
Outline of today's activities
1. Discuss Stephenson 1990
2. Analysis of field trip data
   2.1. Investigate forest structure along elevation gradient
   2.2. Evaluate plant community formation with respect to energy and water

What you should get out of today's class
You should understand how potential evapotranspiration (PET) and actual evapotranspiration (AET), as determined by topography, proximity to coasts, latitude – in essence the type of environment at a location – determines what vegetation communities occur. You should also see how evolution tailors species to specific ranges of PET and AET, and how other conditions (e.g., wind, fire, soils) may modify vegetation community structure or species composition.

Handouts
1. Identification key of tree species
2. Spreadsheet for data entry, via email, after the lab

Introduction
A central question in ecology is how plant communities form. In New Mexico, there are striking gradients in plant communities, from cottonwood and willow bosque along riparian areas, through desert grassland and shrubland, into pinyon-juniper woodland, pine-oak forests, spruce-fir forests, and alpine tundra at the top of the highest mountains. Why do these particular vegetation communities occur where they do? Clearly, spruce trees do not grow well in Albuquerque, and cottonwoods would not fare well on the Sandia Crest, so there is the issue that plant species are adapted to their environments. But what are they adapted to?

The two fundamental physical parameters to which plant species adapt are the amount of solar energy available and the amount of solar energy that can be used given the amount of water present. These two parameters are formalized in the concepts of potential evapotranspiration (PET) and actual evapotranspiration (AET), respectively. The units of measure for both of these variables usually is mm of precipitation per year, because we are talking about an amount of water that could (PET) evapotranspire or that does evapotranspire (AET; think about how we measure rain in inches). In dry climates like New Mexico's, AET can be approximated by precipitation, because nearly all of the water that falls as rain or snow gets used by plants or evaporates (Hobbins et al. 2004). Many other factors may influence plant community development, such as soils, topography, wind, and disturbances, but we will be focusing on PET and AET in this lab. Both PET and AET vary across the landscape, due to latitude, distance from the coasts, topography, and other factors. It is the difference between them, known as the water deficit, that really comes into play here (deficit = PET – AET). Does the area have an abundance of sunlight and little water, or more water than it can use? A plant's physiology determines how it can respond to the water deficit, which in turn determines what types of plant communities sprout up on the landscape.

Today we are going to look in detail at how plant communities form in relation to the water deficit and AET. We will discuss Stephenson's (1990) classic paper and then look at estimated PET and AET gradients to evaluate our observations of plant communities in the Sandia Mountains.
Hypothesis

1. As the water deficit declines and the AET increases, the plant communities should change from a dry conifer forest to a wetter spruce-fir forest.

Materials

- Measuring tape
- Compass (for measuring slope and aspect)
- Data sheets
- Key to the tree species

Field Methods

We will use a standard ecological sampling method called the line-intercept transect. Because nature is so vast, counting or measuring everything of interest is impossible. Rather, we must sample some manageable portion of the system we believe to be representative of the system (recall sampling, randomization, and inference from Chapter 2: Introduction to Ecological Methods). Sampling allows us to answer our questions efficiently, without measuring every parameter or counting every individual. The line-intercept transect is a simple form of sampling where a line is placed along a gradient or randomly in some place of interest. Then, more-or-less perpendicular lines are placed along the transect at some interval, and measurements are taken along these secondary lines at uniform intervals.

Our interest in this lab is to investigate the plant communities on the eastern slope of the Sandia Mountains. Since we all need to actually get up the mountain to take our samples, we will simplify matters by making the road the main line of our transect. The side transects will be 30-m lines heading...
into the forest approximately perpendicular to the road, starting ~5 m past the edge of the road cut. Along these side transects, two per elevation, we will determine the species composition and canopy coverage of the forest (the percentage of the sky blocked by leaves or branches). Notice that we will not count every tree or determine canopy coverage across a large area. Rather, our transect will be a sample of the forest that occurs at that elevation. So, to the best of our ability, we want to minimize the many factors that could make our transect unrepresentative of the forest. We want to place all transects more or less horizontally on east-facing slopes, and we do not want to include road banks, drainage bottoms, or gaps in our transect, as these features may alter the typical forest structure. There are two tasks:

1. Lay out the side transect (30-m measuring tape) along the ground and measure the slope and aspect.

2. Identify and tally every tree whose branches crosses the transect at any point.

We will go over techniques in more detail during the field trip. These three tasks will be divided up and we will rotate at each transect so that everyone gets a chance to do each task.

Analysis Methods

1. Pool data from all groups and classes and enter in the spreadsheet provided

2. Investigate forest structure along the elevation gradient.

   2.1. Enter the forest type at the appropriate elevation in Table 6.1.

   2.2. Graph relative abundance as a function of elevation. To get relative abundance, divide the number of individuals of a given species found at one transect by the total population of trees at that transect. For example, if there are 10 trees at a transect and one of them is a ponderosa pine, then the relative abundance of ponderosa pine is 0.1. Elevation should be on the x-axis and relative abundance should be on the y-axis.

   a) Are the species evenly distributed along the elevation gradient, or do they seem to be more common at certain locations?
   b) Are there any pairs of species that seem to respond to elevation synchronously?

3. Evaluate habitat formation with respect to energy and water.

   3.1. We have average annual precipitation data from along the elevation gradient that was obtained from the Western Regional Climate Center (www.wrcc.dri.edu). We will assume AET = precipitation, except I have made a slight adjustment for more runoff at higher elevations (stream flow is typically greater higher up because of snow melt and thunderstorm runoff).
3.2. You will estimate PET using the Hamon equation (see Sidebar: Estimating PET with the Hamon Equation). This equation is an empirical relationship that will be adequate for our purposes, although it is possible to undertake a much more rigorous assessment of PET by measuring myriad physical parameters and entering them into complicated-looking equations. The Hamon equation estimates PET in mm/day, so we will need to multiply by 365 to get mm/year.

3.3. Now calculate the water deficit (AET – PET) for each elevation.

3.4. Graph the different habitat types in the AET/water deficit space. This graph should be similar to Stephenson's (1990) Figure 3, except there will be points to graph, not whole ranges for a habitat type.

   a) Are the habitat types associated with particular ranges of AET and water deficit? Do the distributions mirror Stephenson's (1990) results?
   b) How might the temporal pattern of precipitation in New Mexico influence the water deficit of the plant communities?

Literature Cited


Sidebar: Estimating PET with the Hamon Equation

The Hamon equation (Hamon [1963] as reported by Vörösmarty et al. [1998]) is an empirical estimate of PET (note – this is in mm/day) based on temperature and daylength:

\[
PET = \frac{715.5 \Lambda e_s(T_m)}{T_m + 273.2}
\]

where \( \Lambda \) = fraction of day that is day time, \( T_m \) is the mean daytime temperature (°C), and \( e_s(T_m) \) is the saturation vapor pressure at temperature \( T_m \) (kPa – this is the vapor pressure for saturated air at a particular temperature). We have \( T_m \) for our five elevations, and we will set \( \Lambda \) equal to 0.6 (that is, an average of 60% of the day is daylight).


Table 6.1. Forest and energy characteristics across the elevation gradient along the east side of the Sandia Mountains. Precipitation values were derived from a relationship between precipitation and elevation using precipitation values from Western Regional Climate Center stations, including Tijeras, Sandia Park, and Sandia Crest.

<table>
<thead>
<tr>
<th>Site</th>
<th>Elevation (m)</th>
<th>Forest Type</th>
<th>Average Precipitation = AET (mm/year)</th>
<th>e(T_m) (kPa)</th>
<th>T_m (°C)</th>
<th>Estimated PET (mm/year)</th>
<th>Water Deficit = PET - AET (mm/year)</th>
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</thead>
<tbody>
<tr>
<td>Canyon Estates TH</td>
<td>2,152</td>
<td>408</td>
<td>1.7</td>
<td>14.4</td>
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</tr>
<tr>
<td>Cienega TH</td>
<td>2,408</td>
<td>427</td>
<td>1.6</td>
<td>13.6</td>
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<tr>
<td>Tree Spring TH</td>
<td>2,756</td>
<td>453</td>
<td>1.22</td>
<td>9.5</td>
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<tr>
<td>10 K TH</td>
<td>3,280</td>
<td>490</td>
<td>0.96</td>
<td>6.4</td>
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<tr>
<td>Near the crest</td>
<td>3,465</td>
<td>500</td>
<td>0.87</td>
<td>5.3</td>
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</table>
Data sheet for forest community structure

Date: _____________  Observer(s): ____________________________________________________

Site name: ______________________
Elevation: ___________ (m)
Transect slope/aspect: ______° / ______°

<table>
<thead>
<tr>
<th>Relative Abundance</th>
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<td>Species</td>
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Site name: ______________________
Elevation: ___________ (m)
Transect slope/aspect: ______° / ______°

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Homework # 6 – Lab Report 1 (30 points)

You will write up a lab report covering this chapter's questions and analyses. The report is due on October 9th (Tuesday section) and 10th (Wednesday section). The goal here is to get you thinking about the whole package of a scientific report in as simple a way as possible. You are to write a short but complete report that tells the reader what your question was, how you answered it, and what the answer was.

What needs to be in the report:

1. **Introduction.** Introduce the broad topic of ecological explanations for the distribution of vegetation types. Narrow the focus to climatic influences on plant communities. In your own words describe the theory and patterns of plant communities relative to climate. Describe how your study relates to that theory. What specific questions are you asking? Generally, how are you going to answer them? Specify what needs to be shown to support or refute your hypothesis. Strategically, you want to pose a compelling question that is answerable by the results, thereby creating a meaningful storyline for the reader to follow.

2. **Methods.** Describe precisely what you did in sufficient detail to allow someone to repeat your study.

3. **Results.** Without any discussion or interpretation, say what you found. You must include the figures discussed in Sections 2 and 3 of the analysis methods above. The graphs must be produced in a spreadsheet program and each graph must have clearly labeled x- and y-axes and a figure legend (below the figure) that says what it is the reader is looking at. Describe the results in words and refer to them in the text. For example, you could say, “Temperature decreased with increasing elevation (Figure 1),” or “Ponderosa pine occurred at all elevations (Figure 2).” Say what you found as simply and directly as possible. As an author, your task is to guide the reader's attention to the key information. Some specific style requirements are 1) italicize scientific names but leave common names in regular type, 2) use the past tense, as you have already conducted the study, and 3) do not add additional tables of data or printouts of your spreadsheet.

4. **Discussion.** What is/are the answer(s) to your question(s)? Is it what you expected? If not, why not? Were the methods sufficient? Were there enough data? How does this study relate to the major studies? Was there something we did that limits what we can say from our results? What about our assumptions in calculating AET and PET? Do you have alternative interpretations that are consistent with your results?

5. **Literature cited.** Properly list the references cited in your text. This list should definitely include Stephenson (1990) and Hamon (1963). It should also include at least two other peer-reviewed journal articles that you found. Format your references using the examples in the Literature Cited of this chapter.
Grading key to the lab report on elevation, water balance, and vegetation

Use this key as a guide to ensure you have included the necessary components of the paper (30 points total).

Introduction (6 points)
- General opening to paper..........................................................1
- Define AET/PET...........................................................................2
- State hypothesis/question.............................................................1
- Errors and readability................................................................2

Methods (7 points)
- Explained how we got relative abundance......................................1
- Explained how we estimated AET..................................................1
- Explained how we estimated PET..................................................1
- Explained effort to reduce variability............................................1
- Errors and readability................................................................2

Results (9 points)
- Both figures included.................................................................2
- Legends good.............................................................................1
- Presented variation in tree species...............................................2
- Presented relationship between deficit, AET, and plant community...2
- Errors and readability................................................................2

Discussion (8 points)
- Discussed relationship between deficit, AET, and plant community....1
- Discussed variation in tree species...............................................1
- Two additional references............................................................2
- Critique of methods....................................................................2
- Errors and readability................................................................2