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BEE 6740: Week 5 Assignment
Single Crop Coefficient PET Model
3/2/18

Purpose:
Crop evapotranspiration is an important metric to include in evapotranspiration analyses. The Priestley-Taylor PET model can be modified by the single crop coefficient method to incorporate information on a plant's ability to transpire. This crop coefficient value, K_C, and climate PET data can be used to create crop coefficient curves to determine crop evapotranspiration. PET calculated from the Priestley-Taylor model and PET calculated from the single crop coefficient model provide different results for PET analysis, and a comparison of the two methods provides important insight into choosing which model is most appropriate for analysis work. Coniferous and deciduous forests in Ithaca, NY from 1950-1954 were used to develop the single crop coefficient method.

Methods:
Using the "EcoHydRology" package and "PET_fromTemp" function in R, PET data for Ithaca, NY were calculated. Meteorological data was obtained from NOAA "Global Summary of the Year." The function "PET_fromTemp" calculated PET in millimeters using inputs of Julian date, maximum temperature (Celsius), minimum temperature (Celsius), latitude, average temperature (Celsius), and albedo. The function uses the Priestley-Taylor equation (1972):

$$\lambda ET_0 = \frac{\alpha\Delta}{\Delta+\gamma}(R_n - G),$$

where λ = latent heat of vaporization, ET_0 = reference ET value, α = Priestley-Taylor constant, Δ = slope of saturation curve, γ = psychrometric constant, R_n = net radiation, and G = soil heat flux. The latitude used for Ithaca was 42.44 degrees. PET calculated using the Priestley-Taylor equation is reported as PET_0.

The single crop coefficient model calculates PET from the crop coefficient K_C. K_C is calculated using growing degree day (GDD) and growth factor calculations (α) assuming 5 development stages, shown in Table 1. T_b is the base temperature for calculating GDD and K_C is the crop coefficient for adjusting PET to reflect the crop capacity to transpire. GDD is calculated as the difference between average daily temperature and T_b, with all negative values set to zero and all values above GDD_{max} set to equal GDD_{max}. Cumulative GDD was calculated by adding the GDD of each day to the GDD of the previous day. Cumulative GDD as a percentage of GDD_{max} was calculated by dividing cumulative GDD by GDD_{max}. This percentage was then compared to value reported in Table 1 and was used to determine plant growth stage.

Table 1: Plant properties and GDD stage information for coniferous and deciduous forests.

	Plant Properties				**Percent of GDD_{max} at which each stage begins**				
Forest Type	**T_b (℃)**	**GDD_{max} (℃)**	**K_{Cmin}**	**K_{Cmax}**	**I**	**II**	**III**	**IV**	**V**
Deciduous	1	2500	0.25	1	0	10	22.5	90	100
Coniferous	0	2500	0.9	0.9	0	5	10	95	100

Growth factor for each stage, (α), was found by the following equations:

$$\alpha_I = \frac{GDD_i}{GDD_{IV}}$$

$$\alpha_{II} = \frac{(GDD_i - GDD_{II})}{GDD_{IV}} * \frac{(GDD_{IV} - GDD_{II})}{GDD_{III} - GDD_{II}}$$

$$\alpha_{III} = 1$$

$$\alpha_{IV} = 1 - 0.6 * \frac{GDD_i - GDD_{IV}}{GDD_{max} - GDD_{IV}}$$

$$\alpha_V = 0$$

K_C was calculated by $K_{C,i} = K_{Cmin} + \alpha_i(K_{Cmax} - K_{Cmin})$. Five years of K_C and temperature data were plotted and are shown in Figures 1 and 2. PET from the single crop coefficient (PET_C) was calculated by $PET_C = K_{C,i} * PET_0$. Figures 3 and 4 compare PET_0 and PET_C as a time-series plot. Each analysis step was completed for Ithaca in coniferous and deciduous forests and then the results were compared to understand how changes in plant cover and PET model choice impact PET calculations.

Conclusion:

In conifer forests shown in Figure 1, K_C does not vary seasonally. In deciduous forests shown in Figure 2, K_C appears to vary seasonally. This is likely because deciduous forests lose their leaves in the winter time and grow leaves in the spring and summer, while conifers are evergreens that do not lose their pines. These different phenologies greatly impact the plant's ability to transpire, which is clear in that conifers have a constant K_C of 0.9 while K_C varies seasonally for deciduous plants.

Because K_C is constant for coniferous forests, PET_0 and PET_C are almost the same, as shown in Figure 3. However, because K_C values for deciduous forests, the two models for PET are not the same, as shown in Figure 4. PET from the single crop coefficient method (PET_C) includes more information about plant growth and interaction with the water cycle. However, PET_C model is highly dependent on GDD, which is a greatly simplified model and is not the most accurate measure of plant growth. Additionally, the PET_C model assumes that plant phenology can be compared to grass. Nevertheless, PET_C is an overall better estimate than PET_0 for real PET for deciduous and coniferous forests in Ithaca.

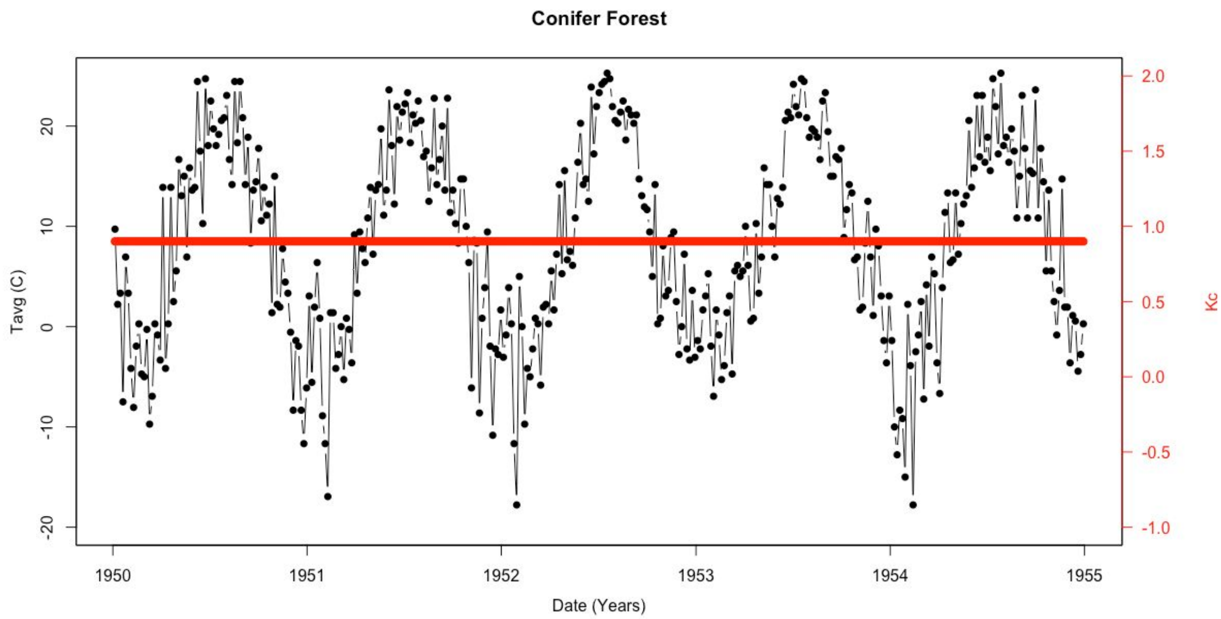

Figure 1: Temperature (C) and K_C by year for conifer forests in Ithaca, NY.

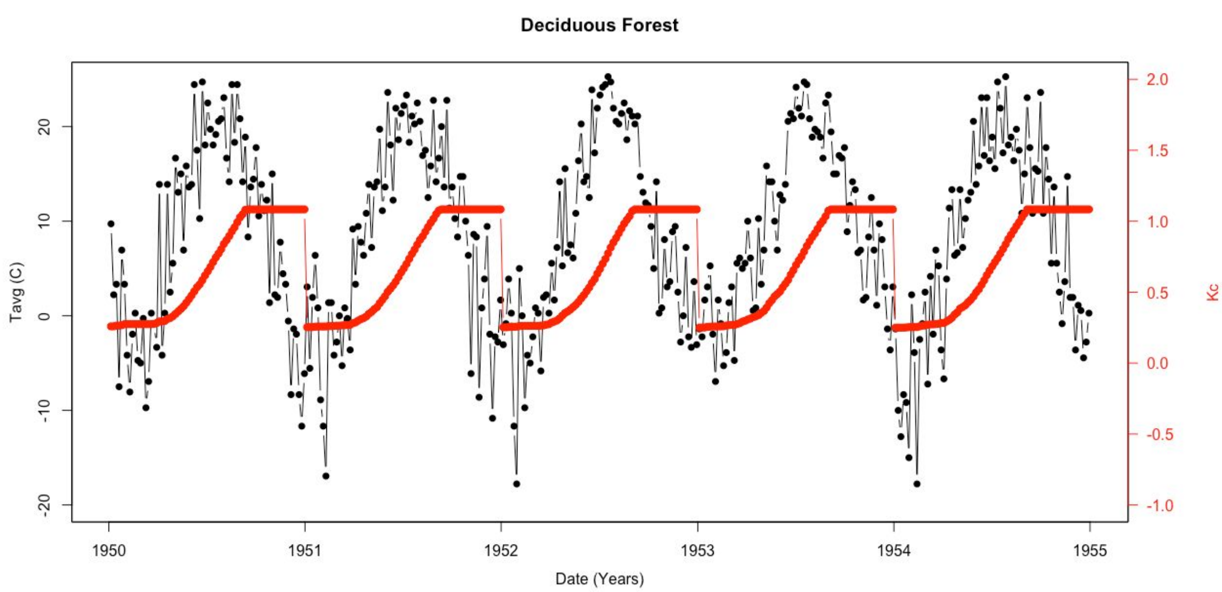

Figure 2: Temperature (C) and K_C by year for deciduous forests in Ithaca, NY.

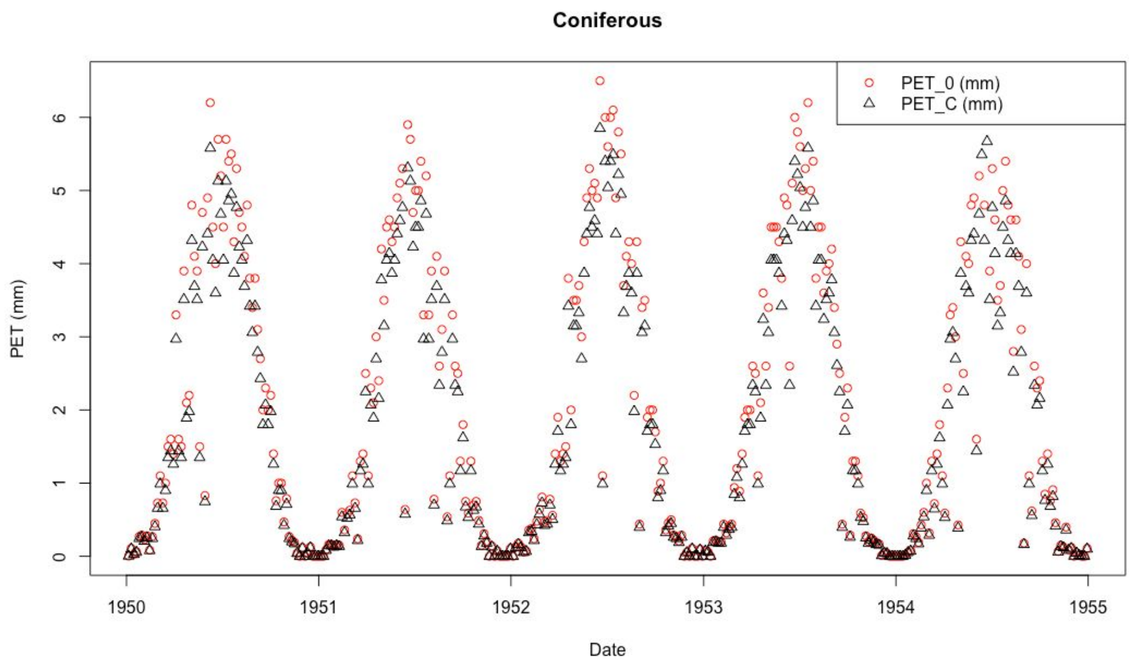

Figure 3: PET_0 and PET_C (mm) by year for coniferous forests in Ithaca, NY.

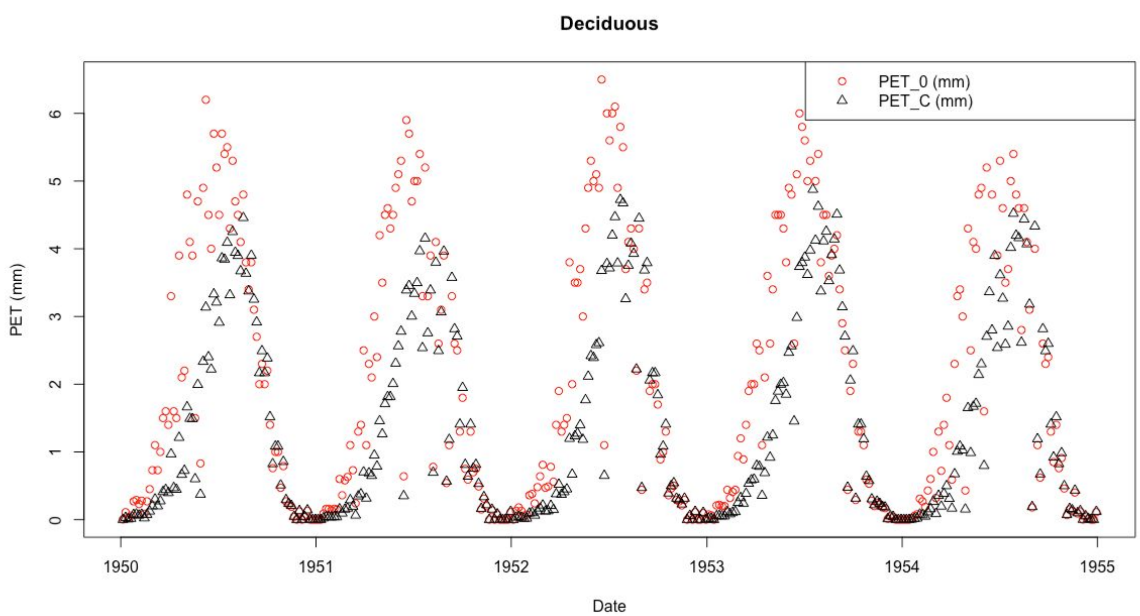

Figure 4: PET_0 and PET_C (mm) by year for deciduous forests in Ithaca, NY.