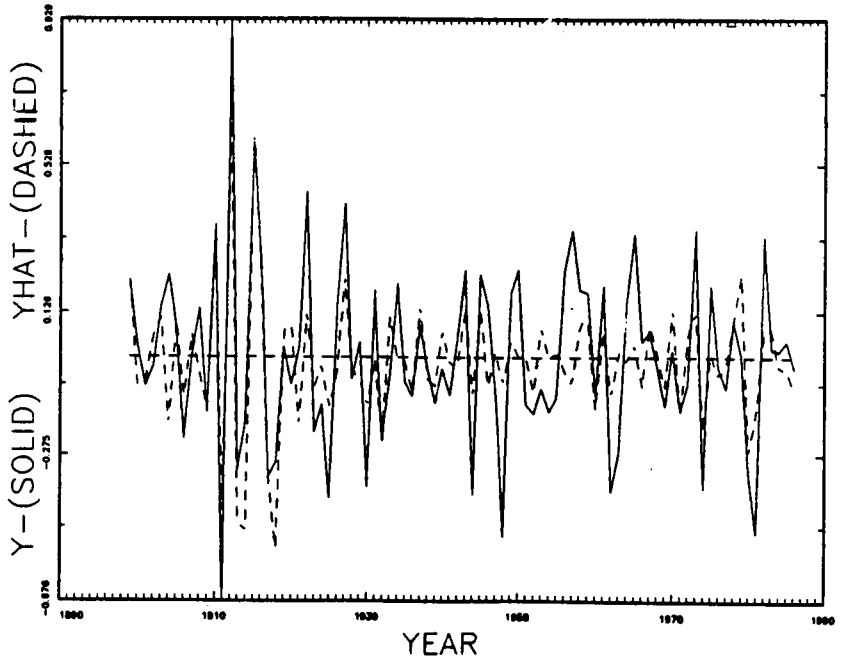
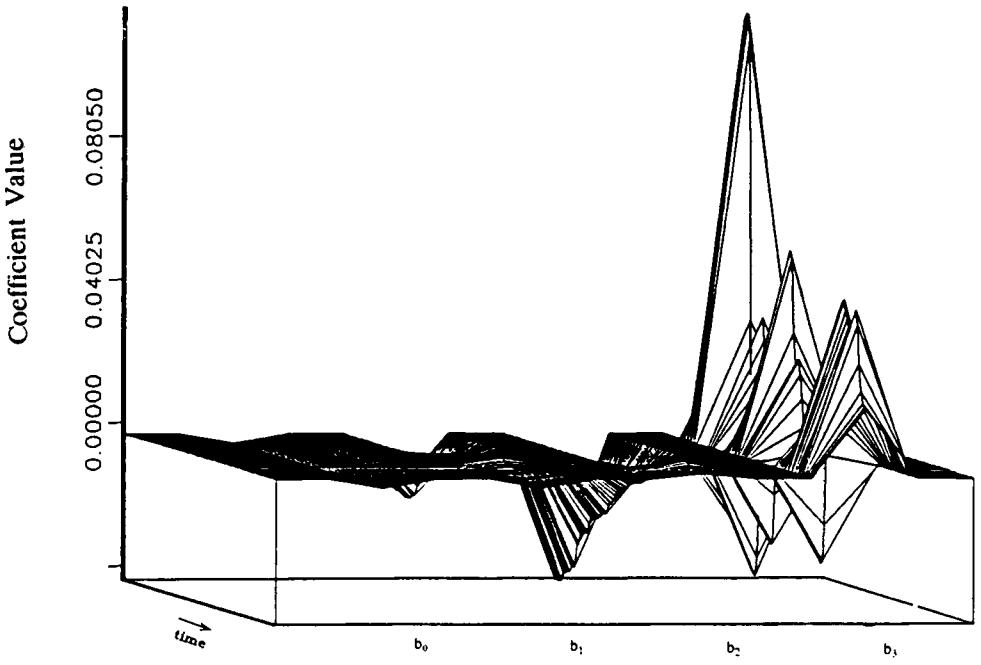


Figure A134. Graph of predicted and actual standardized growth, Wayne County northern red oak, cluster 3.



Where:

b_0 = the intercept (non-varying)
b_1 = February temperature
b_2 = June temperature
b_3 = past December temperature

Figure A135. Three dimensional graph of changes in parameter coefficients over time, Wayne County northern red oak, cluster 3.

Table A45. Climate parameter estimates by year for Wayne County northern red oak, cluster 3.

YEAR	February temperature b_1	June temperature b_2	Past December rain b_3
1899	-0.019	-0.044*	-0.012
1900	-0.019	-0.044*	-0.018
1901	-0.019	-0.044*	-0.019
1902	-0.019*	-0.044*	-0.019
1903	-0.019*	-0.044*	-0.019
1904	-0.020*	-0.042*	-0.017
1905	-0.020*	-0.041*	-0.017
1906	-0.020*	-0.041*	-0.018
1907	-0.020*	-0.041*	-0.026
1908	-0.020*	-0.041*	-0.024
1909	-0.019*	-0.039*	0.025
1910	-0.019*	-0.039*	0.028
1911	-0.019*	-0.039*	0.031
1912	-0.016	-0.033*	0.053
1913	-0.016	-0.032*	0.060
1914	-0.014	-0.030*	0.104*
1915	-0.014	-0.029	0.116*
1916	-0.014	-0.029	0.117*
1917	-0.014	-0.029	0.117*
1918	-0.014	-0.028	0.110*
1919	-0.012	-0.026	0.032
1920	-0.010	-0.024	-0.030
1921	-0.010	-0.024	-0.039
1922	-0.010	-0.024	-0.040
1923	-0.010	-0.024	-0.035
1924	-0.010	-0.024	-0.019
1925	-0.010	-0.023	0.002
1926	-0.009	-0.022	0.033*
1927	-0.009	-0.022	0.027
1928	-0.009	-0.022	0.022
1929	-0.009	-0.021	0.017
1930	-0.008	-0.019	-0.012
1931	-0.007	-0.018	-0.030*
1932	-0.007	-0.018	-0.029*
1933	-0.007	-0.017	-0.016
1934	-0.006	-0.016	0.001
1935	-0.005	-0.015	0.016
1936	-0.004	-0.014	0.023
1937	-0.004	-0.014	0.029
1938	-0.004	-0.013	0.032
1939	-0.003	-0.013	0.036
1940	-0.003	-0.012	0.045
1941	-0.003	-0.012	0.046
1942	-0.003	-0.011	0.055
1943	-0.003	-0.011	0.052
1944	-0.003	-0.011	0.032
1945	-0.003	-0.011	0.023
1946	-0.003	-0.010	0.024
1947	-0.003	-0.010	0.024
1948	-0.003	-0.010	0.020
1949	-0.003	-0.010	0.014
1950	-0.002	-0.009	0.006
1951	-0.002	-0.009	-0.004

Table A45. Continued.

YEAR	b_1	b_2	b_3
1952	-0.002	-0.009	-0.003
1953	-0.002	-0.007	-0.010
1954	-0.002	-0.006	-0.012
1955	-0.001	-0.006	-0.011
1956	-0.001	-0.006	-0.000
1957	-0.001	-0.006	-0.011
1958	-0.001	-0.006	-0.028
1959	-0.001	-0.006	-0.028
1960	-0.001	-0.006	-0.031
1961	-0.001	-0.005	-0.030
1962	-0.001	-0.005	-0.020
1963	-0.002	-0.004	-0.000
1964	-0.002	-0.004	0.014
1965	-0.002	-0.003	0.011
1966	-0.003	-0.002	0.014
1967	-0.003	-0.002	0.018
1968	-0.003	-0.002	0.020
1969	-0.003	-0.001	0.023
1970	-0.003	-0.001	0.029
1971	-0.004	-0.000	0.036
1972	-0.004	0.000	0.044
1973	-0.004	0.000	0.045
1974	-0.005	0.000	0.042
1975	-0.005	-0.000	0.040
1976	-0.005	-0.000	0.038
1977	-0.006	-0.001	0.032
1978	-0.006	-0.001	0.030*
1979	-0.006	-0.002	0.040*
1980	-0.006	-0.002	0.043*
1981	-0.006	-0.002	0.039*
1982	-0.006	-0.002	0.028
1983	-0.006	-0.002	0.021
1984	-0.006	-0.002	0.017
1985	-0.006	-0.002	0.016
1986	-0.006	-0.002	0.016

* Indicates coefficient is significant at $P \leq 0.05$

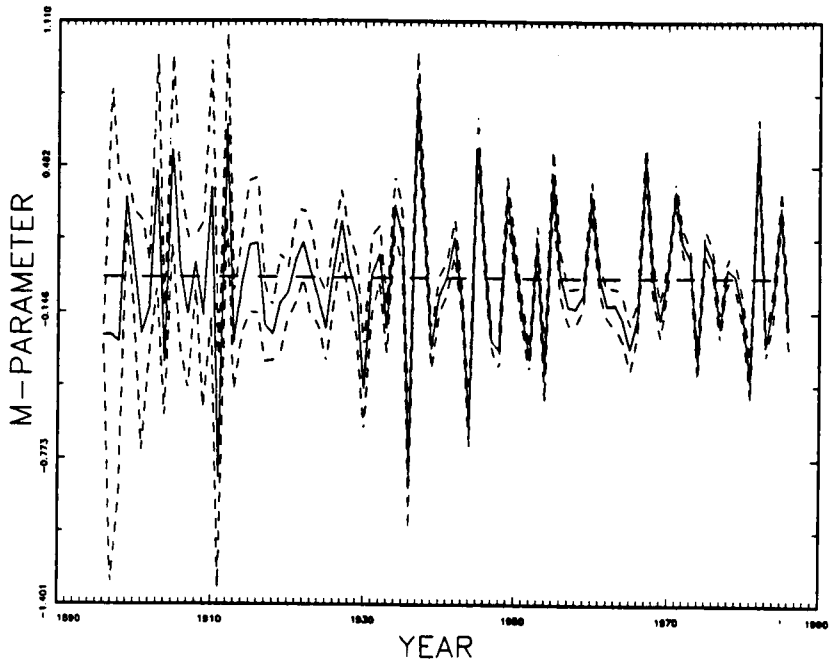


Figure A136. Graph of M-parameter and associated 95% confidence interval over time, Emory River yellow-poplar, cluster 1.

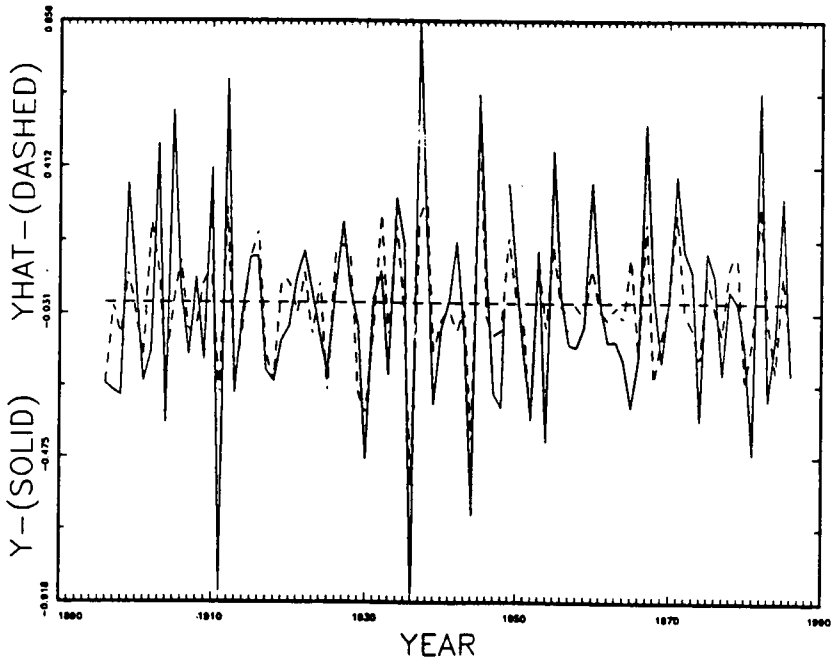
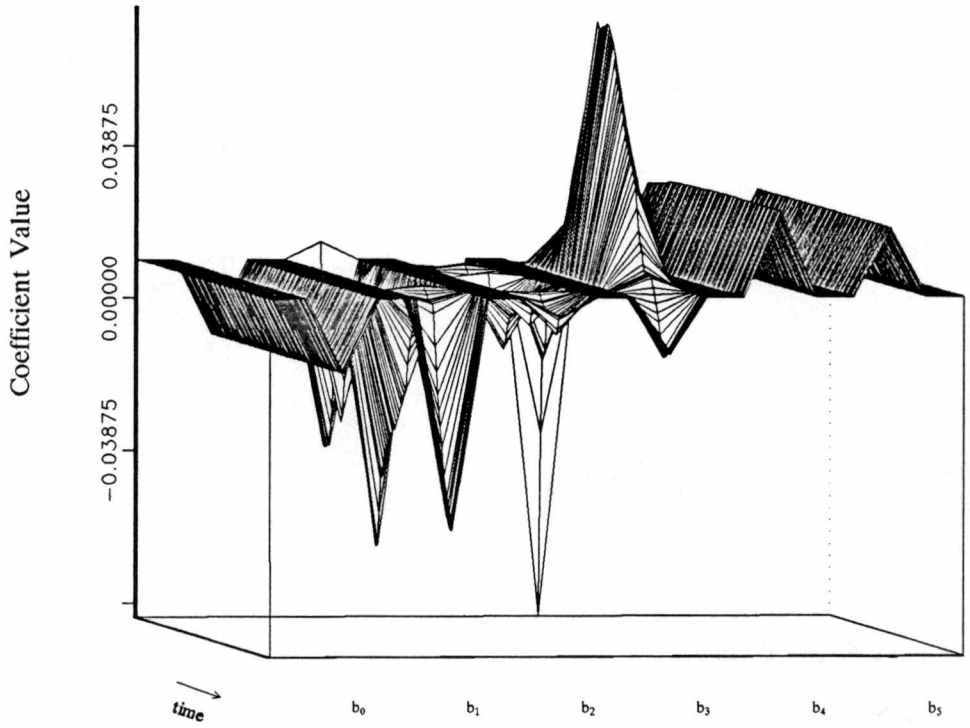


Figure A137. Graph of predicted and actual standardized growth, Emory River yellow-poplar, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = June temperature
b_2 = past December temperature
b_3 = June rain
b_4 = July rain
b_5 = past August rain

Figure A138. Three dimensional graph of changes in parameter coefficients over time, Emory River yellow-poplar, cluster 1.

Table A46. Climate parameter estimates for Emory River yellow-poplar, cluster 1.

YEAR	June temperature b_1	Past December temperature b_2	June rain b_3	July rain b_4	Past August rain b_5
1897	-0.023	-0.031	-0.035	0.029	0.027*
1898	-0.037	-0.033	-0.016	0.029	0.027*
1899	-0.038	-0.032	-0.015	0.029	0.027*
1900	-0.038	-0.028	-0.013	0.029	0.027*
1901	-0.036	-0.007	-0.004	0.029	0.027*
1902	-0.037	-0.006	-0.003	0.029	0.027*
1903	-0.032	0.000	0.008	0.030	0.027*
1904	-0.028	0.000	0.009	0.030	0.027*
1905	-0.016	-0.001	0.010	0.030	0.027*
1906	-0.009	-0.003	0.011	0.030*	0.027*
1907	-0.003	-0.004	0.011	0.030*	0.027*
1908	-0.004	-0.004	0.011	0.030*	0.027*
1909	-0.015	-0.002	0.013	0.030*	0.027*
1910	-0.030	0.005	0.018	0.031*	0.027*
1911	-0.028	0.009	0.019	0.031*	0.027*
1912	-0.020	0.010	0.020	0.031*	0.027*
1913	-0.017	0.010	0.020	0.031*	0.027*
1914	-0.015	0.009	0.020	0.031*	0.027*
1915	-0.012	0.009	0.021	0.031*	0.027*
1916	-0.009	0.009	0.022	0.031*	0.027*
1917	-0.009	0.009	0.022	0.031*	0.027*
1918	-0.008	0.009	0.022	0.031*	0.027*
1919	-0.006	0.011	0.022	0.031*	0.027*
1920	-0.008	0.011	0.022	0.031*	0.027*
1921	-0.014	0.010	0.024	0.031*	0.027*
1922	-0.018	0.009	0.025	0.031*	0.027*
1923	-0.024	0.007	0.026	0.031*	0.027*
1924	-0.024	0.007	0.027	0.031*	0.027*
1925	-0.024	0.007	0.029	0.031*	0.027*
1926	-0.027	0.007	0.031	0.031*	0.027*
1927	-0.030	0.007	0.033	0.031*	0.027*
1928	-0.033	0.007	0.037	0.031*	0.027*
1929	-0.038	0.006	0.043	0.031*	0.027*
1930	-0.044	0.006	0.051	0.031*	0.027*
1931	-0.049	0.005	0.057	0.032*	0.027*
1932	-0.052	0.007	0.062*	0.032*	0.027*
1933	-0.054	0.007	0.064*	0.032*	0.027*
1934	-0.059	0.007	0.067*	0.032*	0.027*
1935	-0.058*	0.009	0.070*	0.032*	0.027*
1936	-0.050	0.011	0.074*	0.032*	0.027*
1937	-0.041	0.006	0.073*	0.032*	0.027*
1938	-0.041	0.005	0.073*	0.032*	0.027*
1939	-0.037	0.003	0.073*	0.032*	0.027*
1940	-0.035	0.001	0.074*	0.032*	0.027*
1941	-0.033	-0.000	0.074*	0.032*	0.027*
1942	-0.032	-0.002	0.074*	0.032*	0.027*
1943	-0.031	-0.003	0.074*	0.032*	0.027*
1944	-0.030	-0.005	0.074*	0.032*	0.027*
1945	-0.028	-0.007	0.072*	0.032*	0.027*
1946	-0.028	-0.008	0.071*	0.032*	0.027*
1947	-0.028	-0.007	0.070*	0.032*	0.027*
1948	-0.026	-0.004	0.067*	0.032*	0.027*
1949	-0.025	-0.001	0.062*	0.032*	0.027*

Table A46. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5
1950	-0.023	0.000	0.060*	0.032*	0.027*
1951	-0.021	0.001	0.058*	0.032*	0.027*
1952	-0.020	0.001	0.057*	0.032*	0.027*
1953	-0.018	0.002	0.055*	0.032*	0.027*
1954	-0.017	0.003	0.052*	0.032*	0.027*
1955	-0.011	0.004	0.048*	0.032*	0.027*
1956	-0.007	0.005	0.045*	0.032*	0.027*
1957	-0.004	0.006	0.044*	0.032*	0.027*
1958	-0.002	0.006	0.042*	0.032*	0.027*
1959	-0.001	0.006	0.042*	0.032*	0.027*
1960	-0.000	0.005	0.039	0.032*	0.027*
1961	0.001	0.004	0.037	0.032*	0.027*
1962	0.002	0.004	0.035	0.032*	0.027*
1963	0.006	0.002	0.030	0.032*	0.027*
1964	0.011	0.000	0.025	0.032*	0.027*
1965	0.011	0.003	0.022	0.032*	0.027*
1966	0.011	0.005	0.020	0.032*	0.027*
1967	0.010	0.008	0.016	0.032*	0.027*
1968	0.009	0.009	0.015	0.032*	0.027*
1969	0.008	0.009	0.014	0.032*	0.027*
1970	0.007	0.009	0.014	0.032*	0.027*
1971	0.005	0.009	0.014	0.032*	0.027*
1972	0.007	0.007	0.014	0.032*	0.027*
1973	0.005	0.007	0.013	0.032*	0.027*
1974	-0.004	0.006	0.011	0.032*	0.027*
1975	-0.010	0.006	0.009	0.032*	0.027*
1976	-0.016	0.005	0.007	0.032*	0.027*
1977	-0.020	0.004	0.005	0.032*	0.027*
1978	-0.024	0.003	0.003	0.032*	0.027*
1979	-0.029	0.003	-0.000	0.032*	0.027*
1980	-0.037	0.002	-0.004	0.032*	0.027*
1981	-0.044*	0.001	-0.006	0.032*	0.027*
1982	-0.046*	-0.000	-0.006	0.032*	0.027*
1983	-0.047*	0.001	-0.005	0.032*	0.027*
1984	-0.049	0.004	-0.005	0.032*	0.027*
1985	-0.049	0.005	-0.005	0.032*	0.027*
1986	-0.049	0.005	-0.005	0.032*	0.027*

* Indicates coefficient is significant at $P \leq 0.05$.

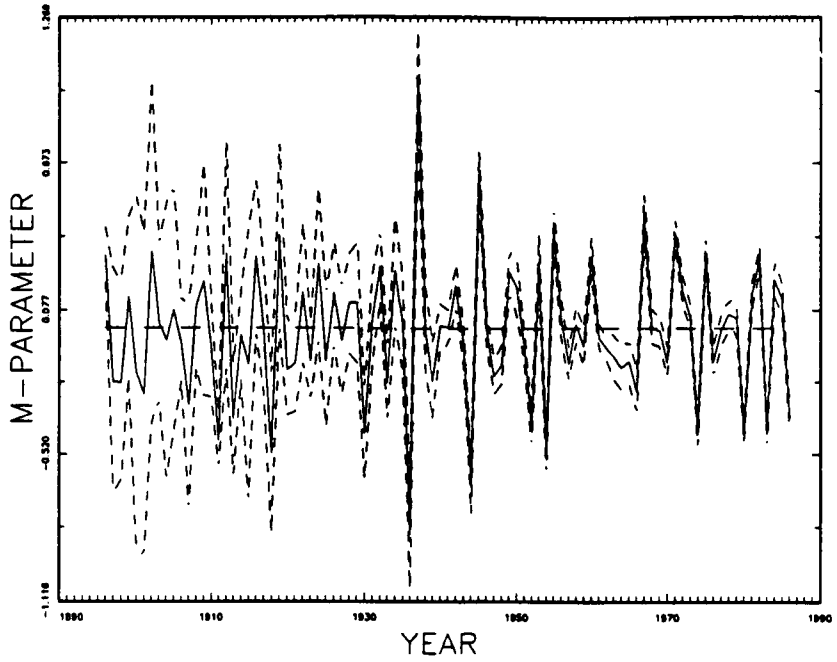


Figure A139. Graph of M-parameter and associated 95% confidence interval over time, Emory River yellow-poplar, cluster 2.

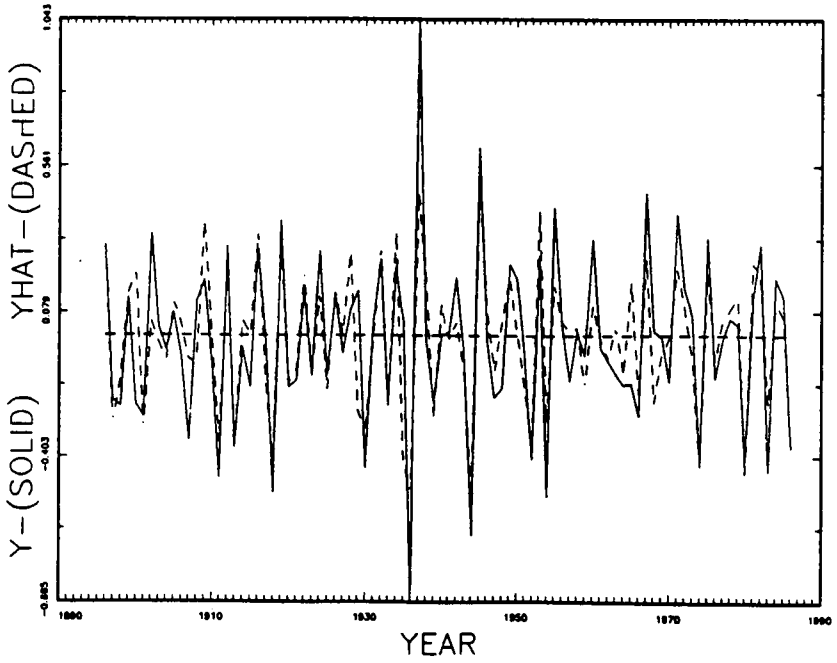
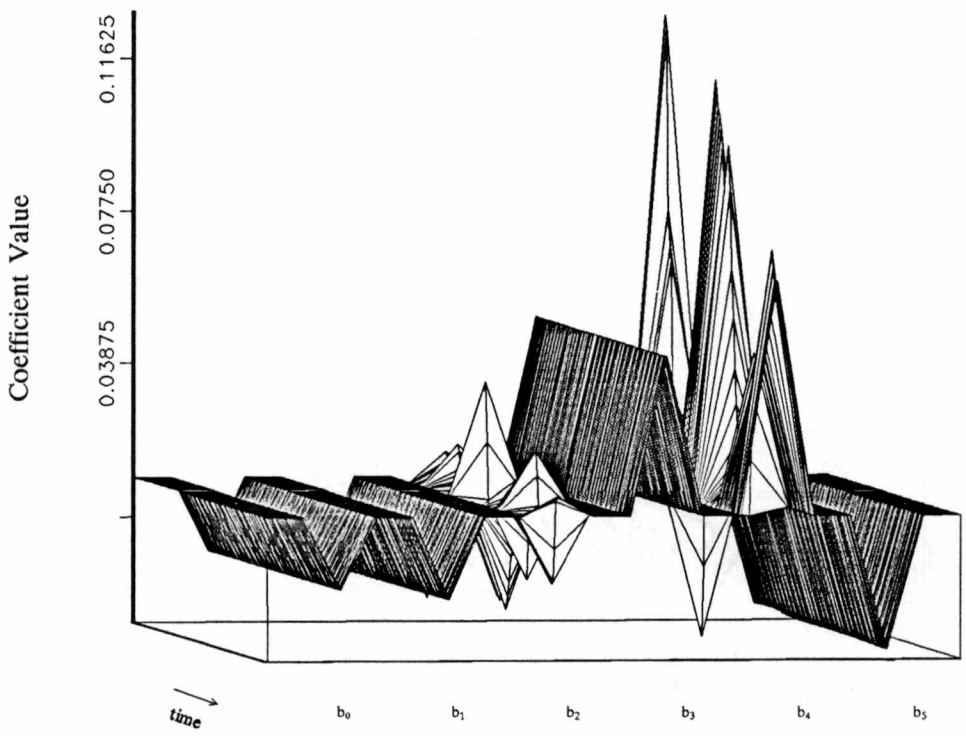


Figure A140. Graph of predicted and actual standardized growth, Emory River yellow-poplar, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = past September temperature
b_2 = past December temperature
b_3 = June rain
b_4 = July rain
b_5 = past March rain

Figure A141. Three dimensional graph of changes in parameter coefficients over time, Emory River yellow-poplar, cluster 2.

Table A47. Climate parameter estimates for Emory River yellow-poplar, cluster 2.

YEAR	Past September temperature b_1	Past December temperature b_2	June rain b_3	July rain b_4	Past March rain b_5
1897	-0.012	-0.020	0.050*	0.042	-0.023
1898	-0.012	-0.017	0.050*	0.043	-0.023
1899	-0.012	-0.017	0.050*	0.042	-0.023
1900	-0.012	-0.015	0.050*	0.040	-0.023
1901	-0.012	-0.015	0.050*	0.040	-0.023
1902	-0.012	-0.006	0.050*	0.040	-0.023
1903	-0.012	-0.006	0.050*	0.038	-0.023
1904	-0.012	-0.004	0.050*	0.029	-0.023
1905	-0.012	-0.002	0.050*	0.023	-0.023
1906	-0.012	-0.002	0.050*	0.029	-0.023
1907	-0.012	0.001	0.050*	0.057	-0.023*
1908	-0.012	0.005	0.050*	0.070	-0.023*
1909	-0.012	0.018	0.050*	0.118	-0.023*
1910	-0.012	0.016	0.050*	0.128*	-0.023*
1911	-0.012	0.015	0.050*	0.125*	-0.023*
1912	-0.012	0.013	0.050*	0.079	-0.023*
1913	-0.012	0.013	0.050*	0.070	-0.023*
1914	-0.012	0.014	0.050*	0.066	-0.023*
1915	-0.012	0.016	0.050*	0.033	-0.023*
1916	-0.012	0.018	0.050*	0.028	-0.023*
1917	-0.012	0.020	0.050*	0.030	-0.023*
1918	-0.012	0.019	0.050*	0.026	-0.023*
1919	-0.011	0.014	0.050*	0.022	-0.023*
1920	-0.011	0.013	0.050*	0.022	-0.023*
1921	-0.011	0.012	0.050*	0.021	-0.023*
1922	-0.011	0.011	0.050*	0.022	-0.024*
1923	-0.011	0.011	0.050*	0.022	-0.024*
1924	-0.011	0.008	0.050*	0.023	-0.024*
1925	-0.011	0.008	0.050*	0.024	-0.024*
1926	-0.011	0.008	0.050*	0.025	-0.024*
1927	-0.011	0.010	0.050*	0.027	-0.024*
1928	-0.011	0.009	0.050*	0.027	-0.024*
1929	-0.011	0.006	0.050*	0.022	-0.024*
1930	-0.011	0.003	0.050*	0.015	-0.024*
1931	-0.011	0.001	0.050*	0.005	-0.024*
1932	-0.011	0.002	0.050*	-0.000	-0.024*
1933	-0.011	0.003	0.050*	-0.006	-0.024*
1934	-0.011	0.007	0.050*	-0.021	-0.024*
1935	-0.011	0.027	0.050*	-0.027	-0.024*
1936	-0.011	0.038	0.050*	-0.009	-0.024*
1937	-0.011	0.023	0.050*	0.022	-0.024*
1938	-0.011	0.009	0.050*	0.049	-0.024*
1939	-0.011	-0.003	0.050*	0.069*	-0.024*
1940	-0.011	-0.006	0.050*	0.080*	-0.024*
1941	-0.011	-0.008	0.050*	0.085*	-0.024*
1942	-0.011	-0.011	0.050*	0.095*	-0.024*
1943	-0.011	-0.012	0.050*	0.106*	-0.024*
1944	-0.011	-0.015	0.050*	0.115*	-0.024*
1945	-0.011	-0.015	0.050*	0.113*	-0.024*
1946	-0.011	-0.016	0.050*	0.109*	-0.024*
1947	-0.011	-0.013	0.050*	0.107*	-0.024*
1948	-0.011	-0.014	0.050*	0.104*	-0.024*
1949	-0.011	-0.016	0.050*	0.099*	-0.024*

Table A47. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5
1950	-0.011	-0.018	0.050*	0.088*	-0.024*
1951	-0.011	-0.014	0.050*	0.088*	-0.024*
1952	-0.011	-0.011	0.050*	0.088*	-0.024*
1953	-0.011	-0.004	0.050*	0.100*	-0.024*
1954	-0.011	-0.002	0.050*	0.089*	-0.024*
1955	-0.011	0.001	0.050*	0.069*	-0.024*
1956	-0.011	0.003	0.050*	0.056*	-0.024*
1957	-0.011	0.008	0.050*	0.043*	-0.024*
1958	-0.011	0.010	0.050*	0.035	-0.024*
1959	-0.011	0.017	0.050*	0.026	-0.024*
1960	-0.011	0.013	0.050*	0.022	-0.024*
1961	-0.011	0.011	0.050*	0.020	-0.024*
1962	-0.011	0.010	0.050*	0.019	-0.024*
1963	-0.011	-0.000	0.050*	0.019	-0.024*
1964	-0.011	-0.009	0.050*	0.019	-0.024*
1965	-0.011	0.001	0.050*	0.019	-0.024*
1966	-0.011	0.010	0.050*	0.019	-0.024*
1967	-0.011	0.021*	0.050*	0.008	-0.024*
1968	-0.011	0.022*	0.050*	0.022	-0.024*
1969	-0.011	0.024*	0.050*	0.038*	-0.024*
1970	-0.011	0.024*	0.050*	0.049*	-0.024*
1971	-0.011	0.018	0.050*	0.047*	-0.024*
1972	-0.011	0.011	0.050*	0.045*	-0.024*
1973	-0.011	0.010	0.050*	0.047*	-0.024*
1974	-0.011	0.008	0.050*	0.049*	-0.024*
1975	-0.011	0.006	0.050*	0.049*	-0.024*
1976	-0.011	0.004	0.050*	0.050*	-0.024*
1977	-0.011	-0.000	0.050*	0.050*	-0.024*
1978	-0.011	-0.004	0.050*	0.052*	-0.024*
1979	-0.011	-0.005	0.050*	0.057*	-0.024*
1980	-0.011	-0.006	0.050*	0.062*	-0.024*
1981	-0.011	-0.008	0.050*	0.073*	-0.024*
1982	-0.011	-0.007	0.050*	0.076*	-0.024*
1983	-0.011	0.001	0.050*	0.072*	-0.024*
1984	-0.011	0.013*	0.050*	0.068*	-0.024*
1985	-0.011	0.015*	0.050*	0.069*	-0.024*
1986	-0.011	0.015	0.050*	0.069*	-0.024*

* Indicates coefficient is significant at $P \leq 0.05$.

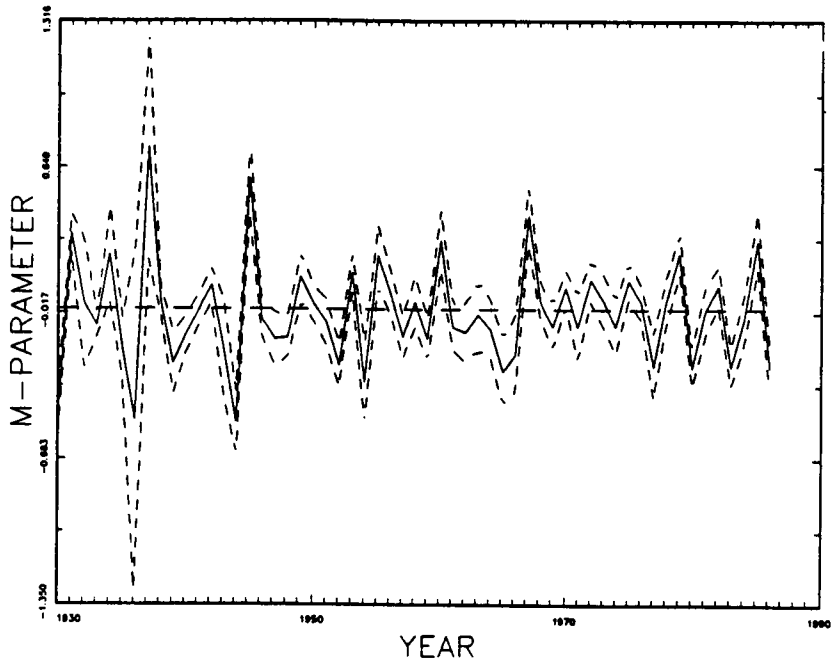


Figure A142. Graph of M-parameter and associated 95% confidence interval over time, Emory River yellow-poplar, cluster 3.

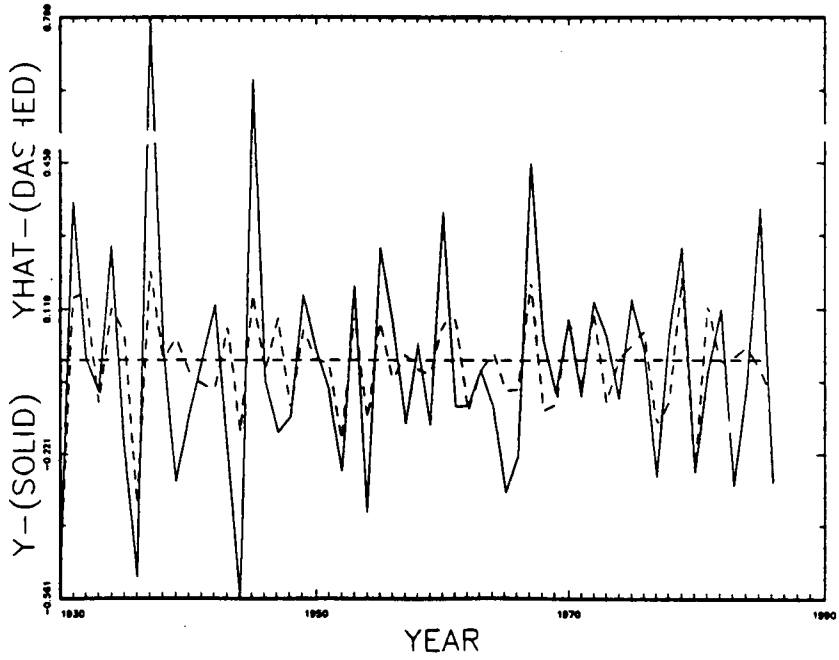
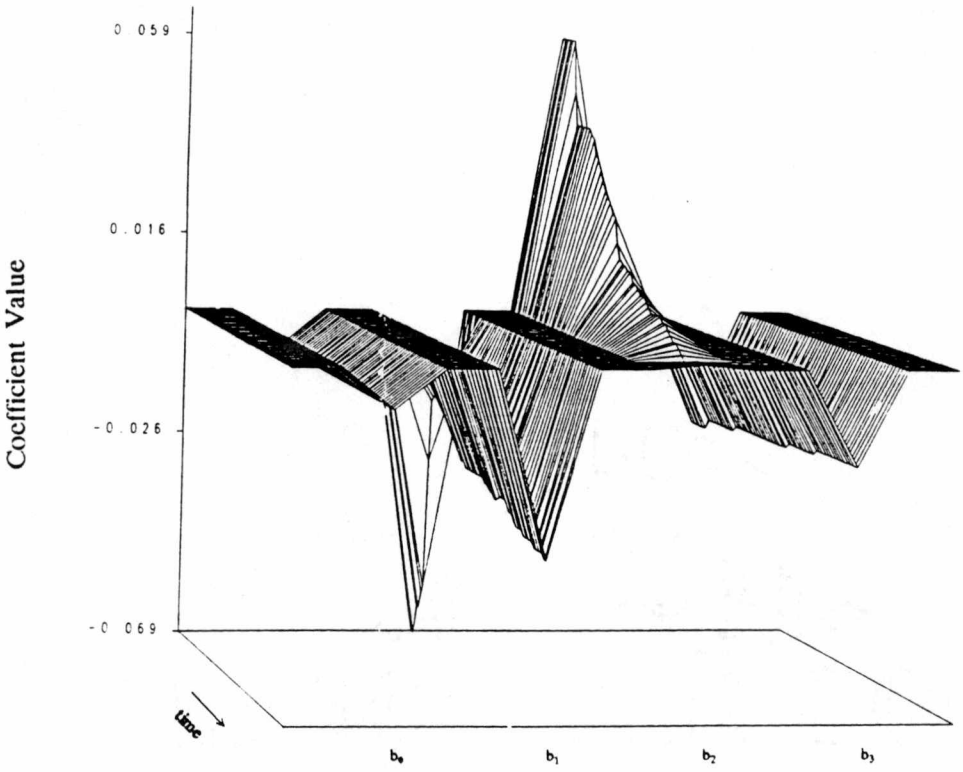


Figure A143. Graph of predicted and actual standardized growth, Emory River yellow-poplar, cluster 3.



Where:

b_0 = the intercept (non-varying)
b_1 = July temperature
b_2 = June rain
b_3 = past April rain

Figure A144. Three dimensional graph of changes in parameter coefficients over time, Emory River yellow-poplar, cluster 3.

Table A48. Climate parameter estimates by year for Emory River yellow-poplar, cluster 3.

YEAR	July temperature b_1	June rain b_2	Past April rain b_3
1930	-0.069*	0.059*	-0.024
1931	-0.069*	0.059*	-0.024
1932	-0.063*	0.059*	-0.024
1933	-0.063*	0.059*	-0.024
1934	-0.059*	0.059*	-0.024
1935	-0.058*	0.059*	-0.024
1936	-0.031	0.048	-0.022*
1937	-0.018	0.041	-0.022*
1938	-0.017	0.041	-0.022*
1939	-0.016	0.041	-0.022*
1940	-0.016	0.041	-0.022*
1941	-0.016	0.041	-0.022*
1942	-0.017	0.041	-0.022*
1943	-0.019	0.040*	-0.022*
1944	-0.020	0.039*	-0.022*
1945	-0.021	0.036	-0.022*
1946	-0.021	0.035	-0.021*
1947	-0.023	0.033	-0.021*
1948	-0.024	0.031	-0.021*
1949	-0.025	0.029	-0.021*
1950	-0.026	0.028	-0.021*
1951	-0.027	0.027	-0.021*
1952	-0.027	0.025	-0.021*
1953	-0.028	0.024	-0.021*
1954	-0.028	0.019	-0.021*
1955	-0.028	0.016	-0.021*
1956	-0.028	0.015	-0.021*
1957	-0.028	0.015	-0.021*
1958	-0.028	0.014	-0.021*
1959	-0.028	0.014	-0.021*
1960	-0.028	0.012	-0.021*
1961	-0.029	0.012	-0.021*
1962	-0.029	0.011	-0.021*
1963	-0.030*	0.010	-0.021*
1964	-0.030*	0.010	-0.020*
1965	-0.031*	0.009	-0.020*
1966	-0.031*	0.008	-0.020*
1967	-0.030*	0.007	-0.020*
1968	-0.030*	0.007	-0.020*
1969	-0.030*	0.007	-0.020*
1970	-0.031*	0.007	-0.020*
1971	-0.032*	0.006	-0.020*
1972	-0.032*	0.006	-0.020*
1973	-0.033*	0.005	-0.019*
1974	-0.034*	0.004	-0.019*
1975	-0.034*	0.003	-0.019*
1976	-0.034*	0.003	-0.019*
1977	-0.035*	0.002	-0.019*
1978	-0.035*	0.001	-0.019*
1979	-0.035*	0.000	-0.019*
1980	-0.035*	-0.000	-0.019*
1981	-0.036*	-0.000	-0.019*
1982	-0.036*	0.000	-0.019*

Table A48. Continued.

YEAR	b_1	b_2	b_3
1983	-0.036*	0.001	-0.019*
1984	-0.036*	0.001	-0.019*
1985	-0.037*	0.001	-0.019*
1986	-0.037*	0.001	-0.019*

* Indicates coefficient is significant at $P \leq 0.05$

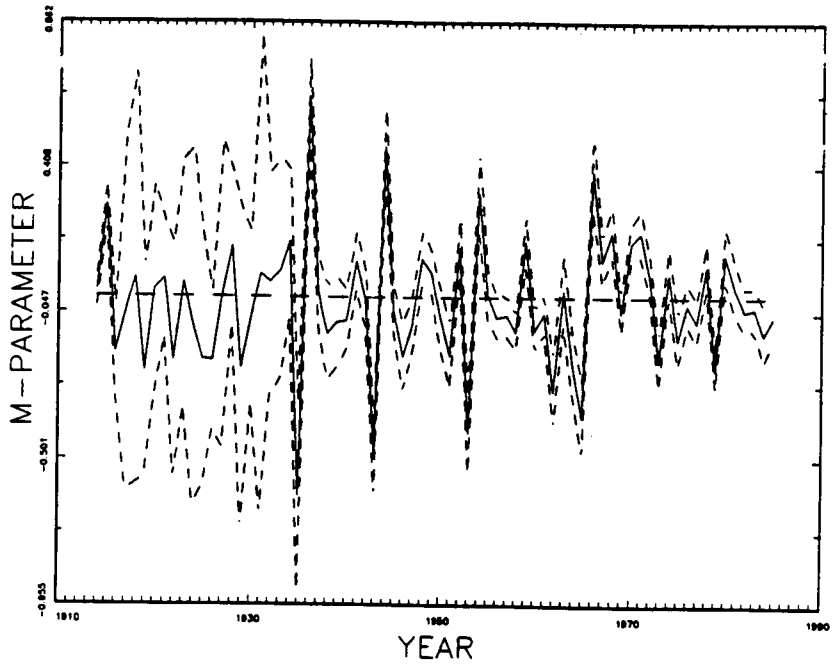


Figure A145. Graph of M-parameter and associated 95% confidence interval over time, Emory River yellow-poplar, cluster 4.

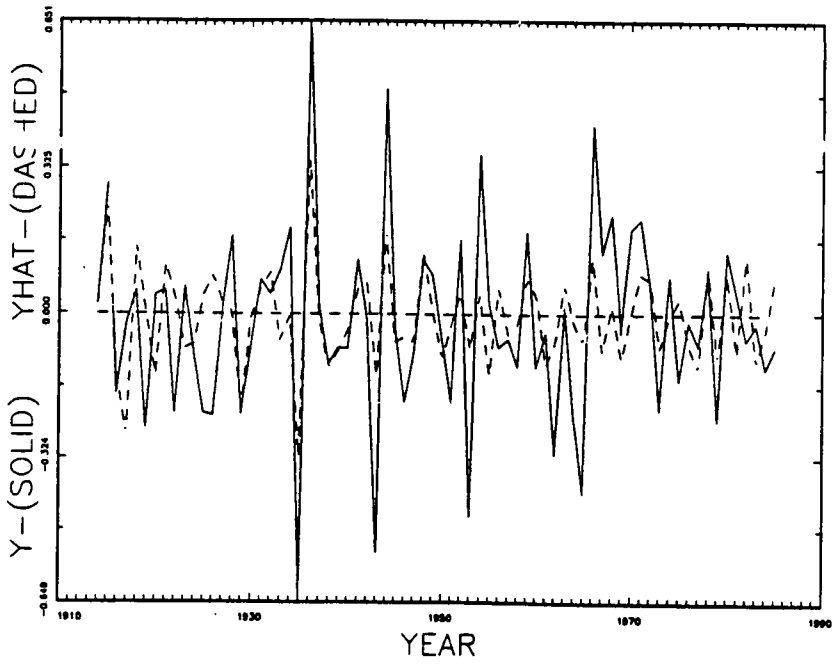
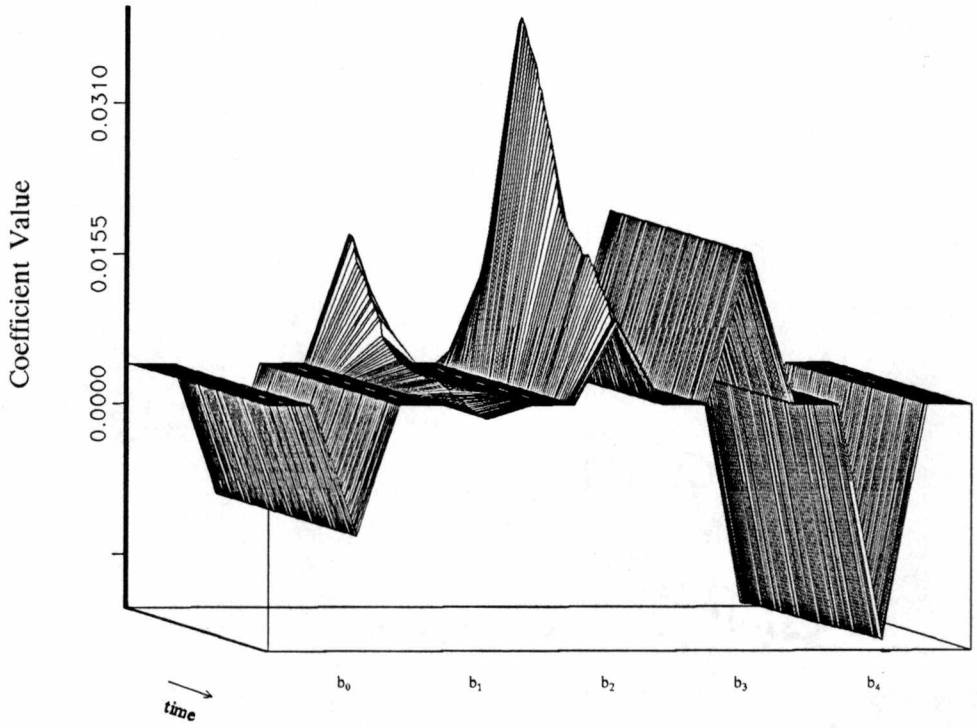


Figure A146. Graph of predicted and actual standardized growth, Emory River yellow-poplar, cluster 4.



Where:

b_0 = the intercept (non-varying)
b_1 = July temperature
b_2 = June rain
b_3 = past April rain
b_4 = January temperature

Figure A147. Three dimensional graph of changes in parameter coefficients over time, Emory River yellow-poplar, cluster 4.

Table A49. Climate parameter estimates for Emory River yellow-poplar, cluster 4.

YEAR	January temperature b_1	May rain b_2	June rain b_3	Past April rain b_4
1915	0.017	0.008	0.020*	-0.021*
1916	0.017	0.008	0.020*	-0.021*
1917	0.017	0.008	0.020*	-0.021*
1918	0.016	0.011	0.020*	-0.021*
1919	0.015	0.015	0.020*	-0.020*
1920	0.015	0.016	0.020*	-0.020*
1921	0.014	0.017	0.020*	-0.020*
1922	0.014	0.017	0.020*	-0.020*
1923	0.014	0.018	0.020*	-0.020*
1924	0.013	0.019	0.020*	-0.020*
1925	0.012	0.021	0.020*	-0.020*
1926	0.012	0.023	0.020*	-0.020*
1927	0.011	0.023	0.020*	-0.020*
1928	0.011	0.027	0.020*	-0.020*
1929	0.011	0.028	0.020*	-0.020*
1930	0.010	0.030	0.020*	-0.020*
1931	0.010	0.031	0.020*	-0.020*
1932	0.008	0.037	0.020*	-0.020*
1933	0.008	0.038	0.020*	-0.020*
1934	0.007	0.040	0.020*	-0.020*
1935	0.007	0.041*	0.020*	-0.020*
1936	0.007	0.041*	0.020*	-0.020*
1937	0.007	0.040*	0.020*	-0.020*
1938	0.007	0.040*	0.020*	-0.020*
1939	0.006	0.039*	0.020*	-0.020*
1940	0.006	0.038*	0.020*	-0.020*
1941	0.006	0.038*	0.020*	-0.020*
1942	0.006	0.037*	0.020*	-0.020*
1943	0.006	0.037*	0.020*	-0.020*
1944	0.006	0.036*	0.020*	-0.020*
1945	0.006	0.035*	0.020*	-0.020*
1946	0.006	0.034*	0.020*	-0.020*
1947	0.005	0.033*	0.020*	-0.020*
1948	0.005	0.032*	0.020*	-0.020*
1949	0.005	0.031*	0.020*	-0.020*
1950	0.005	0.030*	0.020*	-0.020*
1951	0.005	0.029*	0.020*	-0.020*
1952	0.005	0.028*	0.020*	-0.020*
1953	0.005	0.027*	0.020*	-0.020*
1954	0.005	0.025*	0.020*	-0.020*
1955	0.005	0.023	0.020*	-0.020*
1956	0.005	0.023	0.020*	-0.020*
1957	0.005	0.022	0.020*	-0.020*
1958	0.005	0.022	0.020*	-0.020*
1959	0.005	0.021	0.020*	-0.020*
1960	0.005	0.021	0.020*	-0.020*
1961	0.005	0.021	0.020*	-0.020*
1962	0.005	0.020	0.020*	-0.020*
1963	0.005	0.020	0.020*	-0.020*
1964	0.005	0.020	0.020*	-0.020*
1965	0.005	0.020	0.020*	-0.020*
1966	0.005	0.019	0.020*	-0.020*
1967	0.004	0.019*	0.020*	-0.020*
1968	0.004	0.019*	0.020*	-0.020*
1969	0.004	0.019*	0.020*	-0.020*

Table A49. Continued.

YEAR	b_1	b_2	b_3	b_4
1970	0.004	0.019*	0.020*	-0.020*
1971	0.004	0.018*	0.020*	-0.020*
1972	0.004	0.018*	0.020*	-0.020*
1973	0.004	0.018*	0.020*	-0.020*
1974	0.004	0.017	0.020*	-0.020*
1975	0.003	0.016	0.020*	-0.020*
1976	0.003	0.016	0.020*	-0.020*
1977	0.003	0.016	0.020*	-0.020*
1978	0.003	0.015	0.020*	-0.020*
1979	0.003	0.015	0.020*	-0.020*
1980	0.003	0.014	0.020*	-0.020*
1981	0.003	0.013	0.020*	-0.020*
1982	0.003	0.013	0.020*	-0.020*
1983	0.003	0.013	0.020*	-0.020*
1984	0.003	0.013	0.020*	-0.020*
1985	0.003	0.013	0.020*	-0.020*
1986	0.003	0.013	0.020*	-0.020*

* Indicates coefficient is significant at $P \leq 0.05$.

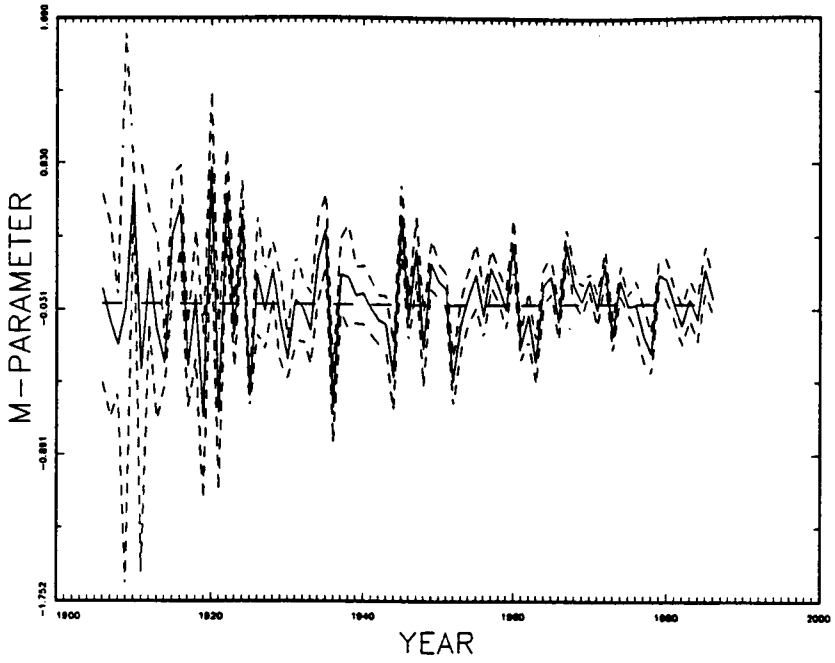


Figure A148. Graph of M-parameter and associated 95% confidence interval over time, Land Between the Lakes yellow-poplar, cluster 1.

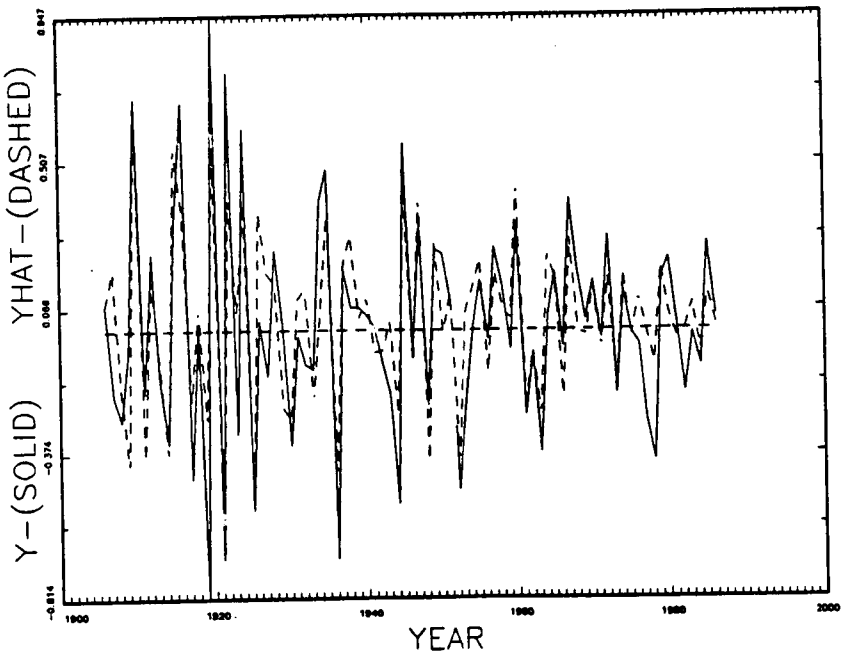
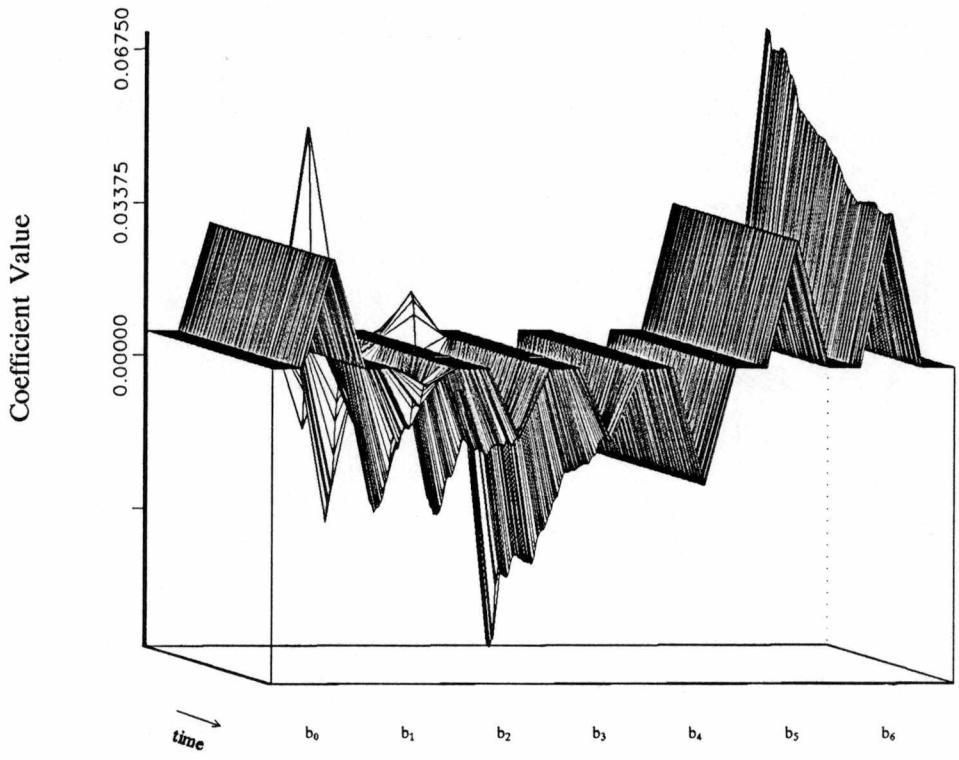


Figure A149. Graph of predicted and actual standardized growth, Land Between the Lakes yellow-poplar, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = March temperature
b_2 = May temperature
b_3 = June temperature
b_4 = past May temperature
b_5 = June rain
b_6 = past August rain

Figure A150. Three dimensional graph of changes in parameter coefficients over time, Land Between the Lakes yellow-poplar, cluster 1.

Table A50. Climate parameter estimates for LBL yellow-poplar, cluster 1.

YEAR	March temp. b_1	May temp. b_2	June temp. b_3	Past May temp. b_4	June rain b_5	Past August rain b_6
1907	-0.008	-0.021	-0.064	-0.020*	0.033*	0.071
1908	-0.007	-0.021	-0.064	-0.020*	0.033*	0.071
1909	0.050*	-0.005	-0.062	-0.020*	0.033*	0.067
1910	0.050*	-0.005	-0.062	-0.020*	0.033*	0.067
1911	0.022	0.008	-0.050*	-0.020*	0.033*	0.068*
1912	0.021	0.009	-0.049*	-0.020*	0.033*	0.067*
1913	0.019	0.012	-0.046*	-0.020*	0.033*	0.067*
1914	0.020	0.012	-0.046*	-0.020*	0.033*	0.067*
1915	0.021	0.014	-0.047*	-0.020*	0.033*	0.068*
1916	0.016	0.015	-0.047*	-0.020*	0.033*	0.068*
1917	0.013	0.013	-0.048*	-0.020*	0.033*	0.068*
1918	0.006	0.010	-0.048*	-0.020*	0.033*	0.068*
1919	-0.012	0.002	-0.047*	-0.020*	0.033*	0.066*
1920	-0.026	-0.007	-0.046*	-0.020*	0.033*	0.065*
1921	-0.035*	-0.014	-0.044*	-0.020*	0.033*	0.063*
1922	-0.031*	-0.017	-0.043*	-0.020*	0.033*	0.063*
1923	-0.030*	-0.021	-0.042*	-0.020*	0.033*	0.062*
1924	-0.028*	-0.023	-0.042*	-0.020*	0.033*	0.061*
1925	-0.027*	-0.023	-0.042*	-0.020*	0.033*	0.061*
1926	-0.020	-0.028	-0.042*	-0.020*	0.033*	0.057*
1927	-0.013	-0.029	-0.043*	-0.020*	0.033*	0.056*
1928	-0.008	-0.030	-0.043*	-0.020*	0.033*	0.056*
1929	-0.001	-0.031	-0.043*	-0.020*	0.033*	0.055*
1930	-0.000	-0.031	-0.043*	-0.020*	0.033*	0.055*
1931	-0.001	-0.032*	-0.043*	-0.020*	0.033*	0.054*
1932	-0.001	-0.032	-0.043*	-0.020*	0.033*	0.054*
1933	-0.001	-0.032	-0.043*	-0.020*	0.033*	0.054*
1934	0.001	-0.032	-0.043*	-0.020*	0.033*	0.053*
1935	-0.001	-0.031	-0.043*	-0.020*	0.033*	0.053*
1936	-0.005	-0.030	-0.041*	-0.020*	0.033*	0.053*
1937	-0.010	-0.028	-0.039*	-0.020*	0.033*	0.052*
1938	-0.011	-0.025	-0.037*	-0.020*	0.033*	0.052*
1939	-0.012	-0.024	-0.036*	-0.020*	0.033*	0.052*
1940	-0.012	-0.023	-0.035*	-0.020*	0.033*	0.051*
1941	-0.012	-0.023	-0.035*	-0.020*	0.033*	0.051*
1942	-0.011	-0.023	-0.035*	-0.020*	0.033*	0.051*
1943	-0.013	-0.023	-0.034*	-0.020*	0.033*	0.051*
1944	-0.012	-0.021	-0.033*	-0.020*	0.033*	0.050*
1945	-0.014	-0.020	-0.031*	-0.020*	0.033*	0.050*
1946	-0.015	-0.019	-0.031*	-0.020*	0.033*	0.050*
1947	-0.017	-0.017	-0.030*	-0.020*	0.033*	0.049*
1948	-0.024*	-0.015	-0.028*	-0.020*	0.033*	0.048*
1949	-0.027*	-0.014	-0.028*	-0.020*	0.033*	0.048*
1950	-0.028*	-0.014	-0.027*	-0.020*	0.033*	0.048*
1951	-0.029*	-0.014	-0.026*	-0.020*	0.033*	0.047*
1952	-0.030*	-0.015	-0.025*	-0.020*	0.033*	0.046*
1953	-0.029*	-0.014	-0.023*	-0.020*	0.033*	0.046*
1954	-0.029*	-0.015	-0.022*	-0.020*	0.033*	0.045*
1955	-0.028*	-0.015	-0.021*	-0.020*	0.033*	0.043*
1956	-0.027*	-0.016	-0.021*	-0.020*	0.033*	0.043*
1957	-0.027*	-0.016	-0.021*	-0.020*	0.033*	0.042*
1958	-0.025*	-0.016	-0.020*	-0.020*	0.033*	0.042*
1959	-0.023*	-0.015	-0.020*	-0.020*	0.033*	0.041*
1960	-0.022*	-0.015	-0.020*	-0.020*	0.033*	0.041*
1961	-0.021*	-0.015	-0.020*	-0.020*	0.033*	0.041*

Table A50. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1962	-0.018*	-0.015	-0.020*	-0.020*	0.033*	0.040*
1963	-0.014	-0.016	-0.019*	-0.020*	0.033*	0.040*
1964	-0.012	-0.016	-0.019*	-0.020*	0.033*	0.040*
1965	-0.010	-0.016	-0.019*	-0.020*	0.033*	0.039*
1966	-0.011	-0.015	-0.018*	-0.020*	0.033*	0.040*
1967	-0.013*	-0.015	-0.018*	-0.020*	0.033*	0.040*
1968	-0.012*	-0.014	-0.018*	-0.020*	0.033*	0.040*
1969	-0.011	-0.014	-0.018*	-0.020*	0.033*	0.040*
1970	-0.011	-0.013	-0.017*	-0.020*	0.033*	0.040*
1971	-0.009	-0.013	-0.017*	-0.020*	0.033*	0.040*
1972	-0.009	-0.013	-0.017*	-0.020*	0.033*	0.040*
1973	-0.009	-0.013	-0.016*	-0.020*	0.033*	0.040*
1974	-0.009	-0.013	-0.015	-0.020*	0.033*	0.040*
1975	-0.009	-0.013	-0.015	-0.020*	0.033*	0.040*
1976	-0.005	-0.013	-0.014	-0.020*	0.033*	0.040*
1977	-0.000	-0.011	-0.013	-0.020*	0.033*	0.039*
1978	-0.003	-0.012	-0.012	-0.020*	0.033*	0.039*
1979	-0.004	-0.012	-0.011	-0.020*	0.033*	0.039*
1980	-0.003	-0.012	-0.011	-0.020*	0.033*	0.039*
1981	-0.004	-0.012	-0.010	-0.020*	0.033*	0.038*
1982	-0.001	-0.011	-0.011	-0.020*	0.033*	0.039*
1983	0.000	-0.011	-0.011	-0.020*	0.033*	0.039*
1984	0.002	-0.010	-0.011	-0.020*	0.033*	0.039*
1985	0.001	-0.010	-0.011	-0.020*	0.033*	0.039*
1986	0.001	-0.010	-0.011	-0.020*	0.033*	0.039*

* Indicates coefficient is significant at $P \leq 0.05$.

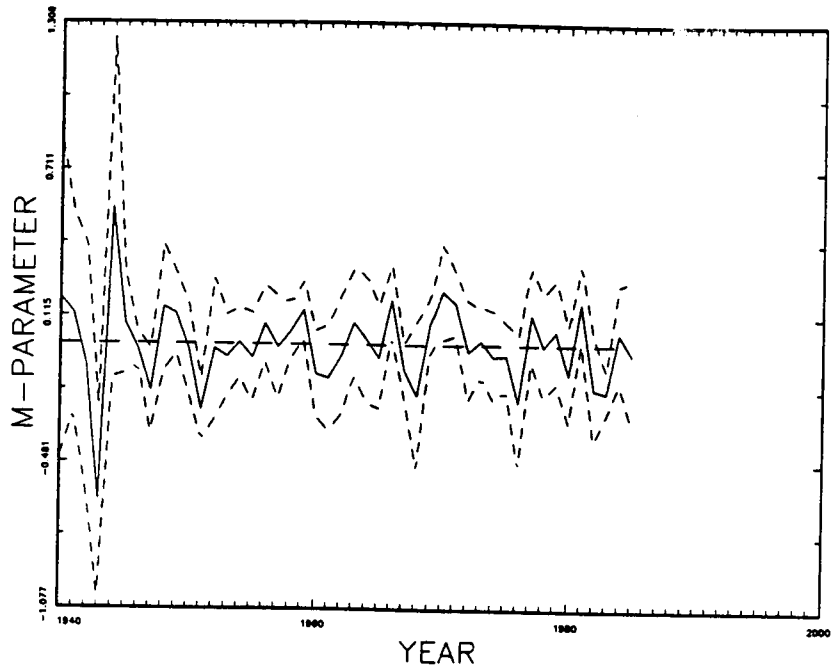


Figure A151. Graph of M-parameter and associated 95% confidence interval over time, Wayne County yellow-poplar, cluster 1.

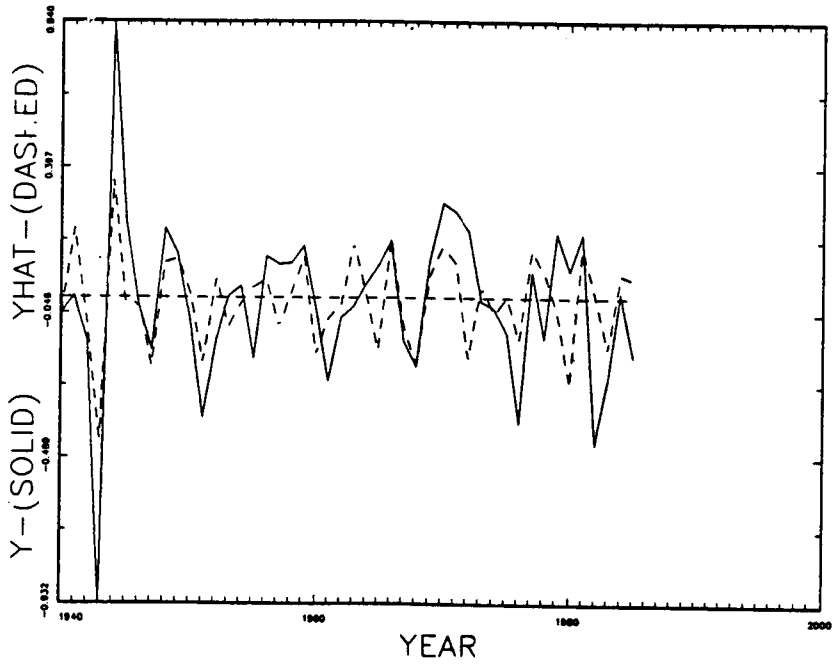
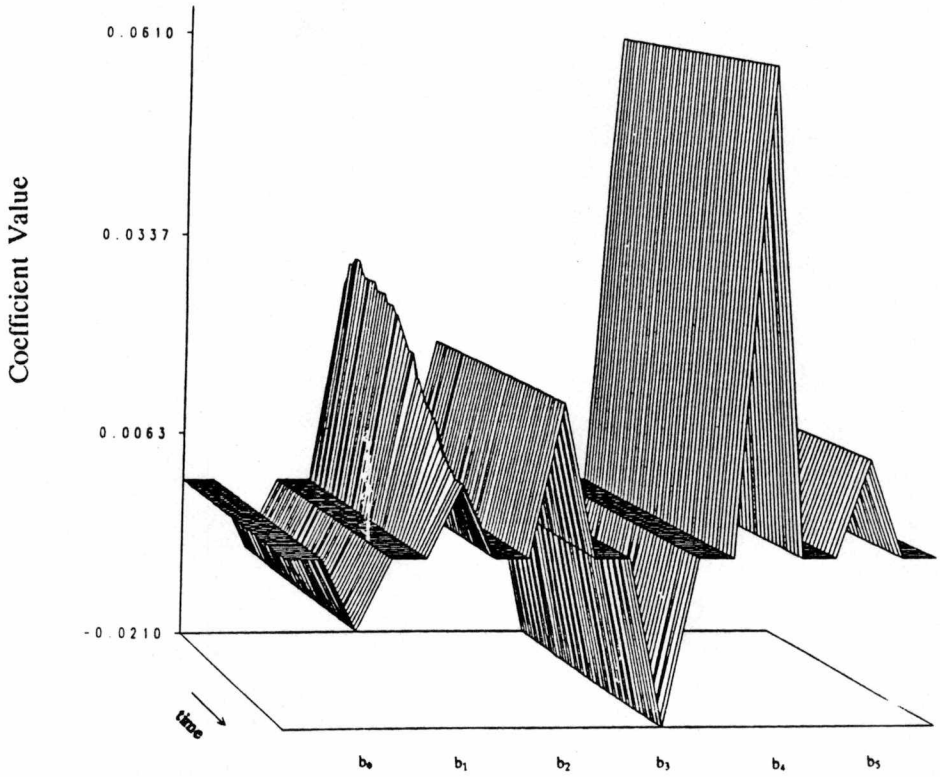


Figure A152. Graph of predicted and actual standardized growth, Wayne County yellow-poplar, cluster 1.



Where:

b_0 = the intercept (non-varying)
b_1 = past September temperature
b_2 = January rain
b_3 = February rain
b_4 = past August rain
b_5 = past October rain

Figure A153. Three dimensional graph of changes in parameter coefficients over time, Wayne County yellow-poplar, cluster 1.

Table A51. Climate parameter estimates for Wayne County yellow-poplar, cluster 1.

YEAR	Past September temperature b_1	January rain b_2	February rain b_3	Past August rain b_4	Past October rain b_5
1941	0.027	0.019*	-0.021*	0.061*	0.012
1942	0.028	0.019*	-0.021*	0.061*	0.012
1943	0.030	0.019*	-0.021*	0.061*	0.012
1944	0.030	0.019*	-0.021*	0.061*	0.012
1945	0.031*	0.019*	-0.021*	0.061*	0.012
1946	0.031*	0.019*	-0.021*	0.061*	0.012
1947	0.031*	0.019*	-0.021*	0.061*	0.012
1948	0.030*	0.019*	-0.021*	0.061*	0.012
1949	0.029*	0.019*	-0.021*	0.061*	0.012
1950	0.029*	0.019*	-0.021*	0.061*	0.012
1951	0.029*	0.019*	-0.021*	0.061*	0.012
1952	0.029*	0.019*	-0.021*	0.061*	0.012
1953	0.029*	0.019*	-0.021*	0.061*	0.012
1954	0.028*	0.019*	-0.021*	0.061*	0.012
1955	0.028*	0.019*	-0.021*	0.061*	0.012
1956	0.028*	0.019*	-0.021*	0.061*	0.012
1957	0.028*	0.019*	-0.021*	0.061*	0.012
1958	0.027*	0.019*	-0.021*	0.061*	0.012
1959	0.027*	0.019*	-0.021*	0.061*	0.012
1960	0.027*	0.019*	-0.021*	0.061*	0.012
1961	0.026*	0.019*	-0.021*	0.061*	0.012
1962	0.026	0.019*	-0.021*	0.061*	0.012
1963	0.025	0.019*	-0.021*	0.061*	0.012
1964	0.024	0.019*	-0.021*	0.061*	0.012
1965	0.023	0.019*	-0.021*	0.061*	0.012
1966	0.022	0.019*	-0.021*	0.061*	0.012
1967	0.022	0.019*	-0.021*	0.061*	0.012
1968	0.022	0.019*	-0.021*	0.061*	0.012
1969	0.019	0.019*	-0.021*	0.061*	0.012
1970	0.019	0.019*	-0.021*	0.061*	0.012
1971	0.018	0.019*	-0.021*	0.061*	0.012
1972	0.017	0.019*	-0.021*	0.061*	0.012
1973	0.016	0.019*	-0.021*	0.061*	0.012
1974	0.016	0.019*	-0.021*	0.061*	0.012
1975	0.015	0.019*	-0.021*	0.061*	0.012
1976	0.015	0.019*	-0.021*	0.061*	0.012
1977	0.013	0.019*	-0.021*	0.061*	0.012
1978	0.012	0.019*	-0.021*	0.061*	0.012
1979	0.011	0.019*	-0.021*	0.061*	0.012
1980	0.011	0.019*	-0.021*	0.061*	0.012
1981	0.010	0.019*	-0.021*	0.061*	0.012
1982	0.010	0.019*	-0.021*	0.061*	0.012
1983	0.009	0.019*	-0.021*	0.061*	0.012
1984	0.009	0.019*	-0.021*	0.061*	0.012
1985	0.009	0.019*	-0.021*	0.061*	0.012
1986	0.009	0.019*	-0.021*	0.061*	0.012

* Indicates coefficient is significant at $P \leq 0.05$.

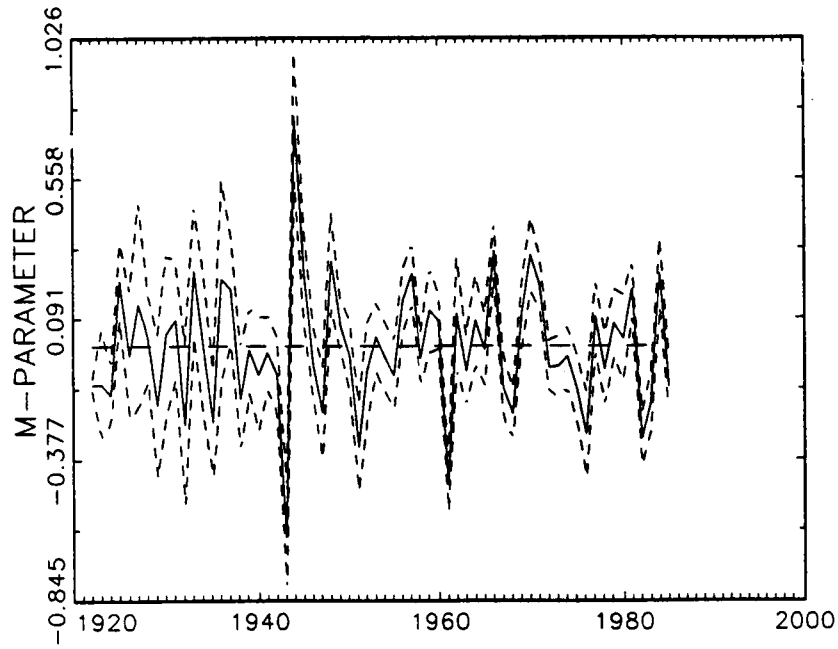


Figure A154. Graph of M-parameter and associated 95% confidence interval over time, Wayne County yellow-poplar, cluster 2.

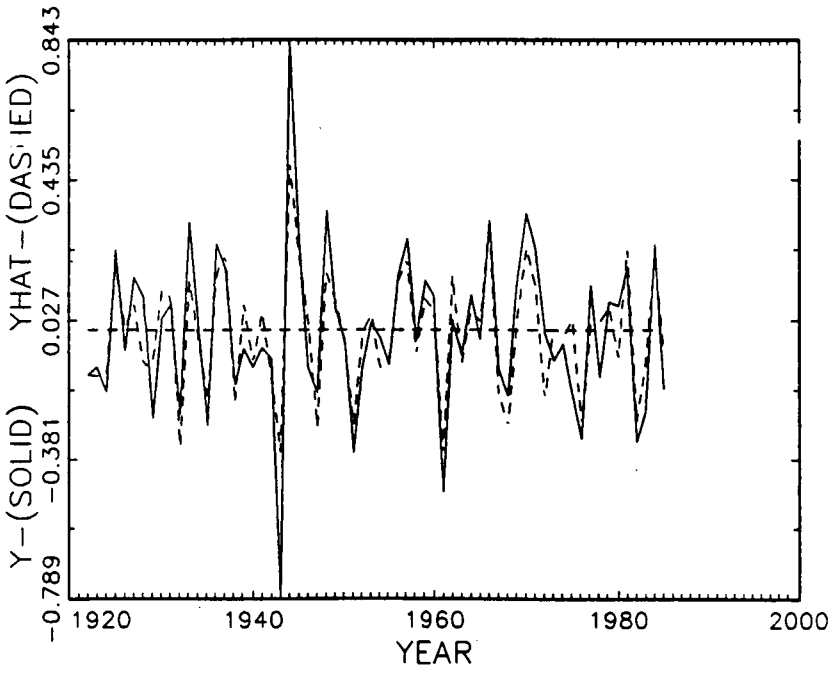
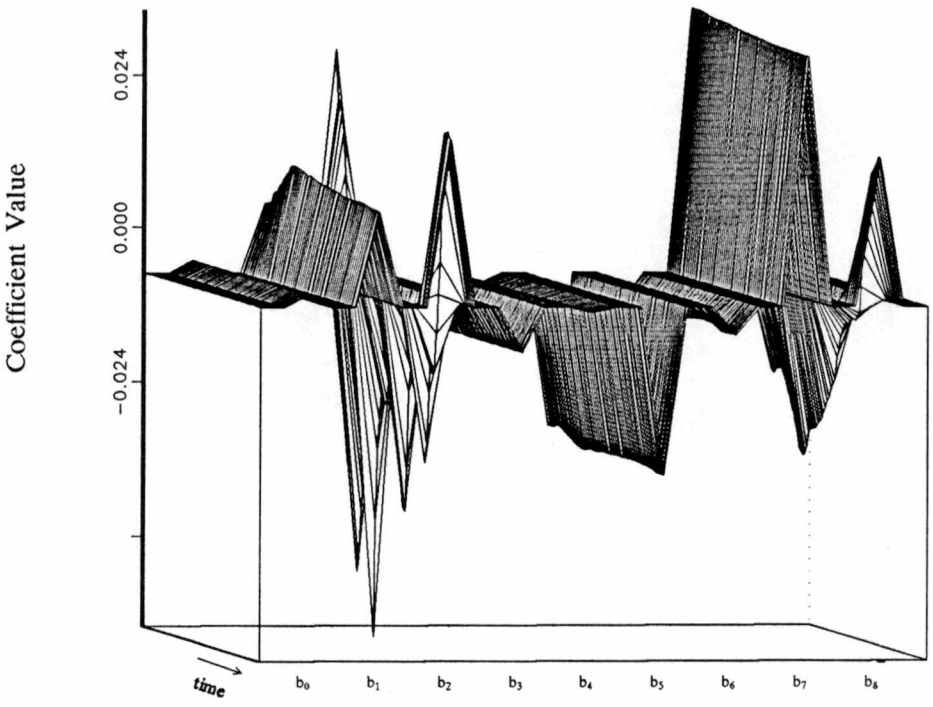


Figure A155. Graph of predicted and actual standardized growth, Wayne County yellow-poplar, cluster 2.



Where:

b_0 = the intercept (non-varying)
b_1 = May temperature
b_2 = June temperature
b_3 = September temperature
b_4 = May rain
b_5 = June rain
b_6 = July rain
b_7 = August rain
b_8 = past August rain

Figure A156. Three dimensional graph of changes in parameter coefficients over time, Wayne County yellow-poplar, cluster 2.

Table A52. Climate parameter estimates for Wayne County yellow-poplar, cluster 2.

YEAR	January temp. b_1	May temp. b_2	June temp. b_3	September temp. b_4	Past August temp. b_5	April rain b_6	July rain b_7	Past March rain b_8
1923	0.004	0.028	-0.014*	-0.009	-0.031*	-0.012	0.034*	-0.000
1924	0.004	0.020	-0.014*	-0.009	-0.031*	-0.012	0.034*	-0.001
1925	0.004	0.020	-0.014*	-0.009	-0.031*	-0.012	0.034*	-0.002
1926	0.004	0.018	-0.014*	-0.009	-0.031*	-0.012	0.034*	-0.004
1927	0.005	0.015	-0.014*	-0.009	-0.031*	-0.012	0.034*	-0.008
1928	0.006	0.009	-0.014*	-0.009	-0.030*	-0.012	0.034*	-0.022
1929	0.006	0.004	-0.014*	-0.009	-0.030*	-0.012	0.034*	-0.022
1930	0.007	-0.007	-0.014*	-0.009	-0.031*	-0.012	0.034*	-0.022
1931	0.007	-0.023	-0.014*	-0.009	-0.031*	-0.012	0.034*	-0.021
1932	0.008	-0.029	-0.014*	-0.009	-0.031*	-0.012	0.034*	-0.021
1933	0.008	-0.044	-0.014*	-0.009	-0.031*	-0.012	0.034*	-0.021
1934	0.009	-0.048	-0.014*	-0.009	-0.031*	-0.012	0.034*	-0.022
1935	0.009	-0.053	-0.014*	-0.009	-0.032*	-0.012	0.033*	-0.023
1936	0.010	-0.051	-0.014*	-0.009	-0.032*	-0.012	0.033*	-0.023
1937	0.011*	-0.043	-0.014*	-0.008	-0.032*	-0.012	0.033*	-0.025
1938	0.011*	-0.040	-0.014*	-0.008	-0.032*	-0.012	0.033*	-0.025
1939	0.011*	-0.037	-0.014*	-0.008	-0.032*	-0.012	0.033*	-0.027
1940	0.011*	-0.041	-0.014*	-0.008	-0.033*	-0.012	0.033*	-0.028
1941	0.011*	-0.044	-0.014*	-0.008	-0.033*	-0.012	0.033*	-0.029
1942	0.011*	-0.049*	-0.014*	-0.008	-0.033*	-0.013	0.033*	-0.031
1943	0.011*	-0.055*	-0.014*	-0.008	-0.033*	-0.013	0.033*	-0.033*
1944	0.010*	-0.062*	-0.014*	-0.008	-0.033*	-0.012	0.033*	-0.033*
1945	0.010*	-0.044	-0.014*	-0.008	-0.033*	-0.012	0.033*	-0.034*
1946	0.010*	-0.033	-0.014*	-0.008	-0.032*	-0.012	0.033*	-0.033*
1947	0.010*	-0.028	-0.014*	-0.008	-0.032*	-0.012	0.033*	-0.032*
1948	0.010*	-0.023	-0.014*	-0.008	-0.033*	-0.012	0.033*	-0.030*
1949	0.010*	-0.025	-0.014*	-0.008	-0.033*	-0.012	0.033*	-0.029*
1950	0.010*	-0.025	-0.014*	-0.008	-0.033*	-0.012	0.033*	-0.029*
1951	0.010*	-0.024	-0.014*	-0.008	-0.033*	-0.012	0.033*	-0.029*
1952	0.010*	-0.021	-0.014*	-0.008	-0.032*	-0.012	0.033*	-0.029*
1953	0.009*	-0.014	-0.014*	-0.008	-0.032*	-0.012	0.033*	-0.028*
1954	0.009*	-0.014	-0.014*	-0.008	-0.032*	-0.011	0.033*	-0.028*
1955	0.009*	-0.019	-0.014*	-0.008	-0.032*	-0.011	0.033*	-0.027*
1956	0.009*	-0.025	-0.014*	-0.008	-0.032*	-0.011	0.033*	-0.026*
1957	0.009*	-0.030*	-0.014*	-0.008	-0.032*	-0.011	0.033*	-0.025*
1958	0.009*	-0.034*	-0.014*	-0.008	-0.032*	-0.011	0.033*	-0.024*
1959	0.009*	-0.037*	-0.014*	-0.008	-0.032*	-0.011	0.033*	-0.024*
1960	0.009*	-0.040*	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.022
1961	0.009*	-0.041*	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.021
1962	0.009*	-0.034*	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.020
1963	0.009*	-0.022	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.017
1964	0.009*	-0.018	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.016
1965	0.009*	-0.014	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.014
1966	0.009*	-0.015	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.013
1967	0.009*	-0.015	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.012
1968	0.008*	-0.017	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.011
1969	0.008*	-0.020	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.012
1970	0.008*	-0.027	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.011
1971	0.008*	-0.027	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.011
1972	0.008*	-0.032*	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.010
1973	0.008*	-0.029*	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.010
1974	0.008*	-0.021	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.010
1975	0.008*	-0.012	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.009

Table A52. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
1976	0.008*	-0.018	-0.014*	-0.008	-0.032*	-0.011	0.032*	-0.005
1977	0.008	-0.018	-0.014*	-0.008	-0.032*	-0.012	0.032*	0.000
1978	0.008	-0.012	-0.014*	-0.008	-0.033*	-0.012	0.032*	0.004
1979	0.008	-0.006	-0.014*	-0.008	-0.033*	-0.012	0.032*	0.007
1980	0.008	-0.001	-0.014*	-0.008	-0.033*	-0.012	0.032*	0.010
1981	0.008	0.014	-0.014*	-0.008	-0.033*	-0.012	0.032*	0.013
1982	0.008	0.020	-0.014*	-0.008	-0.033*	-0.012	0.032*	0.014
1983	0.008	0.020	-0.014*	-0.008	-0.033*	-0.012	0.032*	0.014
1984	0.008	0.020	-0.014*	-0.008	-0.033*	-0.012	0.032*	0.015
1985	0.008	0.019	-0.014*	-0.008	-0.033*	-0.012	0.032*	0.016
1986	0.008	0.019	-0.014*	-0.008	-0.033*	-0.012	0.032*	0.016

* Indicates coefficient is significant at $P \leq 0.05$.

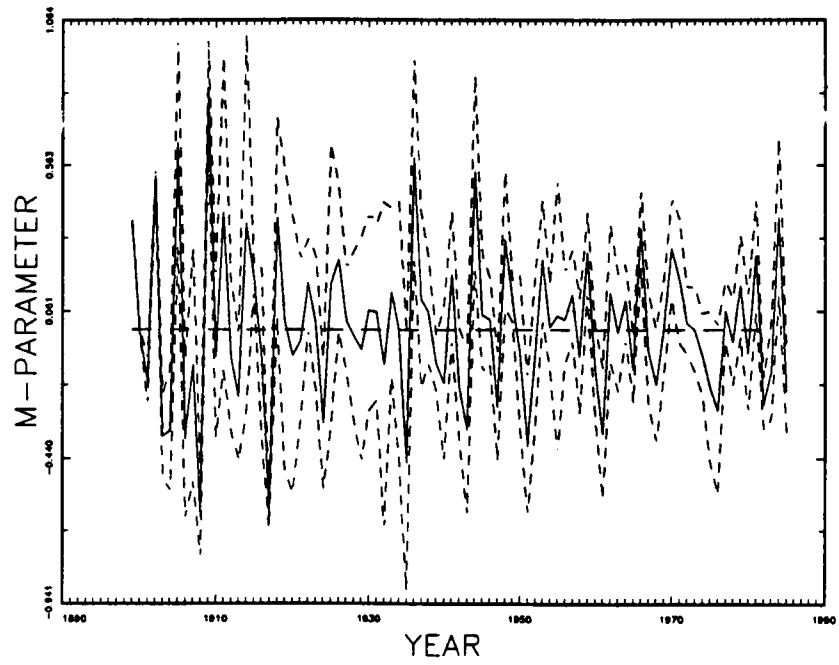


Figure A157. Graph of M-parameter and associated 95% confidence interval over time, Wayne County yellow-poplar, cluster 3.

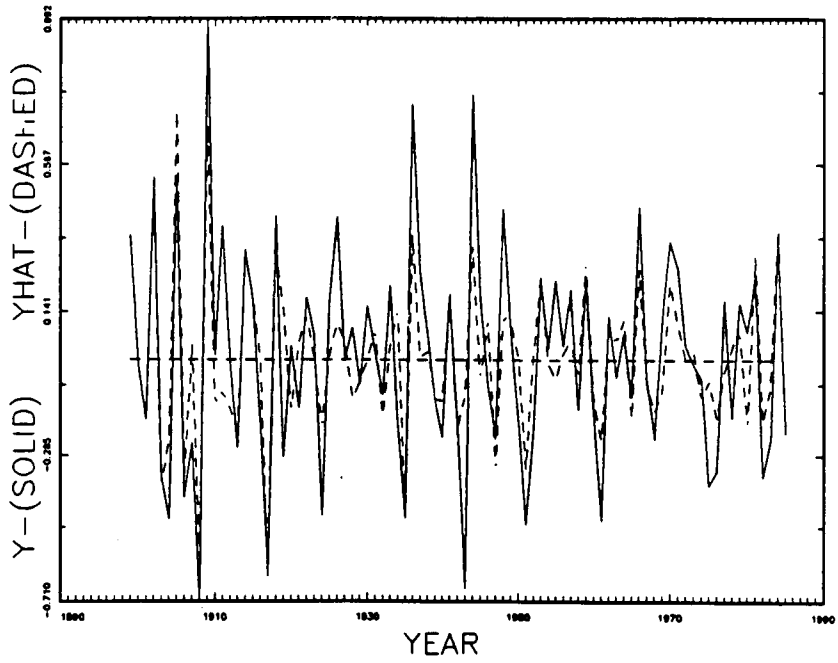
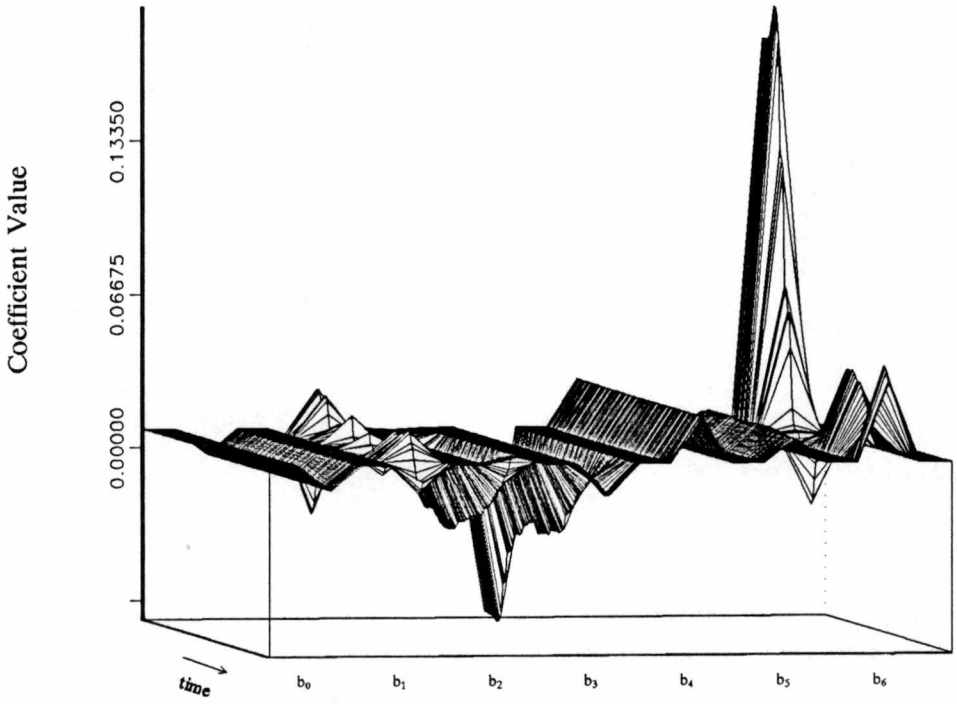


Figure A158. Graph of predicted and actual standardized growth, Wayne County yellow-poplar, cluster 3.



Where:

b_0 = the intercept (non-varying)
b_1 = January temperature
b_2 = May temperature
b_3 = June temperature
b_4 = past July rain
b_5 = past August rain
b_6 = past October rain

Figure A159. Three dimensional graph of changes in parameter coefficients over time, Wayne County yellow-poplar, cluster 3.

Table A53. Climate parameter estimates for Wayne County yellow-poplar, cluster 3.

YEAR	January temp. b_1	May temp. b_2	June temp. b_3	Past July rain b_4	Past August rain b_5	Past October rain b_6
1900	-0.014	0.007	-0.072*	0.029*	0.005	0.176*
1901	-0.014	0.007	-0.072*	0.029*	0.005	0.176*
1902	-0.014	0.007	-0.073*	0.029*	0.005	0.177*
1903	-0.014	0.007	-0.073*	0.029*	0.005	0.177*
1904	-0.014	0.007	-0.073*	0.029*	0.005	0.177*
1905	-0.018	0.007	-0.073*	0.029*	0.005	0.178*
1906	-0.020	0.006	-0.074*	0.029*	0.006	0.183*
1907	-0.021	0.006	-0.074*	0.029*	0.006	0.186*
1908	-0.028	0.005	-0.075*	0.029*	0.007	0.192*
1909	-0.027	0.005	-0.075*	0.029*	0.007	0.191*
1910	-0.023	0.005	-0.074*	0.029*	0.007	0.188*
1911	-0.014	0.004	-0.071*	0.029*	0.007	0.178*
1912	0.027	-0.001	-0.059*	0.029*	0.009	0.130*
1913	0.027	-0.002	-0.058*	0.029*	0.010	0.125*
1914	0.027	-0.003	-0.057*	0.029*	0.010	0.121*
1915	0.020*	-0.010	-0.044*	0.029*	0.013	0.071
1916	0.020*	-0.010	-0.044*	0.029*	0.013	0.071
1917	0.025*	-0.012	-0.043	0.029*	0.014	0.061
1918	0.025*	-0.012	-0.043	0.029*	0.014	0.061
1919	0.023	-0.014	-0.040	0.029*	0.014	0.045
1920	0.018	-0.019	-0.036	0.029*	0.016	0.019
1921	0.011	-0.021	-0.034	0.029*	0.018	0.012
1922	0.006	-0.022	-0.035	0.029*	0.018	0.010
1923	0.004	-0.022	-0.035	0.029*	0.018	0.010
1924	0.003	-0.022	-0.035	0.029*	0.019	0.009
1925	0.005	-0.022	-0.034	0.029*	0.019	0.007
1926	0.014	-0.022	-0.031	0.029*	0.020	-0.005
1927	0.015	-0.022	-0.030	0.029*	0.020	-0.003
1928	0.015	-0.022	-0.030	0.029*	0.020	-0.003
1929	0.014	-0.023	-0.029	0.029*	0.020	-0.006
1930	0.013	-0.024	-0.028	0.029*	0.020	-0.010
1931	0.011	-0.025	-0.028	0.029*	0.020	-0.012
1932	0.011	-0.025	-0.028	0.029*	0.020	-0.014
1933	0.013	-0.027	-0.027	0.029*	0.020	-0.020
1934	0.015	-0.027	-0.027	0.029*	0.020	-0.018
1935	0.018	-0.028	-0.030	0.029*	0.020	-0.010
1936	0.020	-0.029	-0.031	0.029*	0.020	-0.002
1937	0.011	-0.029	-0.032	0.029*	0.020	0.001
1938	0.009	-0.029	-0.031	0.029*	0.020	0.002
1939	0.008	-0.029	-0.031	0.029*	0.020	0.003
1940	0.008	-0.029	-0.031	0.029*	0.020	0.003
1941	0.008	-0.028	-0.031	0.029*	0.020	0.008
1942	0.009	-0.028	-0.030	0.028*	0.020	0.012
1943	0.009	-0.028	-0.030	0.028*	0.020	0.014
1944	0.009	-0.027	-0.031	0.028*	0.020	0.013
1945	0.012	-0.025	-0.029	0.028*	0.019	0.013
1946	0.011	-0.024	-0.028	0.028*	0.019	0.012
1947	0.012	-0.024	-0.028	0.028*	0.019	0.011
1948	0.015	-0.024	-0.028	0.028*	0.019	0.010
1949	0.010	-0.024	-0.028	0.028*	0.019	0.007
1950	0.010	-0.024	-0.028	0.028*	0.019	0.008
1951	0.005	-0.023	-0.029	0.028*	0.019	0.013
1952	0.004	-0.022	-0.028	0.028*	0.019	0.017

Table A53. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1953	0.001	-0.021*	-0.027	0.028*	0.019	0.024
1954	0.000	-0.021	-0.027	0.028*	0.019	0.027
1955	0.000	-0.020	-0.027	0.028*	0.019	0.028
1956	-0.001	-0.020	-0.020	0.028*	0.020	0.041
1957	-0.002	-0.020*	-0.019	0.028*	0.020	0.043
1958	-0.001	-0.019*	-0.018	0.028*	0.020	0.043
1959	0.002	-0.019*	-0.017	0.028*	0.020	0.042
1960	0.003	-0.019*	-0.017	0.028*	0.020	0.043
1961	0.004	-0.019*	-0.016	0.028*	0.020	0.043
1962	0.007	-0.018	-0.014	0.028*	0.020	0.042
1963	0.012	-0.016	-0.011	0.028*	0.020	0.041
1964	0.016	-0.015	-0.009	0.028*	0.020	0.039
1965	0.017	-0.015	-0.009	0.028*	0.020	0.039
1966	0.019	-0.014	-0.008	0.028*	0.020	0.039
1967	0.019	-0.013	-0.008	0.028*	0.020	0.038
1968	0.018	-0.012	-0.007	0.028*	0.020	0.035
1969	0.017	-0.010	-0.006	0.028*	0.020	0.032
1970	0.019	-0.009	-0.004	0.028*	0.020	0.031
1971	0.020	-0.008	-0.004	0.028*	0.020	0.028
1972	0.019	-0.006	-0.001	0.028*	0.020	0.026
1973	0.019	-0.005	-0.001	0.028*	0.020	0.025
1974	0.020	-0.004	-0.001	0.028*	0.020	0.022
1975	0.021*	-0.004	-0.001	0.028*	0.020	0.021
1976	0.020	-0.002	-0.001	0.028*	0.019	0.024
1977	0.016	0.001	-0.001	0.028*	0.019	0.028
1978	0.014	0.002	-0.001	0.028*	0.019	0.030
1979	0.009	0.003	-0.002	0.028*	0.019	0.033
1980	0.003	0.005	-0.003	0.028*	0.019	0.036
1981	-0.001	0.008	-0.004	0.028*	0.019	0.043
1982	-0.005	0.011	-0.006	0.028*	0.019	0.049
1983	-0.004	0.011	-0.006	0.028*	0.019	0.049
1984	-0.003	0.011	-0.006	0.028*	0.019	0.047
1985	0.000	0.011	-0.006	0.028*	0.019	0.043
1986	0.000	0.011	-0.006	0.028*	0.019	0.043

* Indicates coefficient is significant at $P \leq 0.05$.

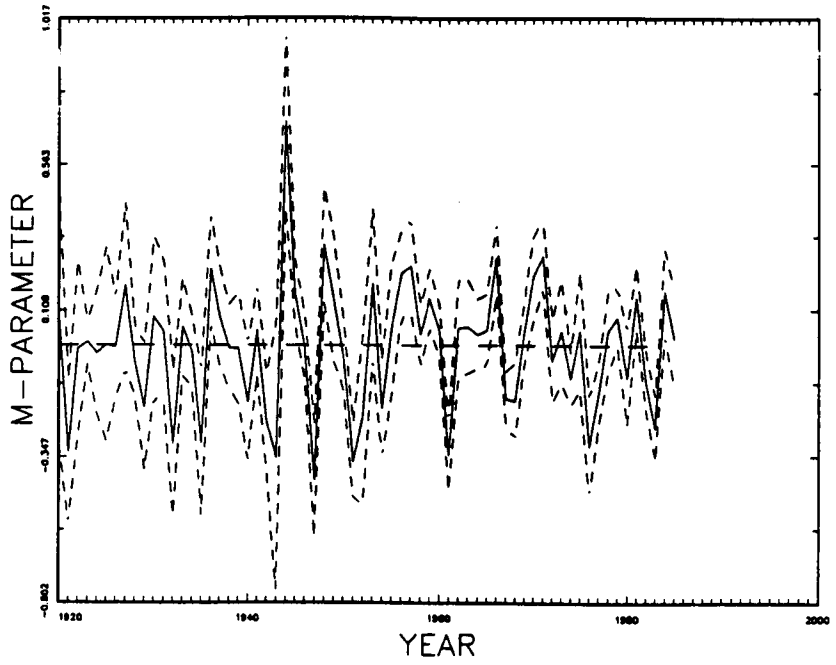


Figure A160. Graph of M-parameter and associated 95% confidence interval over time, Wayne County yellow-poplar, cluster 4.

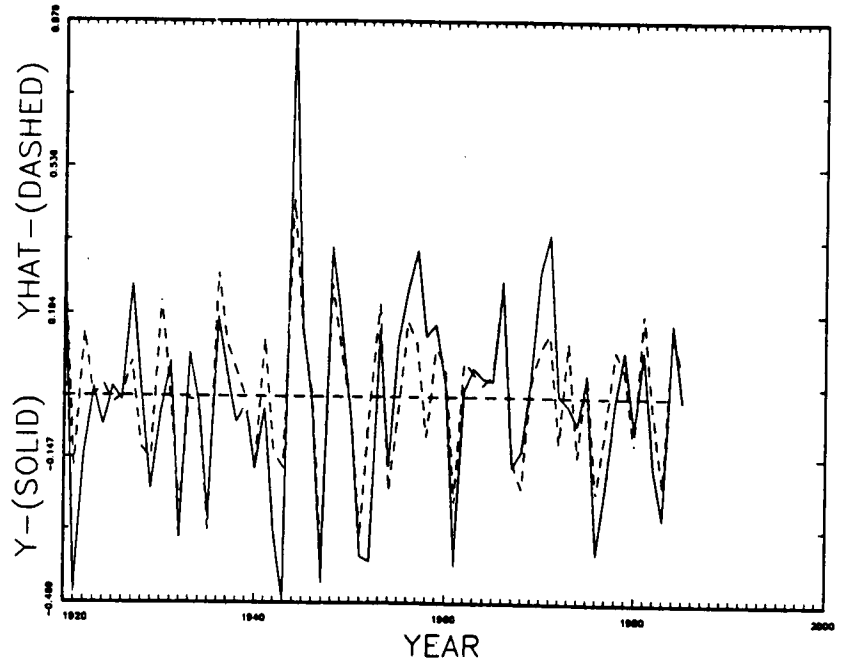
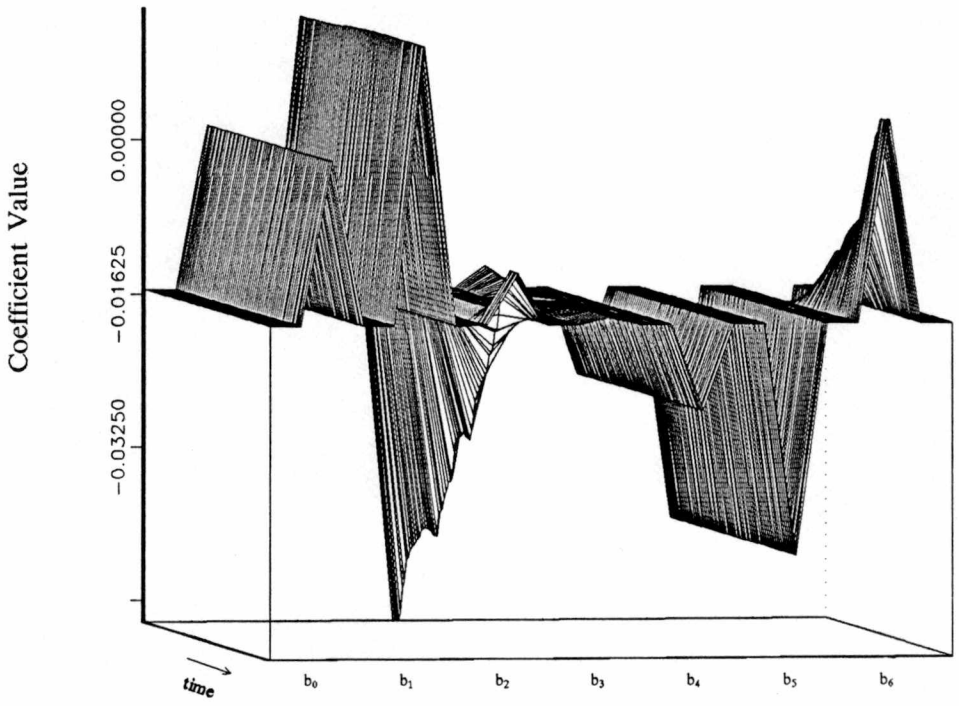


Figure A161. Graph of predicted and actual standardized growth, Wayne County yellow-poplar, cluster 4.



Where:

b_0 = the intercept (non-varying)
b_1 = January temperature
b_2 = May temperature
b_3 = June temperature
b_4 = August temperature
b_5 = past August temperature
b_6 = past March rain

Figure A162. Three dimensional graph of changes in parameter coefficients over time, Wayne County yellow-poplar, cluster 4.

Table A54. Climate parameter estimates for Wayne County yellow-poplar, cluster 4.

YEAR	January temp. b_1	May temp. b_2	June temp. b_3	August temp. b_4	Past August temp. b_5	Past March rain b_6
1921	0.013*	-0.051*	-0.014	-0.025*	-0.040*	-0.034*
1922	0.013*	-0.051*	-0.014	-0.025*	-0.040*	-0.034*
1923	0.013*	-0.051*	-0.014	-0.025*	-0.040*	-0.033*
1924	0.013*	-0.051*	-0.014	-0.025*	-0.040*	-0.033*
1925	0.013*	-0.050*	-0.014	-0.025*	-0.040*	-0.033*
1926	0.013*	-0.047*	-0.014	-0.025*	-0.040*	-0.032*
1927	0.013*	-0.047*	-0.014	-0.025*	-0.040*	-0.032*
1928	0.013*	-0.044*	-0.014	-0.025*	-0.040*	-0.031*
1929	0.013*	-0.044*	-0.014	-0.025*	-0.040*	-0.031*
1930	0.013*	-0.043*	-0.014	-0.025*	-0.040*	-0.030*
1931	0.013*	-0.043*	-0.014	-0.025*	-0.040*	-0.028*
1932	0.013*	-0.042*	-0.015*	-0.025*	-0.040*	-0.027*
1933	0.013*	-0.042*	-0.015*	-0.025*	-0.040*	-0.026*
1934	0.013*	-0.042*	-0.015*	-0.025*	-0.040*	-0.025*
1935	0.013*	-0.041*	-0.015*	-0.025*	-0.040*	-0.025*
1936	0.013*	-0.041*	-0.015*	-0.025*	-0.040*	-0.024*
1937	0.013*	-0.040*	-0.015*	-0.025*	-0.040*	-0.023*
1938	0.013*	-0.040*	-0.015*	-0.025*	-0.040*	-0.023*
1939	0.013*	-0.040*	-0.015*	-0.025*	-0.040*	-0.023
1940	0.013*	-0.040*	-0.015*	-0.025*	-0.040*	-0.022
1941	0.013*	-0.040*	-0.015*	-0.025*	-0.040*	-0.021
1942	0.013*	-0.041*	-0.015*	-0.025*	-0.040*	-0.021
1943	0.013*	-0.041*	-0.015*	-0.025*	-0.040*	-0.021
1944	0.013*	-0.041*	-0.016*	-0.025*	-0.040*	-0.018
1945	0.013*	-0.038*	-0.016*	-0.025*	-0.040*	-0.017
1946	0.014*	-0.038*	-0.016*	-0.025*	-0.040*	-0.017
1947	0.014*	-0.038*	-0.016*	-0.025*	-0.040*	-0.016
1948	0.014*	-0.037*	-0.016*	-0.025*	-0.040*	-0.016
1949	0.014*	-0.036*	-0.016*	-0.025*	-0.040*	-0.015
1950	0.014*	-0.035*	-0.016*	-0.025*	-0.040*	-0.015
1951	0.014*	-0.035*	-0.016*	-0.025*	-0.040*	-0.015
1952	0.014*	-0.034*	-0.016*	-0.025*	-0.040*	-0.015
1953	0.014*	-0.031*	-0.016*	-0.025*	-0.040*	-0.013
1954	0.014*	-0.030*	-0.016*	-0.025*	-0.040*	-0.012
1955	0.014*	-0.030*	-0.016*	-0.025*	-0.040*	-0.012
1956	0.014*	-0.029*	-0.016*	-0.025*	-0.040*	-0.011
1957	0.014*	-0.029*	-0.016*	-0.025*	-0.040*	-0.011
1958	0.014*	-0.029*	-0.016*	-0.025*	-0.040*	-0.010
1959	0.014*	-0.029*	-0.016*	-0.025*	-0.040*	-0.010
1960	0.014*	-0.029*	-0.016*	-0.025*	-0.040*	-0.010
1961	0.014*	-0.029*	-0.016*	-0.025*	-0.040*	-0.010
1962	0.014*	-0.029*	-0.016*	-0.025*	-0.040*	-0.009
1963	0.014*	-0.027*	-0.016*	-0.025*	-0.040*	-0.009
1964	0.014*	-0.025*	-0.015*	-0.025*	-0.040*	-0.008
1965	0.014*	-0.024*	-0.015*	-0.025*	-0.040*	-0.007
1966	0.014*	-0.024*	-0.015*	-0.025*	-0.040*	-0.007
1967	0.014*	-0.023*	-0.015*	-0.025*	-0.040*	-0.007
1968	0.014*	-0.023*	-0.015*	-0.025*	-0.040*	-0.007
1969	0.014*	-0.022*	-0.015*	-0.025*	-0.040*	-0.006
1970	0.014*	-0.021*	-0.015*	-0.025*	-0.040*	-0.006
1971	0.014*	-0.020*	-0.015*	-0.025*	-0.040*	-0.006
1972	0.014*	-0.020*	-0.015*	-0.025*	-0.040*	-0.005
1973	0.014*	-0.019*	-0.015*	-0.025*	-0.040*	-0.005

Table A54. Continued.

YEAR	b_1	b_2	b_3	b_4	b_5	b_6
1974	0.014*	-0.017*	-0.015*	-0.025*	-0.040*	-0.004
1975	0.014*	-0.017*	-0.015*	-0.025*	-0.040*	-0.003
1976	0.014*	-0.015	-0.015*	-0.025*	-0.040*	-0.000
1977	0.014*	-0.013	-0.015*	-0.025*	-0.040*	0.002
1978	0.014*	-0.013	-0.015*	-0.025*	-0.040*	0.002
1979	0.014*	-0.012	-0.015*	-0.025*	-0.040*	0.003
1980	0.014*	-0.012	-0.015*	-0.025*	-0.040*	0.004
1981	0.014*	-0.011	-0.015*	-0.025*	-0.040*	0.005
1982	0.014*	-0.010	-0.015*	-0.025*	-0.040*	0.005
1983	0.014*	-0.010	-0.015*	-0.025*	-0.040*	0.005
1984	0.014*	-0.010	-0.015*	-0.025*	-0.040*	0.005
1985	0.014*	-0.010	-0.015*	-0.025*	-0.040*	0.006
1986	0.014*	-0.010	-0.015*	-0.025*	-0.040*	0.006

* Indicates coefficient is significant at $P \leq 0.05$.

APPENDIX B

Results of Discriminant Analysis

Table B1. Results of one-way analyses of variance, variable F values and significance levels, Emory River white oaks.

Variable	Numerator DF= 8 Denominator DF= 155 F	Pr > F
Stand size class	1.1034	0.3638
Topographic site	1.9989	0.0500
Slope percent	1.6763	0.1082
Aspect	1.4961	0.1627
Fire damage	1.0500	0.4013
Grazing damage	.	.
Current basal area	1.4033	0.1991
Basal area cut trees	.	.
Basal area dead trees	3.0542	0.0032
White oak frequency	0.8733	0.5405
White oak importance value	0.6014	0.7756
Chestnut oak frequency	1.1629	0.3251
Chestnut oak importance value	1.0014	0.4373
Northern red oak frequency	3.5466	0.0008
Northern red oak importance value	2.5955	0.0109
Yellow-poplar frequency	2.0023	0.0495
Yellow-poplar importance value	2.2820	0.0245
Average basal area increment	1.0339	0.4130
% injury due to fire	3.1930	0.0022
% injury due to insects	0.9806	0.4533
% injury due to disease	0.5426	0.8229
% injury due to animals	3.6550	0.0006
% injury due to weather	2.3125	0.0227
% injury due to suppression	1.6156	0.1244
% injury due to TSI	0.5085	0.8487
% injury due to logging	0.1951	0.9912
% unknown injury	2.3227	0.0221
Diameter of core tree	0.5275	0.8345
Age of core tree	1.0263	0.4186
Prism count	0.6310	0.7509
Elevation	2.3314	0.0216
Depth of A/E horizon	2.1829	0.0316
Texture of A/E horizon	1.0793	0.3805
Depth of B horizon	1.7169	0.0984
Texture of B horizon	1.6185	0.1236
Presence of argillic zone	0.6183	0.7616
Presence of fragipan	5.1617	0.0001

Average R-Squared: Unweighted = 0.0779073
Weighted by Variance = 0.1045429

Table B2. Results of canonical discriminant analysis -- standardized canonical coefficients, Emory River white oaks.

	CAN1	CAN2
Stand size class	0.091786899	-0.964059788
Topographic site	-0.282098139	0.764254800
Slope percent	-0.578019802	-0.902047841
Aspect	0.127559554	0.542431263
Fire damage	-0.341532471	-0.397673544
Grazing damage	0.000000000	0.000000000
Current basal area	-0.803125641	-0.757982602
Basal area cut trees	0.000000000	0.000000000
Basal area dead trees	-0.622421643	-0.278853472
White oak frequency	-3.768887418	4.049906808
White oak importance value	4.042231272	-3.611000782
Chestnut oak frequency	-1.708778625	1.184998434
Chestnut oak importance value	1.967568421	0.017267073
Northern red oak frequency	-0.953081141	1.762722105
Northern red oak importance value	0.998048145	-1.926931452
Yellow-poplar frequency	-1.395234795	-0.872377955
Yellow-poplar importance value	2.015895872	1.359865735
Average basal area increment	0.510826877	0.055927937
% injury due to fire	0.107469132	-0.243288791
% injury due to insects	0.044953424	-0.676692451
% injury due to disease	-0.366631625	-0.215111492
% injury due to animals	-0.715482349	0.401398567
% injury due to weather	-0.143402456	0.428655750
% injury due to suppression	0.085978611	0.515292529
% injury due to TSI	-0.157603308	-0.861134601
% injury due to logging	-0.133816982	0.331764967
% unknown injury	-0.036543927	0.311824910
Diameter of core tree	-0.039266389	0.063539756
Age of core tree	0.164451518	0.320881804
Prism count	-0.110278138	-0.127816913
Elevation	0.131621490	-0.177925745
Depth of A/E horizon	0.555371756	0.490338291
Texture of A/E horizon	-0.230862096	-0.471262825
Depth of B horizon	-0.121375079	0.321403940
Texture of B horizon	-0.756063690	0.620009186
Presence of argillic zone	-0.491315726	-0.263863426
Presence of fragipan	0.959893233	0.169836461

Table B3. Results of one-way analyses of variance, variable F values and significance levels, Land Between the Lakes white oaks.

Numerator DF= 8 Denominator DF= 327

Variable	F	Pr > F
Stand size class	4.7899	0.0001
Topographic site	2.1541	0.0307
Slope percent	3.4847	0.0007
Aspect	7.5423	0.0001
Fire damage	.	.
Grazing damage	.	.
Current basal area	3.1097	0.0021
Basal area cut trees	.	.
Basal area dead trees	0.9365	0.4864
White oak frequency	2.9639	0.0032
White oak importance value	2.1748	0.0290
Chestnut oak frequency	2.8417	0.0046
Chestnut oak importance value	2.8676	0.0043
Northern red oak frequency	4.3707	0.0001
Northern red oak importance value	2.1827	0.0284
Yellow-poplar frequency	2.5252	0.0112
Yellow-poplar importance value	4.1741	0.0001
Average basal area increment	4.6292	0.0001
% injury due to fire	2.1457	0.0314
% injury due to insects	4.8040	0.0001
% injury due to disease	5.2827	0.0001
% injury due to animals	1.9855	0.0476
% injury due to weather	7.2017	0.0001
% injury due to suppression	2.6689	0.0075
% injury due to TSI	3.9300	0.0002
% injury due to logging	2.1920	0.0277
% unknown injury	3.7843	0.0003
Diameter of core tree	4.4525	0.0001
Age of core tree	3.8560	0.0002
Prism count	1.4857	0.1612
Elevation	13.0895	0.0001
Depth of A/E horizon	3.9383	0.0002
Texture of A/E horizon	8.1217	0.0001
Depth of B horizon	2.7043	0.0068
Texture of B horizon	6.6160	0.0001
Presence of argillic zone	1.8229	0.0720
Presence of fragipan	3.9901	0.0002

Average R-Squared: Unweighted = 0.0861733
Weighted by Variance = 0.1614627

Table B4. Results of canonical discriminant analysis -- standardized canonical coefficients, Land Between the Lakes white oaks.

	CAN1	CAN2	CAN3	CAN4
Stand size class	0.125905212	-0.110539029	0.137373401	0.356711054
Topographic site	0.084239170	0.054621830	0.082252376	0.060287493
Slope percent	0.218218357	-0.493809796	-0.412650277	-0.131858675
Aspect	0.688859142	0.520963474	-0.036622905	-0.293164493
Fire damage	0.000000000	0.000000000	0.000000000	0.000000000
Grazing damage	0.000000000	0.000000000	0.000000000	0.000000000
Current basal area	0.369724328	-0.244651185	0.056413508	0.330458210
Basal area cut trees	0.000000000	0.000000000	0.000000000	0.000000000
Basal area dead trees	0.145576711	0.020148367	0.121134245	-0.094918447
White oak frequency	-2.006357468	2.153018572	0.199575502	-2.916047069
White oak importance value	1.460929249	-1.727200519	-0.192080251	2.910538061
Chestnut oak frequency	0.157064236	0.616839810	-0.777095123	-0.920731910
Chestnut oak importance value	0.048442558	-0.871229375	0.561407251	1.401940534
Northern red oak frequency	0.553850634	-0.221728250	-1.093644738	0.382258360
Northern red oak importance value	0.045693855	0.527916115	0.656504624	-0.206037736
Yellow-poplar frequency	-1.556156055	2.070613701	0.492953843	0.111701016
Yellow-poplar importance value	1.752220043	-1.850867005	-0.594612988	-0.168253068
Average basal area increment	0.377826314	-0.384327271	0.132536851	0.123628202
% injury due to fire	-0.358436725	-0.000437998	0.039160097	-0.109658592
% injury due to insects	0.633533222	0.535951418	-0.532724524	0.028063581
% injury due to disease	-0.528322804	-0.419564728	-0.103068536	0.390543375
% injury due to animals	0.251472252	0.052528194	0.271398579	-0.137503878
% injury due to weather	-0.073153097	0.136502505	1.072356003	-0.043549227
% injury due to suppression	-0.207407901	0.353011421	0.341182453	0.090597098
% injury due to TSI	0.290911735	0.446239542	-0.348868223	0.101113933
% injury due to logging	0.115139638	0.082662354	0.097275546	-0.199221725
% unknown injury	0.308499207	-0.594200522	-0.284898820	-0.282502412
Diameter of core tree	0.098321209	-0.201854401	0.129265760	-0.146245048
Age of core tree	0.175652313	0.184403863	-0.217326049	-0.068355866
Prism count	0.061972554	0.162149175	0.026136865	-0.075183112
Elevation	0.557496471	-0.442351537	0.751811969	-0.382679515
Depth of A/E horizon	0.056566200	0.617170237	0.325374052	0.114573717
Texture of A/E horizon	-0.751005118	0.473302863	-0.125102505	-0.154682601
Depth of B horizon	-0.253185971	-0.415240006	0.260712071	-0.207976553
Texture of B horizon	-0.390809798	-0.068461900	0.075258782	-0.153301924
Presence of argillic zone	-0.218296149	-0.164118309	-0.147196425	-0.176968114
Presence of fragipan	-0.022565284	-0.805515229	-0.216577875	0.313302421

Table B5. Results of one-way analyses of variance, variable F values and significance levels, Wayne County white oaks.

Numerator DF= 5 Denominator DF= 168

Variable	F	Pr > F
Stand size class	3.9894	0.0019
Topographic site	4.3191	0.0010
Slope percent	5.9157	0.0001
Aspect	4.4877	0.0007
Fire damage	.	.
Grazing damage	3.8906	0.0023
Current basal area	1.9394	0.0903
Basal area cut trees	1.7834	0.1188
Basal area dead trees	6.8306	0.0001
White oak frequency	5.4379	0.0001
White oak importance value	5.5259	0.0001
Chestnut oakfrequency	2.9758	0.0134
Chestnut oak importance value	2.7971	0.0187
Northern red oak frequency	1.0874	0.3692
Northern red oak importance value	1.0218	0.4065
Yellow-poplar frequency	4.4704	0.0008
Yellow-poplar importance value	4.6415	0.0005
Average basal area increment	3.5787	0.0042
% injury due to fire	4.2613	0.0011
% injury due to insects	0.4975	0.7778
% injury due to disease	12.6461	0.0001
% injury due to animals	0.3995	0.8487
% injury due to weather	4.2924	0.0011
% injury due to suppression	1.6282	0.1551
% injury due to TSI	.	.
% injury due to logging	3.7786	0.0029
% unknown injury	4.6005	0.0006
Diameter of core tree	1.1177	0.3529
Age of core tree	1.1899	0.3162
Prism count	1.9589	0.0873
Elevation	9.0729	0.0001
Depth of A/E horizon	1.3678	0.2389
Texture of A/E horizon	3.5610	0.0044
Depth of B horizon	0.4115	0.8404
Texture of B horizon	2.1455	0.0625
Presence of argillic zone	6.9041	0.0001
Presence of fragipan	1.9583	0.0874

Average R-Squared: Unweighted = 0.0931418
Weighted by Variance = 0.1590583

Table B6. Results of canonical discriminant analysis -- standardized canonical coefficients, Wayne County white oaks.

	CAN1	CAN2	CAN3	CAN4
Stand size class	0.646113056	0.618095220	0.204370188	-0.883341388
Topographic site	0.471236989	0.114852327	-0.111881386	0.239898263
Slope percent	-0.328750607	-0.295101069	-0.780669340	0.565393620
Aspect	-0.217033855	0.441926437	0.126514958	-0.034328629
Fire damage	0.000000000	0.000000000	0.000000000	0.000000000
Grazing damage	-0.140345440	-0.262617097	-0.024932869	0.227705519
Current basal area	1.869451766	0.179694568	1.218369216	-0.576453060
Basal area cut trees	0.403615297	-0.062156338	0.609545682	0.060617873
Basal area dead trees	-0.899477144	0.530679294	-0.261919515	0.049258178
White oak frequency	5.858073857	-4.323412199	7.522684397	0.194133691
White oak importance value	-5.544928537	3.700257234	-6.635583939	0.276321215
Chestnut oak frequency	0.502858946	-0.387505038	2.930412924	-0.613312381
Chestnut oak importance value	0.178422773	0.573192534	-1.597109737	0.457290421
Northern red oak frequency	-3.356112624	0.855857480	0.255231316	3.201831249
Northern red oak importance value	4.439996263	-1.114292507	1.228999307	-3.765942509
Yellow-poplar frequency	-1.617503487	2.194762663	-0.593810255	-0.151123018
Yellow-poplar importance value	2.151787140	-2.377331192	0.672232943	-0.089682295
Average basal area increment	0.000783655	-0.971195939	-0.605506368	-0.147626014
% injury due to fire	0.404783789	-0.007464282	0.649411921	-0.479170316
% injury due to insects	1.038824332	0.222696226	1.127336924	-0.214756999
% injury due to disease	-0.262104834	0.900843379	-0.384165802	0.692855940
% injury due to animals	-0.569851540	0.032054888	0.097957724	0.188449141
% injury due to weather	-0.337684996	-0.068448061	0.343274143	-0.044006115
% injury due to suppression	0.595104189	0.075288232	0.207495799	-0.642516081
% injury due to TSI	0.000000000	0.000000000	0.000000000	0.000000000
% injury due to logging	-0.122716707	0.150411022	-0.640889402	0.451886846
% unknown injury	-0.011180973	-0.566608396	-0.283516123	0.695487123
Diameter of core tree	-0.125724278	-0.298050733	0.141243575	0.073330229
Age of core tree	-0.085569611	0.577481929	0.053518641	-0.309996825
Prism count	-0.049425216	0.146609498	0.073795539	0.168175484
Elevation	-1.319865265	-0.482267701	-0.242313719	0.548494497
Depth of A/E horizon	0.642181284	-0.245395885	0.524285530	-0.814687897
Texture of A/E horizon	0.604016089	0.020064937	-0.086938805	-0.346894445
Depth of B horizon	-0.717060877	-0.018539844	-0.708435771	0.107805976
Texture of B horizon	-0.096291300	-0.433578239	-0.588508153	0.221784111
Presence of argillic zone	0.818815228	-0.669067151	0.503464577	0.306446964
Presence of fragipan	-0.464615117	-0.286574580	-0.506069631	0.696665158

Table B7. Results of one-way analyses of variance, variable F values and significance levels, Emory River chestnut oaks.

	Numerator DF= 6	Denominator DF= 219
Variable	F	Pr > F
Stand size class	0.4488	0.8454
Topographic site	0.9951	0.4295
Slope percent	0.3813	0.8905
Aspect	0.9539	0.4575
Fire damage	1.0314	0.4057
Grazing damage	.	.
Current basal area	0.5547	0.7660
Basal area cut trees	.	.
Basal area dead trees	0.4892	0.8161
White oak frequency	1.6453	0.1359
White oak importance value	1.5830	0.1532
Chestnut oakfrequency	0.6425	0.6961
Chestnut oak importance value	0.5349	0.7814
Northern red oak frequency	1.0236	0.4108
Northern red oak importance value	1.4471	0.1979
Yellow-poplar frequency	1.3460	0.2379
Yellow-poplar importance value	0.9508	0.4596
Average basal area increment	0.9608	0.4527
% injury due to fire	0.3929	0.8832
% injury due to insects	0.7910	0.5778
% injury due to disease	0.7139	0.6387
% injury due to animals	0.4284	0.8596
% injury due to weather	0.7620	0.6006
% injury due to suppression	0.4513	0.8436
% injury due to TSI	1.8044	0.0994
% injury due to logging	0.5860	0.7414
% unknown injury	0.4603	0.8372
Diameter of core tree	0.8571	0.5273
Age of core tree	0.8314	0.5467
Prism count	2.0848	0.0561
Elevation	0.2160	0.9714
Depth of A/E horizon	0.4913	0.8145
Texture of A/E horizon	0.4069	0.8740
Depth of B horizon	1.0691	0.3820
Texture of B horizon	0.9441	0.4643
Presence of argillic zone	1.3477	0.2372
Presence of fragipan	0.8943	0.4998

Average R-Squared: Unweighted = 0.0231977
Weighted by Variance = 0.0079623

Table B8. Results of canonical discriminant analysis -- standardized canonical coefficients, Emory River chestnut oaks.

	CAN1
Stand size class	0.674281
Topographic site	0.149999
Slope percent	0.198102
Aspect	-0.099878
Fire damage	0.046623
Grazing damage	0.000000
Current basal area	0.431781
Basal area cut trees	0.000000
Basal area dead trees	-0.159569
White oak frequency	1.738420
White oak importance value	-1.892059
Chestnut oakfrequency	2.216134
Chestnut oak importance value	-2.174952
Northern red oak frequency	-0.149681
Northern red oak importance value	0.456130
Yellow-poplar frequency	1.974904
Yellow-poplar importance value	-2.252655
Average basal area increment	-0.284598
% injury due to fire	0.435860
% injury due to insects	-0.402700
% injury due to disease	-0.038921
% injury due to animals	0.108478
% injury due to weather	0.175621
% injury due to suppression	-0.170049
% injury due to TSI	0.406420
% injury due to logging	0.786926
% unknown injury	0.070975
Diameter of core tree	0.056566
Age of core tree	0.014114
Prism count	0.415855
Elevation	-0.343037
Depth of A/E horizon	-0.109863
Texture of A/E horizon	0.780786
Depth of B horizon	-0.202559
Texture of B horizon	-0.719983
Presence of argillic zone	-0.295202
Presence of fragipan	-0.001736

Table B9. Results of one-way analyses of variance, variable F values and significance levels, Land Between the Lakes chestnut oaks.

	Numerator DF= 3	Denominator DF= 72
Variable	F	Pr > F
Stand size class	2.4477	0.0706
Topographic site	3.5021	0.0197
Slope percent	2.3825	0.0765
Aspect	1.9771	0.1250
Fire damage	.	.
Grazing damage	.	.
Current basal area	8.5739	0.0001
Basal area cut trees	.	.
Basal area dead trees	1.7002	0.1746
White oak frequency	1.9671	0.1266
White oak importance value	1.9260	0.1330
Chestnut oakfrequency	6.5817	0.0005
Chestnut oak importance value	8.4569	0.0001
Northern red oak frequency	0.9809	0.4067
Northern red oak importance value	0.9255	0.4329
Yellow-poplar frequency	.	.
Yellow-poplar importance value	.	.
Average basal area increment	8.1717	0.0001
% injury due to fire	7.0445	0.0003
% injury due to insects	10.7137	0.0001
% injury due to disease	3.5906	0.0177
% injury due to animals	.	.
% injury due to weather	2.8830	0.0416
% injury due to suppression	3.3296	0.0242
% injury due to TSI	.	.
% injury due to logging	2.7851	0.0469
% unknown injury	3.9362	0.0117
Diameter of core tree	0.7545	0.5234
Age of core tree	3.5512	0.0185
Prism count	0.6276	0.5995
Elevation	0.8486	0.4719
Depth of A/E horizon	6.1324	0.0009
Texture of A/E horizon	0.9376	0.4271
Depth of B horizon	0.8414	0.0438
Texture of B horizon	0.7232	0.5414
Presence of argillic zone	.	.
Presence of fragipan	9.1307	0.0001

Average R-Squared: Unweighted = 0.1269777
Weighted by Variance = 0.0840461

Table B10. Results of canonical discriminant analysis -- standardized canonical coefficients, Land Between the Lakes chestnut oaks.

	CAN1	CAN2	CAN3
Stand size class	-0.22859025	-4.55564175	-1.60285195
Topographic site	-1.15722758	3.21798639	-0.25109241
Slope percent	0.01037058	0.20163527	1.05321819
Aspect	2.23201274	-11.38842350	-0.62887776
Fire damage	0.00000000	0.00000000	0.00000000
Grazing damage	0.00000000	0.00000000	0.00000000
Current basal area	-0.68228941	8.18956294	0.55656626
Basal area cut trees	0.00000000	0.00000000	0.00000000
Basal area dead trees	1.28259138	-4.09954976	-0.15378930
White oak frequency	23.88772587	-96.82090865	-5.66739096
White oak importance value	-17.64205579	77.22790162	4.27276112
Chestnut oak frequency	-5.07333248	17.08970136	2.91972224
Chestnut oak importance value	11.09643230	-34.83875552	-4.56556420
Northern red oak frequency	18.38061439	-71.70077174	-0.60764889
Northern red oak importance value	-15.35494774	65.15524405	0.85772530
Yellow-poplar frequency	0.00000000	0.00000000	0.00000000
Yellow-poplar importance value	0.00000000	0.00000000	0.00000000
Average basal area increment	0.00000000	0.00000000	0.00000000
% injury due to fire	0.00000000	0.00000000	0.00000000
% injury due to insects	0.00000000	0.00000000	0.00000000
% injury due to disease	0.00000000	0.00000000	0.00000000
% injury due to animals	0.00000000	0.00000000	0.00000000
% injury due to weather	0.00000000	0.00000000	0.00000000
% injury due to suppression	0.00000000	0.00000000	0.00000000
% injury due to TSI	0.00000000	0.00000000	0.00000000
% injury due to logging	0.00000000	0.00000000	0.00000000
% unknown injury	0.00000000	0.00000000	0.00000000
Diameter of core tree	-0.38447908	-0.32562655	-0.32404176
Age of core tree	0.42434758	-0.01902025	0.78000840
Prism count	0.25473417	-0.02750141	0.02424504
Elevation	0.00000000	0.00000000	0.00000000
Depth of A/E horizon	0.00000000	0.00000000	0.00000000
Texture of A/E horizon	0.00000000	0.00000000	0.00000000
Depth of B horizon	0.00000000	0.00000000	0.00000000
Texture of B horizon	0.00000000	0.00000000	0.00000000
Presence of argillic zone	0.00000000	0.00000000	0.00000000
Presence of fragipan	0.00000000	0.00000000	0.00000000

Table B11. Results of one-way analyses of variance, variable F values and significance levels, Wayne County chestnut oaks.

	Numerator DF= 2	Denominator DF= 89
Variable	F	Pr > F
Stand size class	2.5295	0.0854
Topographic site	0.0462	0.9548
Slope percent	2.7461	0.0696
Aspect	5.5873	0.0052
Fire damage	1.9917	0.1425
Grazing damage	1.6278	0.2021
Current basal area	0.0613	0.9406
Basal area cut trees	1.2741	0.2847
Basal area dead trees	5.2684	0.0069
White oak frequency	0.2520	0.7778
White oak importance value	0.1382	0.8711
Chestnut oak frequency	3.9960	0.0218
Chestnut oak importance value	3.2084	0.0451
Northern red oak frequency	5.6251	0.0050
Northern red oak importance value	5.1108	0.0079
Yellow-poplar frequency	0.0471	0.9540
Yellow-poplar importance value	0.2123	0.8091
Average basal area increment	0.2286	0.7961
% injury due to fire	0.9405	0.3943
% injury due to insects	2.1404	0.1236
% injury due to disease	3.6112	0.0311
% injury due to animals	6.2101	0.0030
% injury due to weather	3.6230	0.0307
% injury due to suppression	1.3505	0.2644
% injury due to TSI	.	.
% injury due to logging	2.4218	0.0946
% unknown injury	1.5226	0.2238
Diameter of core tree	0.5402	0.5845
Age of core tree	2.2497	0.1114
Prism count	0.8029	0.4512
Elevation	7.0924	0.0014
Depth of A/E horizon	1.2425	0.2936
Texture of A/E horizon	0.0825	0.9209
Depth of B horizon	3.0676	0.0515
Texture of B horizon	3.0699	0.0514
Presence of argillic zone	.	.
Presence of fragipan	0.2967	0.7440

Average R-Squared: Unweighted = 0.0473071
Weighted by Variance = 0.1159049

Table B12. Results of canonical discriminant analysis -- standardized canonical coefficients, Wayne County chestnut oaks.

	CAN1	CAN2
Stand size class	1.14361869	1.46169730
Topographic site	3.28262554	-0.28684191
Slope percent	1.45932683	-0.06683760
Aspect	4.46129452	-1.69239943
Fire damage	1.28086422	0.62058791
Grazing damage	1.34705510	-1.41037221
Current basal area	-3.00045139	1.43369496
Basal area cut trees	-2.24890639	1.05774959
Basal area dead trees	-2.09894365	0.28069813
White oak frequency	10.60670895	1.65560082
White oak importance value	-12.03271528	-1.15170164
Chestnut oak frequency	-3.50061428	7.08561097
Chestnut oak importance value	-1.52332990	-5.83818531
Northern red oak frequency	21.43629415	-5.84984277
Northern red oak importance value	-20.24177441	6.98290553
Yellow-poplar frequency	-12.86089699	-0.51263708
Yellow-poplar importance value	13.86814388	0.47203248
Average basal area increment	-0.18020805	0.27161055
% injury due to fire	-0.46623375	0.19802112
% injury due to insects	-5.94528403	1.29338874
% injury due to disease	0.00000000	0.00000000
% injury due to animals	0.00000000	0.00000000
% injury due to weather	0.00000000	0.00000000
% injury due to suppression	0.00000000	0.00000000
% injury due to TSI	0.00000000	0.00000000
% injury due to logging	0.00000000	0.00000000
% unknown injury	0.00000000	0.00000000
Diameter of core tree	0.14692538	0.33317909
Age of core tree	0.04808643	-0.48142877
Prism count	-0.56269009	-0.00265649
Elevation	0.00000000	0.00000000
Depth of A/E horizon	0.00000000	0.00000000
Texture of A/E horizon	0.00000000	0.00000000
Depth of B horizon	0.00000000	0.00000000
Texture of B horizon	0.00000000	0.00000000
Presence of argillic zone	0.00000000	0.00000000
Presence of fragipan	0.00000000	0.00000000

Table B13. Results of one-way analyses of variance, variable F values and significance levels, Emory River northern red oaks.

	Numerator DF= 1 Denominator DF= 114	
Variable	F	Pr > F
Stand size class	1.9105	0.1696
Topographic site	0.2544	0.6149
Slope percent	3.2351	0.0747
Aspect	1.3068	0.2554
Fire damage	.	.
Grazing damage	.	.
Current basal area	0.1218	0.7278
Basal area cut trees	.	.
Basal area dead trees	0.8551	0.3571
White oak frequency	0.1361	0.7129
White oak importance value	0.0029	0.9573
Chestnut oak frequency	12.4939	0.0006
Chestnut oak importance value	10.8684	0.0013
Northern red oak frequency	4.1192	0.0447
Northern red oak importance value	4.9108	0.0287
Yellow-poplar frequency	2.2712	0.1346
Yellow-poplar importance value	2.8125	0.0963
Average basal area increment	3.4126	0.0673
% injury due to fire	1.1015	0.2961
% injury due to insects	0.1267	0.7225
% injury due to disease	2.7106	0.1024
% injury due to animals	0.0209	0.8853
% injury due to weather	5.2593	0.0237
% injury due to suppression	0.3478	0.5565
% injury due to TSI	0.0005	0.9827
% injury due to logging	0.0402	0.8415
% unknown injury	1.0261	0.3132
Diameter of core tree	0.1118	0.7387
Age of core tree	1.8919	0.1717
Prism count	4.8975	0.0289
Elevation	21.8760	0.0001
Depth of A/E horizon	1.1407	0.2878
Texture of A/E horizon	0.0919	0.7623
Depth of B horizon	2.1767	0.1429
Texture of B horizon	2.3850	0.1253
Presence of argillic zone	2.6481	0.1064
Presence of fragipan	0.2129	0.6454

Average R-Squared: Unweighted = 0.0231334
Weighted by Variance = 0.1493894

Table B14. Results of canonical discriminant analysis -- standardized canonical coefficients, Emory River northern red oaks.

	CAN1
Stand size class	0.250310478
Topographic site	-0.038848622
Slope percent	0.337081429
Aspect	0.221658180
Fire damage	0.000000000
Grazing damage	0.000000000
Current basal area	0.134805674
Basal area cut trees	0.000000000
Basal area dead trees	0.031334229
White oak frequency	0.795194616
White oak importance value	-0.840284198
Chestnut oak frequency	2.389431789
Chestnut oak importance value	-3.547072538
Northern red oak frequency	1.606045310
Northern red oak importance value	-2.284418558
Yellow-poplar frequency	0.722628822
Yellow-poplar importance value	-1.386260643
Average basal area increment	-0.224018061
% injury due to fire	0.424374298
% injury due to insects	-0.175885187
% injury due to disease	-0.226051531
% injury due to animals	0.156030248
% injury due to weather	0.683253377
% injury due to suppression	0.048037558
% injury due to TSI	-0.284440116
% injury due to logging	0.050147656
% unknown injury	0.148862003
Diameter of core tree	0.024669276
Age of core tree	-0.204854890
Prism count	-0.172127613
Elevation	1.028120522
Depth of A/E horizon	-0.970681252
Texture of A/E horizon	0.909078238
Depth of B horizon	0.012301425
Texture of B horizon	-0.205610551
Presence of argillic zone	-0.173175321
Presence of fragipan	0.048676406

Table B15. Results of one-way analyses of variance, variable F values and significance levels, Land Between the Lakes northern red oaks.

	Numerator DF= 1	Denominator DF= 13
Variable	F	Pr > F
Stand size class	1.5758	0.2315
Topographic site	0.1494	0.7053
Slope percent	0.3903	0.5429
Aspect	0.0015	0.9696
Fire damage	.	.
Grazing damage	.	.
Current basal area	0.1372	0.7170
Basal area cut trees	.	.
Basal area dead trees	0.1494	0.7053
White oak frequency	3.3357	0.0908
White oak importance value	4.1654	0.0621
Chestnut oak frequency	1.2290	0.2877
Chestnut oak importance value	1.1918	0.2948
Northern red oak frequency	2.4682	0.1402
Northern red oak importance value	2.5658	0.1332
Yellow-poplar frequency	0.4815	0.5000
Yellow-poplar importance value	0.4815	0.5000
Average basal area increment	0.0152	0.9037
% injury due to fire	.	.
% injury due to insects	0.0577	0.8139
% injury due to disease	0.1658	0.6905
% injury due to animals	2.1667	0.1648
% injury due to weather	0.8064	0.3855
% injury due to suppression	0.4535	0.5125
% injury due to TSI	.	.
% injury due to logging	0.5417	0.4748
% unknown injury	2.1667	0.1648
Diameter of core tree	2.7346	0.1221
Age of core tree	0.0576	0.8140
Prism count	0.2496	0.6257
Elevation	0.6832	0.4234
Depth of A/E horizon	0.3200	0.5813
Texture of A/E horizon	1.6839	0.2170
Depth of B horizon	0.1727	0.6845
Texture of B horizon	0.3619	0.5578
Presence of argillic zone	.	.
Presence of fragipan	0.1494	0.7053

Average R-Squared: Unweighted = 0.0663497
Weighted by Variance = 0.0090909

Table B16. Results of canonical discriminant analysis -- standardized canonical coefficients, Land Between the Lakes northern red oaks.

	CAN1
Stand size class	-85.69997063
Topographic site	6.95147627
Slope percent	61.90647814
Aspect	5.35340659
Fire damage	0.00000000
Grazing damage	0.00000000
Current basal area	-88.02927056
Basal area cut trees	0.00000000
Basal area dead trees	81.68989064
White oak frequency	0.00000000
White oak importance value	0.00000000
Chestnut oak frequency	0.00000000
Chestnut oak importance value	0.00000000
Northern red oak frequency	0.00000000
Northern red oak importance value	0.00000000
Yellow-poplar frequency	0.00000000
Yellow-poplar importance value	0.00000000
Average basal area increment	0.00000000
% injury due to fire	0.00000000
% injury due to insects	0.00000000
% injury due to disease	0.00000000
% injury due to animals	0.00000000
% injury due to weather	0.00000000
% injury due to suppression	0.00000000
% injury due to TSI	0.00000000
% injury due to logging	0.00000000
% unknown injury	0.00000000
Diameter of core tree	2.05661836
Age of core tree	0.88108801
Prism count	0.73638414
Elevation	0.00000000
Depth of A/E horizon	0.00000000
Texture of A/E horizon	0.00000000
Depth of B horizon	0.00000000
Texture of B horizon	0.00000000
Presence of argillic zone	0.00000000
Presence of fragipan	0.00000000

Table B17. Results of one-way analyses of variance, variable F values and significance levels, Wayne County northern red oaks.

	Numerator DF= 2	Denominator DF= 49
Variable	F	Pr > F
Stand size class	0.6895	0.5066
Topographic site	0.4095	0.6662
Slope percent	0.5359	0.5885
Aspect	2.5623	0.0874
Fire damage	.	.
Grazing damage	1.8474	0.1685
Current basal area	10.7611	0.0001
Basal area cut trees	3.2855	0.0458
Basal area dead trees	2.6467	0.0810
White oak frequency	11.4193	0.0001
White oak importance value	14.8417	0.0001
Chestnut oak frequency	2.1635	0.1258
Chestnut oak importance value	2.1840	0.1234
Northern red oak frequency	2.5050	0.0921
Northern red oak importance value	3.0734	0.0553
Yellow-poplar frequency	3.7628	0.0302
Yellow-poplar importance value	4.0436	0.0237
Average basal area increment	0.4330	0.6510
% injury due to fire	0.9423	0.3967
% injury due to insects	3.4422	0.0399
% injury due to disease	1.8974	0.1608
% injury due to animals	1.1062	0.3389
% injury due to weather	2.6495	0.0808
% injury due to suppression	2.8690	0.0663
% injury due to TSI	.	.
% injury due to logging	0.5476	0.5818
% unknown injury	0.3189	0.7285
Diameter of core tree	4.3668	0.0180
Age of core tree	0.1134	0.8931
Prism count	2.2509	0.1161
Elevation	3.3952	0.0416
Depth of A/E horizon	0.0252	0.9751
Texture of A/E horizon	1.2980	0.2823
Depth of B horizon	0.5329	0.5903
Texture of B horizon	0.1499	0.8612
Presence of argillic zone	0.1771	0.3167
Presence of fragipan	1.1411	0.3278

Average R-Squared: Unweighted = 0.089963
Weighted by Variance = 0.1069043

Table B18. Results of canonical discriminant analysis -- standardized canonical coefficients, Wayne County northern red oaks.

	CAN1	CAN2
Stand size class	-0.96119009	-1.97138704
Topographic site	0.64184198	-0.25176192
Slope percent	-0.23755867	2.23809821
Aspect	1.00178951	2.12306833
Fire damage	0.00000000	0.00000000
Grazing damage	1.10601665	0.71079138
Current basal area	-0.04858090	-0.80959644
Basal area cut trees	-0.38381361	0.59669582
Basal area dead trees	-0.54243017	-1.87245679
White oak frequency	7.47266466	3.17628673
White oak importance value	-8.51211588	-4.17526650
Chestnut oak frequency	5.32996624	11.34096523
Chestnut oak importance value	-6.58412816	-12.81107889
Northern red oak frequency	2.62079844	3.24516091
Northern red oak importance value	-2.89561099	-4.00192493
Yellow-poplar frequency	-5.93324504	-75.40472771
Yellow-poplar importance value	5.46601827	76.69479321
Average basal area increment	-1.20365436	-2.75001167
% injury due to fire	0.00000000	0.00000000
% injury due to insects	0.00000000	0.00000000
% injury due to disease	0.00000000	0.00000000
% injury due to animals	0.00000000	0.00000000
% injury due to weather	0.00000000	0.00000000
% injury due to suppression	0.00000000	0.00000000
% injury due to TSI	0.00000000	0.00000000
% injury due to logging	0.00000000	0.00000000
% unknown injury	0.00000000	0.00000000
Diameter of core tree	0.00811196	-0.49239242
Age of core tree	0.24955792	0.33585942
Prism count	0.11289141	-0.90915880
Elevation	0.00000000	0.00000000
Depth of A/E horizon	0.00000000	0.00000000
Texture of A/E horizon	0.00000000	0.00000000
Depth of B horizon	0.00000000	0.00000000
Texture of B horizon	0.00000000	0.00000000
Presence of argillic zone	0.00000000	0.00000000
Presence of fragipan	0.00000000	0.00000000

Table B19. Results of one-way analyses of variance, variable F values and significance levels, Emory River yellow-poplar.

Numerator DF= 3 Denominator DF= 173

Variable	F	Pr > F
Stand size class	2.3680	0.0725
Topographic site	1.0878	0.3557
Slope percent	1.8997	0.1314
Aspect	6.5989	0.0003
Fire damage	.	.
Grazing damage	.	.
Current basal area	0.4902	0.6896
Basal area cut trees	.	.
Basal area dead trees	3.1103	0.0278
White oak frequency	0.2497	0.8614
White oak importance value	0.2910	0.8318
Chestnut oak frequency	2.5308	0.0588
Chestnut oak importance value	1.5930	0.1929
Northern red oak frequency	3.4077	0.0189
Northern red oak importance value	4.9595	0.0025
Yellow-poplar frequency	2.0588	0.1075
Yellow-poplar importance value	2.7076	0.0468
Average basal area increment	0.1657	0.9194
% injury due to fire	1.3824	0.2498
% injury due to insects	1.7651	0.1556
% injury due to disease	4.1318	0.0074
% injury due to animals	1.3362	0.2643
% injury due to weather	1.7520	0.1582
% injury due to suppression	2.6952	0.0476
% injury due to TSI	4.5455	0.0043
% injury due to logging	1.7199	0.1647
% unknown injury	1.4468	0.2309
Diameter of core tree	1.3167	0.2706
Age of core tree	3.3791	0.0196
Prism count	2.6769	0.0487
Elevation	4.1357	0.0073
Depth of A/E horizon	2.7675	0.0433
Texture of A/E horizon	3.6382	0.0140
Depth of B horizon	1.9462	0.1240
Texture of B horizon	1.3428	0.2622
Presence of argillic zone	0.9843	0.4015
Presence of fragipan	0.4639	0.7078

Average R-Squared: Unweighted = 0.0372081
Weighted by Variance = 0.0687342

Table B20. Results of canonical discriminant analysis -- standardized canonical coefficients, Emory River yellow-poplar.

	CAN1	CAN2
Stand size class	-0.353814248	0.291805852
Topographic site	0.037421014	0.904965004
Slope percent	0.005578053	-0.464669512
Aspect	-0.656493350	-0.327590470
Fire damage	0.000000000	0.000000000
Grazing damage	0.000000000	0.000000000
Current basal area	0.209806979	0.318375998
Basal area cut trees	0.000000000	0.000000000
Basal area dead trees	0.628271616	-0.412677330
White oak frequency	-0.856805355	-0.977491017
White oak importance value	1.245414983	1.680726933
Chestnut oak frequency	3.367099727	-1.699727487
Chestnut oak importance value	-2.807653785	2.421327628
Northern red oak frequency	-0.090526700	-1.531453377
Northern red oak importance value	-0.279384566	1.574755621
Yellow-poplar frequency	-0.967782747	-2.470721166
Yellow-poplar importance value	1.055023129	2.323763005
Average basal area increment	-0.167285460	-0.784272965
% injury due to fire	0.100761046	0.971151735
% injury due to insects	-0.279077228	0.166985694
% injury due to disease	0.094834726	-0.244349589
% injury due to animals	0.264721692	1.013630595
% injury due to weather	0.220371789	0.468065706
% injury due to suppression	-0.227110671	-1.348348768
% injury due to TSI	0.406613106	1.054998698
% injury due to logging	-0.222331828	0.475976717
% unknown injury	0.031708772	-0.225929275
Diameter of core tree	-0.426308700	-0.069351540
Age of core tree	0.442896714	-0.649046643
Prism count	0.297823504	0.283535247
Elevation	0.062575453	0.576113077
Depth of A/E horizon	0.040181163	-0.630610689
Texture of A/E horizon	-0.254368233	-0.307356969
Depth of B horizon	0.673863438	0.748008969
Texture of B horizon	0.685714077	0.574524449
Presence of argillic zone	-0.293434849	-0.516224830
Presence of fragipan	-0.481801374	-0.323268095

Table B21. Results of one-way analyses of variance, variable F values and significance levels, Wayne County yellow-poplar.

	Numerator DF= 3	Denominator DF= 36
Variable	F	Pr > F
Stand size class	1.1114	0.3572
Topographic site	3.0580	0.0405
Slope percent	2.4326	0.0809
Aspect	0.5772	0.6338
Fire damage	.	.
Grazing damage	0.7903	0.5073
Current basal area	0.4694	0.7055
Basal area cut trees	1.9333	0.1416
Basal area dead trees	1.0371	0.3878
White oak frequency	2.1589	0.1099
White oak importance value	2.3546	0.0882
Chestnut oak frequency	1.4631	0.2409
Chestnut oak importance value	1.3884	0.2620
Northern red oak frequency	0.2337	0.8723
Northern red oak importance value	0.2648	0.8503
Yellow-poplar frequency	1.3916	0.2611
Yellow-poplar importance value	1.0483	0.3831
Average basal area increment	1.1105	0.3575
% injury due to fire	.	.
% injury due to insects	0.7624	0.5226
% injury due to disease	1.8328	0.1586
% injury due to animals	0.9088	0.4464
% injury due to weather	0.6873	0.5657
% injury due to suppression	0.4135	0.7443
% injury due to TSI	.	.
% injury due to logging	2.2154	0.1031
% unknown injury	1.2121	0.3193
Diameter of core tree	2.3071	0.0930
Age of core tree	1.1034	0.3604
Prism count	4.0764	0.0137
Elevation	0.4540	0.7161
Depth of A/E horizon	0.6091	0.6135
Texture of A/E horizon	1.4174	0.2536
Depth of B horizon	1.6224	0.2012
Texture of B horizon	1.9781	0.1347
Presence of argillic zone	.	.
Presence of fragipan	1.3547	0.2721

Average R-Squared: Unweighted = 0.1002346
Weighted by Variance = 0.0441735

Table B22. Results of canonical discriminant analysis -- standardized canonical coefficients, Wayne County yellow-poplar.

	CAN1	CAN2	CAN3
Stand size class	-0.34971633	-0.00482991	-0.72731675
Topographic site	-0.88912575	-1.47565042	0.16329217
Slope percent	3.43095474	-2.97518577	-1.80492910
Aspect	0.19838969	-1.31372998	-0.93141606
Fire damage	0.00000000	0.00000000	0.00000000
Grazing damage	-1.93943637	1.44946579	-0.08889233
Current basal area	-2.76420769	4.05999527	2.00583916
Basal area cut trees	-1.58299633	0.73627978	0.63489989
Basal area dead trees	1.57633647	-3.17212544	-1.18388371
White oak frequency	-17.00587137	17.44734062	14.43927235
White oak importance value	12.73416832	-11.33286833	-11.65928666
Chestnut oak frequency	-20.61712536	19.75275216	11.93168306
Chestnut oak importance value	14.72811821	-14.29048410	-8.37107682
Northern red oak frequency	-0.77616589	1.60291880	2.02249072
Northern red oak importance value	0.00000000	0.00000000	0.00000000
Yellow-poplar frequency	0.00000000	0.00000000	0.00000000
Yellow-poplar importance value	0.00000000	0.00000000	0.00000000
Average basal area increment	0.00000000	0.00000000	0.00000000
% injury due to fire	0.00000000	0.00000000	0.00000000
% injury due to insects	0.00000000	0.00000000	0.00000000
% injury due to disease	0.00000000	0.00000000	0.00000000
% injury due to animals	0.00000000	0.00000000	0.00000000
% injury due to weather	0.00000000	0.00000000	0.00000000
% injury due to suppression	0.00000000	0.00000000	0.00000000
% injury due to TSI	0.00000000	0.00000000	0.00000000
% injury due to logging	0.00000000	0.00000000	0.00000000
% unknown injury	0.00000000	0.00000000	0.00000000
Diameter of core tree	-1.05023720	-0.15095447	-0.44418668
Age of core tree	1.24417239	0.44839561	0.21173536
Prism count	0.48950709	-0.30485855	0.95692046
Elevation	0.00000000	0.00000000	0.00000000
Depth of A/E horizon	0.00000000	0.00000000	0.00000000
Texture of A/E horizon	0.00000000	0.00000000	0.00000000
Depth of B horizon	0.00000000	0.00000000	0.00000000
Texture of B horizon	0.00000000	0.00000000	0.00000000
Presence of argillic zone	0.00000000	0.00000000	0.00000000
Presence of fragipan	0.00000000	0.00000000	0.00000000

APPENDIX C

Miscellaneous

Table C1. Species groups and scientific nomenclature[1] for tree species in the Tennessee Valley region.

Yellow Pines Group:	
Slash Pine	*Pinus elliottii*
Longleaf Pine	*Pinus palustris*
Table Mountain Pine	*Pinus pungens*
Shortleaf Pine	*Pinus echinata*
Pitch Pine	*Pinus rigida*
Loblolly Pine	*Pinus taeda*
Virginia Pine	*Pinus virginiana*
Other Softwoods Group:	
Southern Redcedar	*Juniperus silicicola*
Red Spruce	*Picea rubens*
Eastern White Pine	*Pinus strobus*
Eastern Hemlock	*Tsuga canadensis*
Red Oaks Group:	
Scarlet Oak	*Quercus coccinea*
Southern Red Oak	*Quercus falcata*
Cherrybark Oak	*Quercus falcata* var. *pagodifolia*
Blackjack Oak	*Quercus marilandica*
Water Oak	*Quercus nigra*
Pin Oak	*Quercus palustris*
Willow Oak	*Quercus phellos*
Northern Red Oak	*Quercus rubra*
Shumard Oak	*Quercus shumardii*
Black Oak	*Quercus velutina*
White Oak Group:	
White Oak	*Quercus alba*
Swamp White Oak	*Quercus bicolor*
Bur Oak	*Quercus macrocarpa*

Table C1. Continued.

Swamp Chestnut Oak	*Quercus michauxii*
Chinkapin Oak	*Quercus muehlenbergii*
Chestnut Oak	*Quercus prinus*
Post Oak	*Quercus stellata*
Yellow-poplar Group:	
Yellow-poplar	*Liriodendron tulipfera*
Gum Group:	
Sweetgum	*Liquidambar styraciflua*
Blackgum	*Nyssa sylvatica*
Hickory Group:	
Hickory	*Carya spp.*
Other Soft Hardwoods Group:	
Ohio Buckeye	*Aesculus glabra*
Yellow Buckeye	*Aesculus octandra*
Boxelder	*Acer negundo*
Red Maple	*Acer rubrum*
Willow	*Salix nigra*
Sassafras	*Sassafras albidum*
American Basswood	*Tilia americana*
Winged Elm	*Ulmus alata*
American Elm	*Ulmus americana*
Slippery Elm	*Ulmus rubra*
Other Hard Hardwoods Group:	
Sugar Maple	*Acer saccharum*
Sweet Birch	*Betula lenta*
River Birch	*Betula nigra*
Persimmon	*Diospyros virginiana*
Beech	*Fagus grandifolia*
White Ash	*Fraxinus americana*
Green Ash	*Fraxinus pennsylvanica*

Table C1. Continued.

Holly	*Ilex opaca*
Black Walnut	*Juglans nigra*
White Mulberry	*Morus alba*
Red Mulberry	*Morus rubra*
Other Hard Hardwoods Group (Continued)	
Osage-Orange	*Maclura pomifera*
Black Locust	*Robinia pseudoacacia*
Other Species Group:	
Yellow Birch	*Betula alleghaniensis*
Tree-of-Heaven	*Ailanthus altissima*
Serviceberry	*Amelanchier spp.*
Catalpa	*Catalpa spp.*
Hackberry	*Celtis occidentalis*
Redbud	*Cercis canadensis*
Dogwood	*Cornus florida*
Hawthorn	*Crataegus spp.*
Honeylocust	*Gleditsia triacanthos*
Coffeetree	*Gymnocladus dioicus*
Silverbell	*Halesia carolina*
Butternut	*Juglans cinerea*
Cucumbertree	*Magnolia acuminata*
Southern Magnolia	*Magnolia grandiflora*
Bigleaf Magnolia	*Magnolia macrophylla*
Apple	*Malus spp.*
Ironwood	*Ostrya virginiana*
Sourwood	*Oxydendrum arboreum*
Sycamore	*Platanus occidentalis*
Eastern Cottonwood	*Populus deltoides*
Cottonwood	*Populus spp.*
Fire Cherry	*Prunus pensylvanica*
Black Cherry	*Prunus serotina*

[1]Names according to: Little, Elbert L., Jr., 1979. *Checklist of United States Trees (Native and Naturalized)*. U.S. Dept. Agr. Handbook No. 541.

DISTURBANCE HISTORY CHECKLIST

Plot Location _____ # _____ Date _____ Observer _____

FOREST CHARACTER

___ even-aged appearance
___ very large trees present (alive or dead standing)
___ very large logs on ground
___ open (park-like) understory
___ thick understory
___ absence of herb layer (10% or less cover over entire plot)
___ abrupt vegetation boundary

TREE CUTTING

___ presence of large stumps
___ presence of sprouted trees
___ other (describe below)

PLANTED TREES

___ trees in rows
___ exotics reproducing in plot

FIRE

___ fire scarred trees, logs, etc.
___ charcoal on ground

LIVESTOCK GRAZING

current activity:
___ animals present in general vicinity, with access to plot
___ droppings in plot
___ grazed vegetation
past activity:
___ stairstep trails
___ shrubs with browse line
fence lines in proximity of plot
___ old
___ current

MISCELLANEOUS ITEMS

Logging cables, foundations, artifacts: trails, windfalls, forest appearance.

Describe _____

_____

_____

_____

VITA

Elizabeth Ransom Smith was born in Birmingham, Alabama on February 20, 1956. She graduated from the Brooke Hill School in 1974 and entered the University of the South in Sewanee, Tennessee the following fall. In May of 1978 she graduated with a Bachelor of Science degree in forestry.

Following two years of seasonal work with the U.S. Forest Service, she entered graduate school at the University of Tennessee in Knoxville. She graduated with a Master of Science degree in forestry in June of 1983. Following an appointment as a research associate in the Department of Forestry, Wildlife and Fisheries at the University of Tennessee she was employed as a forest biometrician for the Tennessee Valley Authority in June 1984.

In January 1987, while still working for TVA, she entered the Graduate Program in Ecology at the University of Tennessee. She received the Doctorate of Philosophy degree with a major in Ecology in May, 1990.

The author is a member of Xi Sigma Pi, and Gamma Sigma Delta, national honorary societies, the Society of American Foresters, and the Ecological Society of America. Dr. Smith will maintain her position with TVA following graduation.