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Growth Response of Eight Hardwood Species to Current and Past Climatic Variations Using Regression Models.

H. Jalilvand[1], S. Gh. Jalali[2], M. Akbarnia[2], M. Tabari[2] and S. M. Hosseini[2]

ABSTRACT

The impact of climatic variations on basal area growth of basswood (BA) (*Tilia americana* L.), American beech (BE) (*Fagus grandifolia* Enrh.), bitternut hickory (BH) (*Caria cordiformis* (Wang.) K. Koch), largetooth aspen (LA) (*Populus grandidentata* Michx.), red maple (RM) (*Acer rubrum* L.), red oak (RO) (*Quercus rubra* L.), sugar maple (SM) (*Acer saccharum* Marsh.), and white ash (WA) (*Fraxinus americana* L.) was studied in a southern province of Quebec, Canada (45° 25 ' N, 73 ° 57 ' W). In total, forty-eight climatic variations of precipitation (P) (13 variables), temperature (T) (13 variables), heat index (H), (11 variables), and evapotranspiration (11 variables) from the current (C) and past three years (P1, P2, & P3) were tested in regression models to find the best model of the relationship between those independent variables and the last ten years (1985-1994) of basal area growth of the species. Simple individual linear and second degree, mixed, and combination of multiple regression models were used to develop the best regression model for each tree species, separately. The best models explained 79% , 80% , 99% , 91% , 71%, 99% , 49% , and 98% of the total variance of the growth in BA, BE, BH, LA, RM, RO, SM and WA, respectively. The growth in BH, LA, RM, RO, SM, and WA were more associated with the previous year's climatic variations rather than the current year's. Bitternut hickory, LA, RM, SM, and WA growth were more related to the first year rather than the second or third preceding year variables. The June heat index of the third previous year of variables explained only 7% of the growth of white ash. It was concluded that the impact of climatic variables on tree growth may vary and may depend on the species and other unknown variables. Also, the results suggested that the first and second previous climatic variables have an important role on the growth of some species. American beech, BH, RO, and WA seem to be a good species to use for the study in dendrochronological and dendroclimatological studies.

Keywords: Basal area growth, Climatic variations, Regression models.

INTRODUCTION

There are many recent publications discussing the apparent unprecedented decline in tree species in North America and Europe (e.g. Zedaker *et al*., 1987; Fuhrer, 1990). Widespread regional tree mortality for a number of eastern species such as northern red oak (*Quercus rubra* L.), white oak (*Quercus alba* L.), black oak (*Quercus velutina* Lam.), sugar maple (*Acer saccharum* Marsh.), white ash (*Fraxinus americana* L.), American beech (*Fagus grandifolia* Ehrh.), quaking aspen (*Populus tremuloides* Michx.), and southern pines has been related to drought and excessive temperatures (McLaughlin, 1985). Warm winter temperatures have been associated with the decline in sugar maple in the U.S.A. (Bauce and Allen, 1991).

Recently, investigations show that the climate has changed, and this may bring about rapid environmental changes (Hansen *et al*., 1988) which may have extreme impacts on

[1] Department of Forestry, Faculty of Natural Resources, Mazandaran University, P.O.Box 737, Sari, Islamic Republic of Iran.
[2] Tarbiat Modarres University, Noor, Mazandaran, 46414, Islamic Republic of Iran.

tree growth (Kelly *et al.*, 1994). Many studies have been carried out to evaluate the effects of these variables in the current growing season (e.g. McLaughlin, 1991), but only a few weather data were included as independent variables. Some tree growth models predicted growth from climate variables (Ryan *et al*., 1994), but none of them were clearly explained and tested with all the climatic variations to find the proportion of each variable that relates to the growth responses of trees both separately in individual simple, quadratic, and multiple regression models and in a combined model. This is especially true for hardwood species, except for sugar maple (McLaughlin, 1991; Ryan *et al*., 1994). Species may respond differently to atmospheric variables such as temperature (Blasing *et al*., 1988), heat, precipitation (Larsen and McDonald, 1995), and evapotranspiration (Moss and Davis, 1982) by modifying their growth rates. Current and previous climatic variables, however, may have influenced tree growth (Djalilvand, 1996).

Buds are formed during one, two, or three years (depend on species), and the parts formed within them thus expand into shoots the next year. A favorable environment during the year of bud formation produces long shoots with many leaves (Kozlowski *et al*., 1973), and thus the supply of nutrients should be increased for the following year. Growth may increase if the previous and current seasons' climatic conditions are suitable. Precipitation and evapotranspiration levels are critical to tree growth if previous and current temperature conditions prevail.

There are no previous reports evaluating the previous year's climatic variable impact on tree growth in hardwood species in southern Quebec. Studies on the effect of climate on tree growth in which both precipitation and temperature are taken into account tend to explain ring width better than studies which considered only precipitation or temperature alone in current or previous years. In the study of tree responses to climatic variables, it seems that the current and previous years' climatic variables (over three years) may correlate with tree growth. In past work addressing the relationship between tree growth and climatic variables, the current and previous years' climatic variables were rarely considered all at.

The suggestion has been made that tree growth should be influenced by weather conditions over the current and three past years of the growing season. The responses of hardwood species growing at the same location would also differ depending upon the atmospheric conditions. A manager making decisions about and predictions of tree growth or forest ecosystems would depend on our knowledge of how natural species respond to alternative environmental factors. The results of this work may be useful for the sustainable modeling of forest management to improve ecological models that involve climate factors and could also be useful in dendroclimatological and dendroecological studies. Some comparison between the growth of species responses in dry years such as 1980-1981 and 1992-1993 in southern Quebec could also be analyzed. The objective was to find and develop the best regression models that would allow us to undrestand the relaionship between climatic variables and tree growth.

MATERIAL AND METHODS

The study site was located in the Morgan Arboretum on the west Island of Montreal in Southern Quebec (45° 25' N, 73° 57' W; 15.2 m above sea level). Most of the Arboretum is composed of natural forest stands ranging from pioneer to climax forests typical of the Great Lakes-Saint Lawrence forest (Rowe, 1972). The native vegetation of the area is deciduous forest dominated by American beech (*Fagus grandifolia* Ehrn.), sugar maple (*Acer saccharum* Marsh), red maple (*Acer rubrum* L.), yellow birch (*Betula alleghaniensis* Britton), bitternut hickory (*Caria cordiformis* (Wang.) K. Koch), and eastern hemlock (*Tsuga canadensis* (L.) Carr.).The study was carried out in a native hardwood forest. The forest is underlain by a

Ste-Sophie sandy soil series classified as humo-ferric podzol that developed on a fluvial sand deposit (Millette, 1948).

Meteorological data for the study were obtained from the nearest weather station in Sainte-Anne-de-Bellevue (No. 7026839, Latitude 45° 26′, Longitude 73° 56′, Altitude 39 m). The mean annual temperature for the study site was 6.2°C with a mean maximum temperature of 7.5°C and a mean minimum temperature of 4.9°C- averages obtained from 40 years of weather data (Djalilvand, 1996). The average total annual precipitation from 1954 to 1994 was 974.5 mm.

In 1995, one increment core from each tree was extracted due south at breast height (1.30 m above ground). In total, 180 cores were obtained. Some increment cores had very narrow rings and the contrast was often poor. In some cores, rings appeared to be missing or to be double. After the elimination of problematic cores, a total of 164 (BA, 20; BE, 20; BH, 22; LA, 18; RM, 22; RO, 20; SM, 22; and WA, 20) cores were measured to compute the basal area increment for each species. Increment cores were then dried, mounted, labelled, and sanded using a series of grades of sandpaper (400 and 600 grit). Cores were cross-dated using yamaguchi's (1991) technique and the ring width for the last ten years growth was measured by Win/MacDENDRO™ software for Macintosh Apple Computer (Regent Instrument Inc. 1993).

The basal area growth (G) of each core sample was computed using the following formula:

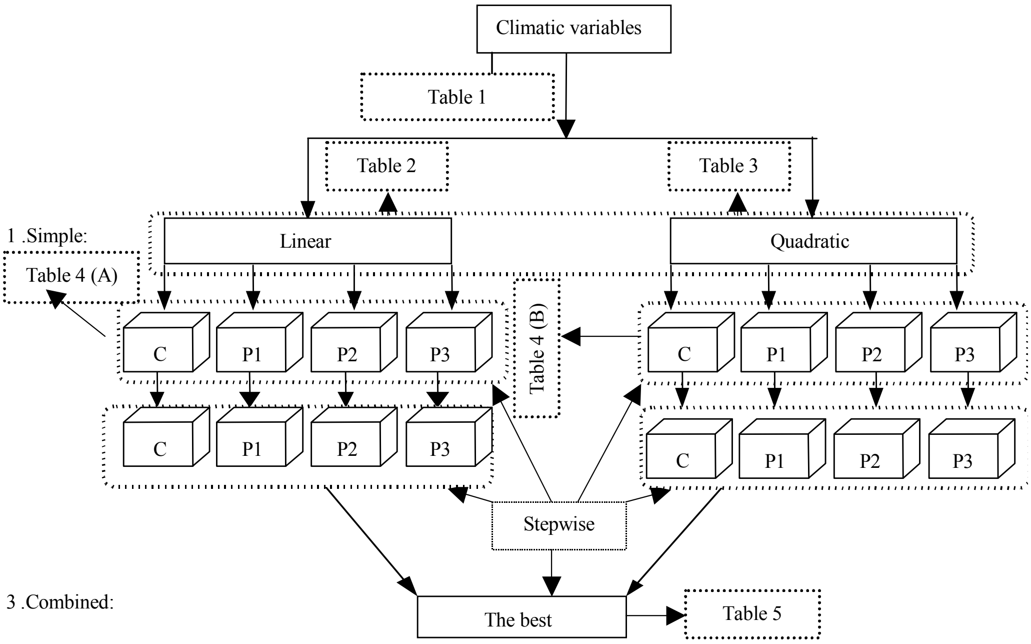

Figure 1. Diagram of the model flow with input of climatic variables (Table 1), processing in simple (linear and second degree), mixed, and combined multiple regression models of current (C) and first (P1), second (P2) and third (P3) previous years' climatic variations using stepwise procedure under the SAS program. The results have been shown in Tables (2, 3, 4 A & B, and 5).

$$G_{jk} = \Pi\ (R^2_{oj} - \Delta R^2_{ij}) \quad (1)$$

where, R_{oj} is the radius (R) outside of the jth (1 to 10) ring for k = 1 to n (number of samples for each species' cores), R_{ij} is the radius inside the ith tree sample for the jth ring, and R - ΔR is the experimentally measured increment ring width from the outside to the inside of the circles of the ith individual tree sample core for the jth ring. This was measured with a ring width measure-

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ment microscope.

Standardized response functions were also applied to compare the species, decline in growth from the population zero mean (index) as a function of the impact of the summer drought (minimum precipitation in a month of growing season where the temperature was highest).

The weather data were computerized for the period of 1982 to 1994. Using the precipitation and mean monthly temperature data, heat index (H) and evapotranspiration (E) were computed (Thornthwaite, 1948) for yearly, monthly, seasonsl, and seasonal growth.

Simple linear regression models using all climatic variables (Table 1) as well as a quadratic response of them as an independent variable, and annual basal area growth as the dependent variable, were first carried out for each species separately to screen for the most promising predictors of the growth. A second screening was carried out on the selected variables to determine if the quadratic responses were significant. All significant variables were then mixed separately for each species using stepwise regression elimination (SAS Institute, 1990). This procedure was followed for both the current and previous (one, two, and three) years' climatic variables. In the final step, both the current and previous years' variables were combined simultaneously with stepwise regression elimination (Figure 1).

RESULTS

Overall, good predictors of simple linear regression models were found for: basswood (BA) (*Tilia americana* L.), current minimum precipitation during the growing season (R^2 = 0.70); for American beech (BE) (*Fagus grandifolia* Enrh.), current precipitation during the growing season (R^2 = 82); for bitternut hickory (BH) (*Caria cordiformis* (Wang.) K. Koch), current and previous summer temperatures (R^2 = 0.68 & 0.75); for largetooth aspen (LA) (*Populus grandidentata* Michx.), two previous years of August heat index (R^2 = 0.95); for red maple (RM) (*Acer rubrum* L.), current year growing season evapotranspiration (R^2 = 0.44), previous year October precipitation (R^2= 0.62), and two previous years, June heat index (R^2 = 0.87); for red oak (RO) (*Quercus rubra* L.), current year April heat index (R^2= 0.50) and two previous years, annual heat index (R^2= 0.75); for sugar maple (SM) (*Acer saccharum* Marsh.), previous year minimum precipitation of growing season (R^2 = 0.63); and for white ash (WA), one

Table 1. The following independent climatic variables were used to identify the effect of current year (C) and previous (one, two, and three; P1, P2 & P3 respectively) years climatic variations on basal area growth of deciduous tree species in individual, mixed, and combination simple first and second degree regression models using stepwise procedures.

No	P (mm)	T (^{o}C)	H	E (mm)
	April (PAP)	April (PAP)	April (PAP)	April (PAP)
2	May (PMY)	May (PMY)	May (PMY)	May (PMY)
3	June (PJN)	June (PJN)	June (PJN)	June (PJN)
4	July (PJL)	July (PJL)	July (PJL)	July (PJL)
5	August (PAU)	August (PAU)	August (PAU)	August (PAU)
6	September (PSE)	September (PSE)	September (PSE)	September (PSE)
7	October (POC)	October (POC)	October (POC)	October (POC)
8	Growing Season (PGR)	Growing Season (PGR)	Growing Season (PGR)	Growing Season (PGR)
9	Spring (PSP)	Spring (PSP)	Spring (PSP)	Spring (PSP)
10	Summer (PSU)	Summer (PSU)	Summer (PSU)	Summer (PSU)
11	Minimum P In GRS (PMI)	Minimum P In GRS (PMI)	----------------------	--------------------
12	Maximum P In GRS (PMA)	Maximum P In GRS (PMA)	----------------------	--------------------
13	Annual (PAN)	Annual (PAN)	Annual (PAN)	Annual (PAN)

and two previous years, precipitation during the growing season (R^2 = 0.56, 0.49), and three previous years, growing season temperature R^2 = 0.57), respectively (Table 2).

From those variables as they were presented for simple models, eighty-five (C= 27, P1 = 20, P2 = 17, & P3 = 21) second degree statistical regression models of climatic variables bore a good relation with the growth of tree species (Table 3).The results show that, in most cases using simple linear models, climatic variations significantly influenced tree growth, and the second degree of these variables also significantly affected growth.

From 64 significant simple linear variables, 51 of them remained in the models (Table 4 A). From 85 second degree significant models, 44 variables remained (Table 4 B). Most of them, however, influenced the growth of diffrent species very little. The linear mixed model of current climatic variations by partial coefficient of determination explained most (91, 84, 80, 79, 74, and 49%) of the total variances in red maple, American beech, bitternut hickory, white ash, basswood, sugar maple, red oak, and large-tooth aspen growth, respectively (Table 4 A). Most of them positively affected growth. Exceptions were the minimum precipitation in the growing season (BA, WA), the May heat index (BE), temperature (LA), evapotranspiration of the growing season (RM), and September precipitation (WA). One previous year's variables explained 96% (RM), 93% (BH), and 85% (SM) of these variances. Two previous mixed linear variables explained 90 (RM) and 81% (RO) of variances, while three previous variables explained 85% (RM) and 81% (SM) of variances (Table 4 A). In the second degree mixed models, most of them were the same as the mixed linear models and explained the growth of species, but fewer variables remained in the models and the signs were inverse in some cases (Table 4 B).

Among all climatic variables inserted in to the combination or multiple regression models, one variable remained for BA, BE, RM, and SM, two variables for BH, three for RO, four for LA, and five for WA (Table 5). Current year minimum precipitation during the growing season alone negatively explained 79% of the growth of basswood. Eighty percent of the growth of beech, however, related to current precipitation during the growing season. The previous summer mean temperature positively affected the growth of BH and explained 90% of the total variance, while the two previous year's June heat index explained only 6% of the variances. The highest relation between large-tooth growth with climatic variables was found with the previous May linear (R^2 = 0.54) and it's second degree (R^2 = 0.18). For red maple, only the quadratic of the previous October precipitation influenced the growth and explained 71% of variables. The growth of red oak was mostly related to the annual heat index (R^2 = 0.81) and precipitation (R^2 = 0.18) over the two previous years. Sugar maple showed a sensitivity to the minimum precipitation of previous growing season. Minimum precipitation during the previous year.

Explained only 49% of variations. Precipitation over previous year in the growing season (R^2 = 0.69) and September (R^2 = 0.15) affected the growth of white ash greatly compared to the other significant variables in the model. The optimum of three previous heat indices for June was 6.7 which was very close to the mean (6.9), while the optimum for the two previous year's minimum precipitation during the growing season at 50 was also close to it's mean (48.7). The current, two, and three previous climatic variations explained together only 14% of the total variances.

DISCUSSION

Growth rates among species were significanly different and a multiple test showed that the highest growth rate was obtained by sugar maple and red oak while the lowest rate of growth was shown by red maple and basswood (Figure 2).

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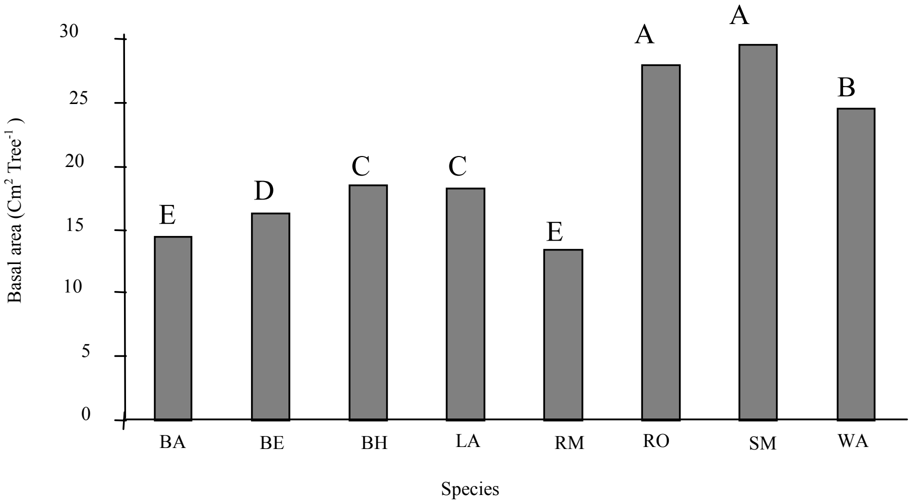

Figure 2. Comparison between species growth by Ryan-Einot-Gabrill-Wilsch multiple F test. Means with the same letter are not significant, but the rest are significant (P<0.05).

Some terms in the models usually resulted in a small but statistically significant increase in R^2 values, e.g. the first and second degree of current and previous years' precipitations, the two previous years' June precipitation, and the previous years' September precipitation in the models for largetoothe aspen, red oak, and white ash, respectively. It seems that the basal area growth as a dependent variable was most likely was caused by such factors as age, site quality, stand density, topography, parent material, and nutrients. Overall, in this study, the year did not significantly affect growth, but the growth of species in the 1988 and 1993 summer droughts or the minimum precipitation in current and previous years negatively affected the growth of species such as sugar maple and basswood (Figure 3).

Thus, in future studies these variables should be taken into account as a compositional data set with a special statistical analysis of a multivariate approach such as factor or principal component analysis. Basswood growth was sensitive to the current minimum precipitation during a growing season, while sugar maple was sensitive to the previous years' minimum precipitation (Table 5). Most species showed that they required one or two previous years' precipitation and temperature, especially during the summer, the growing season, and the months of May, June, August, and September. From all significant variables, only the second degree of the three previous years' heat index with its low explanation of total variance was significant remaining in the model of white ash growth. This result suggested that the growth responses of species to climatic variables varied, and were more related to the first or second years of the growing season climatic variations.

In some species such as red oak and bitternut hickory, growth was associated with two and/or one previous years' temperature to a greater degree than with precipitation. Similar results were reported for oak in Sought-Central USA (Blasing *et al*., 1988), Boston Mountain, and Arkansas (Gyette and Rabeni, 1995). Negative effects of high June and July, early summer and early previous fall temperatures, and positive effects of early summer precipitation influenced the growth of sugar maple in southern Ontario (McLaughlin, 1991), central and southern Ontario (Ryan *et al*., 1994), and in Cook County, Minnesota to Ocean County, Michigan (Lane *et al*., 1993), re-

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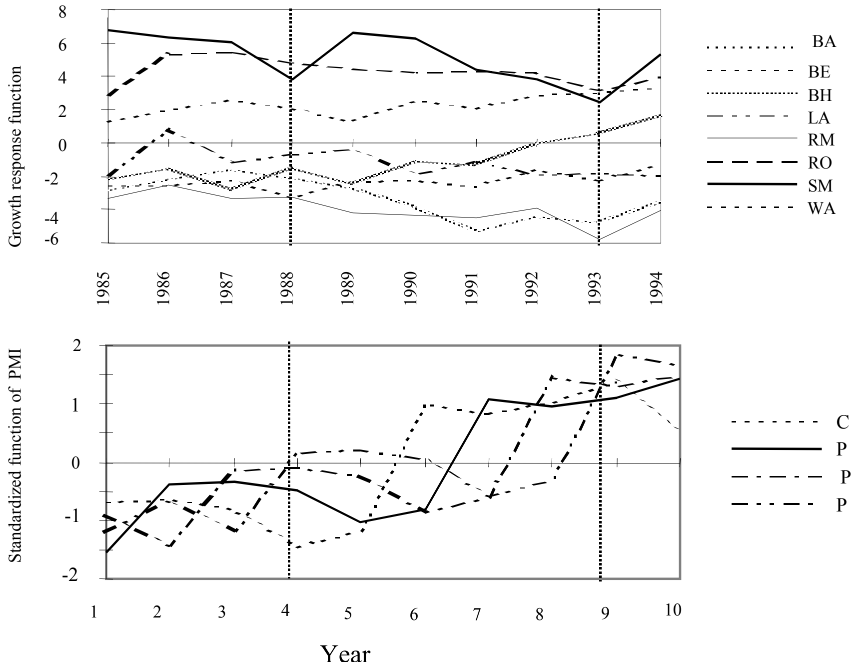

Figure 3. Standardized response function (X-μ/σ) of eight species from 1985 to 1994 in southern Quebes in relation to the standardized minimum precipitation during growing season (PMI). Both current and previous years (C & P1) had negative effects on the growth of red maple and sugar maple, specially in the dryer summer (also see Table 5).

spectively.

Three previous years' climatic variables had a minor influence on white ash. This result suggested that basal area growth was related more to the current and previous years' climate. However, white ash and red oak, which are more likely to grow at a greater rate when the summer temperature during two or three previous years is warmer than those in current year of growing season. Annual and early warmer conditions in the growing season (e.g. The may temperature) could increase the length of the growing season, and may favour the formation of large buds in largetooth aspen, bitternut hickory, red oak, and white ash (Table 5). Small buds may probably lead to relatively low growth in the following year. Favoured conditions could provide a good environment for root development, root respiration, and high root density per unit area, and therefore, could increase the nutrient uptake and water absorption. Wetter conditions in the first and the last months of the growing season may negatively influence the growth of red maple and large aspen. Since, root systems are near the surface in shallow or poorly drained soils, large aspen may grow better on soils where a strong multi-layerd root could develop. High growth requires a dependable supply of well-aerated soil. The severity of frost damage may also be greater on wet soils (Stiell, 1976).

CONCLUSION

The responses of each species to the climatic variables varied. The inclusion of temperature or the heat index and precipitation in the study significantly improved all of the models in the final step, and suggested that studies on climatic variables which affect tree growth should always consider the heat index together with precipitation and temperature. As shown in Tables 2 to Table 5, the coefficient of variations consequently

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improved. Sugar maple showed more sensitivity than the other species to the occurrence of a dry growing season in 1988 and 1993 (Figure 3).

The most important climatic variable for basswood and sugar maple was minimum precipitation during the growing season, while for large aspen precipitation and temperature in May were important variables, even though it was from current or previous years. The most important climatic variables for beech, hickory, and red oak were the current growing season precipitation, the previous years' summer temperature, and the two previous years' annual heat index, respectively (Table 5). For white ash, precipitation during the previous year was more important than the other variables, although it explained only 69% of variables. The previous years' October precipitation may have been mis-identified for red maple. Saturation of soil by water in the growing season may have been problematic for all species, except for red maple if we accept the present model. It seems that more work on the relationship between the root systems of red maple and water in different site conditions is needed. This was truer for red oak and for bitternut hickory than for the other species, because they need dryer and warmer conditions. Red maple, sugar maple, basswood, white ash, aspen, and beech may be better adapted to wet sites, possibly because the wet condition is a specific need for these species.The sensitivity of root system to dry or wet sites might be one of the most important factors to be taken into account. In future studies, it seems that climatic variables associated with morphological conditions of the site (such as topography), upland or lowland, water table movement in the growing season, and nutritional conditions should be considered by multivariate statistical analysis.

REFERENCES

1. Bauce, E., and Allen, D.C. 1991. Aetiology of a Sugar Maple Decline. *Can. J. Forest Res*., **21**: 686-693.
2. Blasing, T.J. Stahle, D.W., and Duvick, D.N. 1988. Tree-ring-based Reconstruction of an Annual Precipitation in the South-central United States from 1750 to 1980. *Water Resour. Res*., **24** : 163-171.
3. Djalilvand, H. 1996**.** Growth Response of *Pinus resinosa* and *Picea abies* to Past and Future Climatic Variations. M.Sc. thesis, McGill University, pp 90.
4. Fuhrer, E. 1990. Forest decline in Europe: Additional Aspects of its Cause. *For. Ecol. Manage*. **37**: 249-258.
5. Gyette, R.P., and Rabeni, C.F. 1995. Climate Response Among Growth Increments of Fish and Trees. *Oecologia* ., **104**: 272-279.
6. Hansen, J., Fung, I., Lacis, A., Rind, D., Lebedeff, S., Rvedy, R., and Russell, G. 1988. Global Climate Changes as Forecast by Goddard Institute for Space Studies Three Dimensional Model. *J. Geophys. Res*., **93** (D8):9341-9364. In: Climate Change and Wildfire in Canada, *Can. J. Forest Res*. **21**: 66-72. M.D. Flannigan and C. E. Van Wagner. 1991.
7. Kelly, P.E. Cook, E.R., and Larson, D.W. 1994. A 1397-year Tree-ring Chronology of *Thuja occidentalis* From Cliff Faces of the Niagara Escarpment. Southern Ontario. *Can. J. Forest Res*., **24**: 1049-1057.
8. Kozlowski, T.T. Torrie, J.H., and Marshall, P.E. 1973. Predictability of Shoot Length From Bud Size in *Pinus resinosa* Ait. *Can. J. Forest Res.*, **3**: 34-38.
9. Lane, C.J. Reed, D.D. Mroz, G.D., and Liechty, H.O. 1993. Width of Sugar Maple (*Acer saccharum*) Tree Rings as Affected by Climate. *Can J. Forest Res*. **23**: 2370-2375.
10. Larsen, C.P.S. and MacDonald, G.M. 1995. Relations Between Tree-ring Widths, Climate, and Annual Burned in the Boreal Forest of Alberta. *Can. J. Forest Res*. **25**: 1746-1755.
11. McLaughlin, D.L. 1985. Sugar Maple Decline in Ontario. Ontario, Ministry of Environment. 18 pp.
12. McLaughlin, D.L. 1991. Dendrochronological Study of Nine Tree Species Exposed to Fluoride Emissions From an Aluminium Smelter. M.Sc. thesis, University of Toronto, Toronto, Ont.
13. Millette, G. 1948. Soil Map of the Morgan Arboretum. W.H. Brittain Memorial Forest Science Laboratory. Department of Natural

Resource Sciences. Macdonald Campus. McGill University.
14. Moss, M.R. and Davis, L.S. 1982. The Potential and Actual Primary Productivity of Southern Ontario's Agro-ecosystem. *Appl. Geog*. **2**: 17-38.
15. Regent Instrument nc. 1993. Mac/ WinDENDRO™, User Manual, V 3.3. National Optics Institute and Universite du Quebec Chicoutimi. 22pp.
16. Rowe, J.S. 1972. Forest Regions of Canada. *Can. J. Forest Serv*. Publ. No. 1300. Ministry of Fisheries and the Environment, Ottawa, ON.
17. Ryan, D.A.J. Allen, O.B. McLaughlin, D.L., and Gordon, A.M. 1994. Interpretation of Sugar Maple (*Acer saccharum*) Ring Chronologies From Central and Southern Ontario Using a Mixed Linear Model. *Can. J. Forest Res*., **24**: 568-575.
18. SAS Institute Inc. 1990. SAS user's Guide. Statistics. SAS Institute Inc., Cary, N.C.
19. Stiell, W.M. 1976. White Spruce: Artificial Regeneration in Canada. Canadian Forestry Service. Information Report FMR-X-85. Forest Management Institute. Ontario, ON. 275 p.
20. Thornthwaite, C.W. 1948. An Approach Toward a Rational Classification of Climate. Geog. Rev., **38**: 55-94.
21. Yamaguchi, D.K. 1991. A Simple Method for Cross-dating Increment Cores From Living Trees. *Can. J. Forest Res*., **21**: 414-416.
22. Zedaker, S.M. Hyink, D.M., and Smith, D.W. 1987. Growth Declines in Red Spruce. *J. For*. **85**: 34-36.

واکنش‌های رشد هشت گونه درختی پهن برگ به متغیرهای آب و هوایی سال رویشی و سه سال قبل از آن در مدل‌های رگرسیون

ح. جلیل‌وند، س. ق. جلیلی، م. اکبرنیا، م. طبری و س. م. حسینی

چکیده

اثرات متغیرهای آب و هوایی روی سطح رویه زمینی هشت گونه پهن برگ صنعتی افرای قرمز (*Acer rubrum* L.)، افرای قندی (*Acer scccharum* March.)، بلوط قرمزشمالی (*Quercus rubra* L.)، زبان گنجشک سفید (*Fraxinus americana* L.)، صنوبرکنگره‌دار(*Populus grandidentata* Michx.)، راش آمریکایی (*Fagus grandifolia* Ehrh.)، کاری (*Carya cordiformis* (Wang.) K. Koch.) و نمدار (*Tilia americana* L.) در جنوب استان کبک در کانادا (٤٥ درجه و ٢٥ دقیقه شمالی، ٧٣ درجه و ٥٧ دقیقه غربی) مورد مطالعه قرار گرفت. در مجموع ٤٨ متغیر آب و هوایی بارندگی (١٣ متغیر)، درجه حرارت (١٣ متغیر)، شاخص گرمایی تورنتوایت (١١ متغیر) و تبخیر و تعرق (١١ متغیر) در سال رشد و یک، دو و سه سال قبل از آن در مدل‌های رگرسیون به منظور یافتن بهترین مدلی که بتواند رشد گونه‌های مذکور را تخمین بزند، مورد ارزیابی قرار گرفتند. بهترین مدل برای نمدار، راش، کاری، صنوبر، ارای قرمز، بلوط قرمز شمالی، افرای قندی و زبان گنجشک از مجموع کل واریانس رشد برای هر یک از آنها را به ترتیب ٧٩، ٨٠، ٩٩، ٩١، ٧١، ٩٩، ٤٩ و ٩٨ درصد شرح داد. رشد گونه‌های کاری، صنوبر، افرای قرمز، بلوط قرمز شمالی، افرای قندی و زبان گنجشک بیشتر به متغیرهای سال‌های قبل از سال رویشی

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وابسته بود. گونه‌های کاری، صنوبر، ارای قرمز، افرای قندی و زبان گنجشک وابستگی بیشتری به متغیرهای آب و هوایی یک سال قبل از سال رویشی واکنش نشان دادند. فقط شاخص گرمایی ماه ژوئن در سال سوم ۷ درصد از رشد زبان گنجشک را تخمین زد. از نتایج حاصل می‌توان چنین نتیجه‌گیری کرد که متغیرهای آب و هوایی روی رشد گونه‌های مختلف اثری متفاوت داشته وبرخی از عوامل ناشناخته نیز در رشد گونه‌های فوق تاثیر می‌گذارند. همچنین نتایج مشخص کرد که متغیرهای آب و هوایی یک و دو سال قبل از سال رویشی نقش بیشتری نسبت به سال سوم در رشد دارند. به نظر می‌رسد که گونه‌های راش، کاری، بلوط قرمز و زبان گنجشک مناسب برای مطالعات وقایع‌نگاری اکولژیکی و آب و هوایی (Dendroecological and dendroclimatological studies) باشند.

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