Plants & Human Affairs – Biol106

Are Leaves Good Predictors of Climate?

Objectives: *The purpose of this lab is to:*

1. use leaf models to test predictions concerning water loss and leaf shape
2. use leaf models to test predictions about heat and leaf shape
3. determine if the leaf margins of deciduous trees provide a good estimate of mean annual temperature
4. use a chi-square statistical test

Introduction:

Since plants are stationary they must respond developmentally, and ultimately evolutionarily, to their environment. As a result, it's not surprising that leaf morphology (shape) has been shown to be related to climate. For example, some the following correlations have been reported (Wiemann *et al*, 1998): (a) leaf length is directly related to the mean annual temperature (MAT), (b) leaf area is directly correlated to both MAT and mean annual precipitation (MAP); and (c) leaf width is directly correlated with MAP. Thus, leaves are longer and larger in climates with warmer temperatures and higher rainfall.

Another interesting observation that was first reported more than 100 year ago is that woody deciduous plants having leaves with toothed margins (termed **serrate**) predominate in temperate climates while species with smooth (termed **entire**) leaf margins predominate in frigid (arctic) and tropical climates. This relationship has been used to derive a mathematical model for predicting climate from leaf margins. This has been particularly useful in determining MAT in the geological past by analyzing the leaf margins of fossil plants.

It is not clear why there should be such a strong correlation between leaf margin and temperature. It is suggested that teeth may help to increase sap flow in plants which may be a benefit in temperate environments.

Wiemann *et al*, (1998) report that the following equations have been derived to predict MAT (in degrees C) from leaf margin structure (% is expressed as a whole number, not a decimal):

- Equation 1. MAT = 1.14 + (0.306 x % entire leaves)
- Equation 2. MAT = 4.4 + (0.22 x % entire)
- Equation 3. MAT = 2.24 + (0.286 x % entire)

The purpose of today's lab is to test the accuracy of these models for our area.

Methods: We will go into the woods today and locate as many different species of woody plants, including both trees and shrubs, as we can. It is not necessary to identify the species, though that will be helpful. For each species, determine whether the leaves have a toothed or smooth margin. Record these data in Table 1 and then complete the calculations in Tables 1 and 2. Perform a chi square test to determine if the there is a statistically significant difference between the number of species with serrate leaf margins and those with entire margins. Perform a chi square test and complete table 3 *(Use the CSB/SJU intro bio statistical test website to help perform your calculation: http://www.physics.csbsju.edu/stats/Index.html)*. Complete the post-lab exercises.

References:

- Bailey, IW, EW Sinnott (1916) The climatic distribution of certain types of angiosperm leaves. *American Journal of Botany* 3: 24 - 39.
- Royer, DL & P Wilf (2006) Why do toothed leaves correlate with cold climates? Gas exchange at leaf margins provides new insights into a classic paleotemperature proxy. *Int. J. Plant Sci.* 167: 11 - 18.
- Sinnott, EW, IW Bailey (1915) Investigations on the phylogeny of the angiosperms. 5. Foliar evidence as to the ancestry and early climatic environment of the angiosperms. *American Journal of Botany* 2: 1 - 22.
- Wiemann, MC, SR Manchester, DL Dilcher, LF Hinojosa, EA Wheeler (1998) Estimation of temperature and precipitation from morphological characters of dicotyledonous leaves. *American Journal of Botany* 85: 1796 - 1802.
- Wilf, P (1997) When are leaves good thermometers? A new case for leaf margin analysis. *Paleobiology* 23: 373 - 390.

Climate Sites:

- Midwest regional Climate Center (http://mcc.sws.uiuc.edu/)
- Minnesota Climatology Working Group (http://www.climate.umn.edu/)
- Climate Zone (http://www.climate-zone.com/)

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Leaf Margins as Climate Indicators: Post-Lab Exercises

Data & Calculations:

Table 1. Data Summary		
Margin type	# species observed	%
Entire		
Serrate		
Total		

Table 2. Predicted MAT for central Minnesota	
Model	**degree C**
predicted MAT (based on equation 1)	
predicted MAT (based on equation 2)	
predicted MAT (based on equation 3)	
mean MAT (from three equations)	

Table 3. Chi square goodness-of-fit test comparing woody plants with serrate and entire margins	
null hypothesis:	
Observed values:	serrate: entire:
Expected values:	serrate: entire:
p value =	
Conclusion:	The null hypothesis should be: rejected accepted

Analysis: Type the answers to the following questions on a separate sheet of paper and append to Tables 1-3.

1. How does the predicted MAT compare to the actual value. How closely do these values match? Are the mathematical models valid for our area?
2. We didn't distinguish between native and introduced species in our analysis. How might this affect our data? Which species should we use in our analyses - native, introduced or all woody species?
3. Which model(s) is most accurate for our area? How much error exists in the model(s)? [*calculate percent difference = (observed - expected)/expected x 100].* Why might there be differences between the predicted and actual data?
4. Statistically speaking, are there a greater number of leaves with serrate or entire margins in our area? Explain citing your data/chi square test.
5. If you are a horticulturalist, which species would most likely be suited for introduction to our area - those with serrate or entire margins? Explain.
6. Offer an explanation why plants with serrated leaf margins predominant in our area and are correlated to temperature. *(see article by Royer & Wilf, 2006)*
7. How might climate change impact woody species in our area?