Multivariate Analysis

Lab Data and Background

Introduction

This document describes the data sets we will be exploring during the course of the semester. The data are part of a larger project aiming to compare forest pattern in montane systems in the Oregon Cascades, the Sierra Nevada of California, the White Mountains of New Hampshire, and the southern Appalachians in western North Carolina. The following sections describe the sampling protocols and define the variables (common to all sites) and also summarize the tree species and forests of the Sierra Nevada, specifically in the Kaweah Basin of Sequoia National Park.

Sampling Design

The samples are 20x20-m (0.04 ha) quadrats arranged in clusters of 3 or 4 plots, with the clusters themselves distributed along transects along elevation gradients (figure 1).

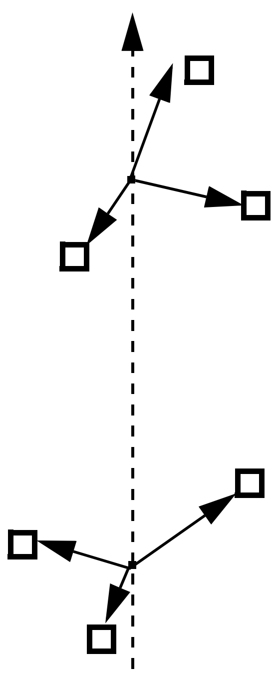

Figure 1. Schematic of sample plot locations as a cluster of 3 plots located at random distances and azimuths from a stratified center-point, along a bearing transect oriented to sample local gradients.

The exact arrangement of transects and number of plots per cluster varied somewhat over the three years of sampling (1997-1999). Each sample is intended to represent a homogeneous slope facet, so the plots are oriented on the slope with the baseline of the plot running across the slope and the left edge of the plot aligned in the direction of maximum slope. The lower-left corner of the plot was staked and its position recorded with a GPS unit.

Each plot was flagged into 4 quadrants for ease of measurement (figure 2). Within each plot, measurements were made on woody vegetation, topographic position, and soils.

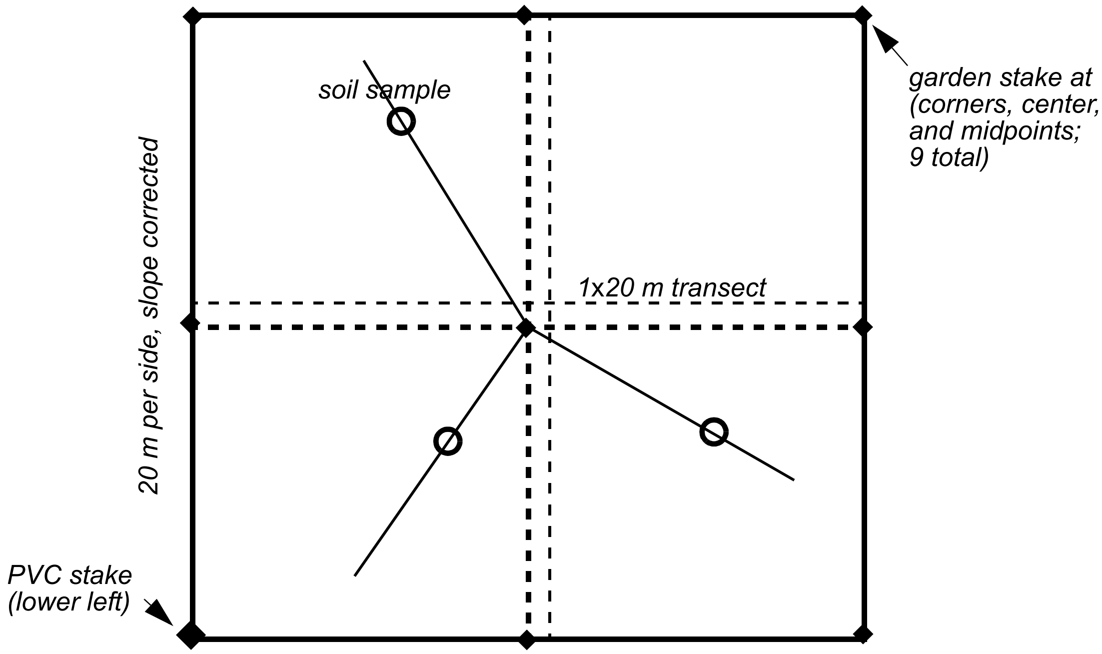

Figure 2. Sample plot orientation and layout of seedling transects. Uphill distances are slope corrected; horizontal baseline is parallel to slope. Transect radii are in random directions from plot center, with soil samples collected at a random distance along each transect.

Measured Variables

Vegetation Data

Each tree with a diameter at breast height (dbh, 1.37 m) greater than 2.5 cm was tallied and its dbh and species recorded. Saplings (trees taller than 1.37 m but with dbh less than 2.5 cm) were counted by species. Seedlings were tallied by species, in 3 height classes (0-10, 10-50, 50-137 cm), in 2 orthogonal 1x20-m transects across the plot.

Tree diameters were converted to basal area (cross-sectional area at breast height) and basal area was summed over each species to yield a measure of species importance or dominance.

Topographic Variables

On each plot, slope azimuth (degrees, N=0=360^o) was recorded in the average upslope direction across the plot. Degrees slope was recorded in this same direction. Slope was also recorded in each of the 4 cardinal directions, in order to produce an estimate of the slope surface curvature (*e.g.,* convex or concave) as suggested by McNab (1989). Elevation (m) was derived from the GPS measurements.

Soils Variables

In each plot, 3 transect-radii were established in random directions from plot center. Soil depth was measured with a tile probe at points spaced 1-m apart along each transect, for a total of 30 points per plot. Depth was recorded only to a maximum of 100 cm, to represent the rooting zone of trees. These values were averaged for the plot; the standard deviation of these 30 depths was also computed.

At a random distance along each transect, soil samples were collected. An area 0.5x0.5 m was cleared of litter and a soil probe was used to collect 4-5 samples from the top 20 cm of mineral soil. These samples were composited in the field into plastic bags. The samples were air-dried and then sealed and transported to the lab for processing.

In the laboratory, soil samples were passed through a 2-mm screen. Exchangeable nutrient cations (Ca, Mg, and K) and acidity were extracted with 1mol/L ammonium acetate (pH 7) and 1 mol/L KCl solutions, respectively (Thomas 1982, Thomas and Hargrove 1984). The exchangeable cations provided estimates for effective cation exchange capacity (ECEC, the CEC at soil pH) and base saturation (the fraction of ECEC that was balanced by nutrient cations). Soil subsamples were also pulverized and analyzed for total carbon and nitrogen by dry combustion with a Perkin Elmer CHNS analyzer. Soil pH was analyzed in a soil suspension with 0.01 mol/L $CaCl_2$, and extractable phosphorus was determined in a dilute nitric and hydroflouric acid extraction, often known as the Mehlich III (Mehlich 1978). Soil texture analysis used dispersal in Calgon followed by sedimentation that was measured with a pipette method (Sheldrick and Wang 1993).

For most variables, these were estimated separately for the 3 replicate samples per plot and then averaged. Because it required larger samples, textural analysis was performed on a single larger sample composited from equal volumes from each of the replicates.

Sample Distribution in Sequoia National Park

Over the three years of study a total of 99 sample quadrats were collected in the Kaweah Basin. The plots range from ~1500 to 3000 m in elevation and span a wide range of slopes and aspects.

A total of 17 tree species were recorded on the sample plots (table 1). These varied considerably in their environmental distribution as well as in their relative abundance (table 2).

The primary data matrix for this class is provided as a spreadsheet that tallies basal area (m^2/ha) by species for each of the sample plots. These data are provided as file *species.xls*. For convenience, the data in Table 2 are provided as *spp_summary.xls.* The ancillary environmental data (table 3) are provided as *env21.xls*. Note that for some analyses the environmental data may need to be edited to remove linear dependencies (*e.g.,* C:N on C and N, ECEC on cations and acidity, and silt fraction on clay plus sand).

For more information on vegetation pattern in the Sierra Nevada, see the papers by Vankat and Major (1978), Vankat (1982), and Stephenson (1998). The climatic and soil moisture gradient in the Park is described by Urban *et al.* (2000, 2002).

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Table 1. Species names and mnemonic codes for tree species recorded in samples.

Code	**Scientific Name**	**Common Name**
ABCO	*Abies concolor*	White fir
ABMA	*Abies magnifica*	Red fir
ACMA	*Acer macrophyllum*	Bigleaf maple
ARVI	*Arctostaphylos viscida*	Whiteleaf manzanita
CADE	*Calocedrus decurrens*	Incense cedar
CEIN	*Ceanothus integerrimus*	Deer brush
CONU	*Cornus nuttallii*	Pacific dogwood
PICO	*Pinus contorta*	Lodgepole pine
PIJE	*Pinus jeffreyii*	Jeffrey pine
PILA	*Pinus lambertiana*	Sugar pine
PIMO	*Pinus monticola*	Western white pine
PIPO	*Pinus ponderosa*	Ponderosa pine
QUCH	*Quercus chrysolepis*	Canyon live oak
QUKE	*Quercus kelloggii*	California black oak
SEGI	*Sequoiadendron giganteum*	Giant sequoia
TOCA	*Torreya californica*	California torreya
UMCA	*Umbellularia californica*	California bay

Table 2. Species density (stems/ha), relative density (%), basal area (m^2/ha), relative basal area (%), importance value 200[1] (%), and frequency (%) for trees recorded in samples.

Species	Density	Relative Density	Basal Area	Relative BA	IV_{200}	Freq.
ABCO	221.0	36.7	18.1	20.8	28.79	67.7
ABMA	95.2	15.8	13.1	15.0	15.43	34.3
ACMA	1.5	0.3	0.0	0.0	0.13	1.0
ARVI	6.1	1.0	0.0	0.0	0.51	2.0
CADE	79.0	13.1	4.3	4.9	9.02	37.4
CEIN	15.2	2.5	0.0	0.0	1.27	4.0
CONU	16.2	2.7	0.1	0.1	1.37	8.1
PICO	18.7	3.1	3.0	3.5	3.30	6.1
PIJE	28.5	4.7	5.4	6.2	5.47	15.2
PILA	39.6	6.6	7.1	8.2	7.38	46.5
PIMO	24.2	4.0	9.7	11.2	7.62	14.1
PIPO	16.9	2.8	2.5	2.9	2.86	12.1
QUCH	3.8	0.6	0.0	0.0	0.32	3.0
QUKE	30.3	5.0	1.5	1.7	3.36	24.2
SEGI	2.3	0.4	22.1	25.5	12.92	6.1
TOCA	1.3	0.2	0.0	0.0	0.11	2.0
UMCA	1.5	0.3	0.0	0.0	0.13	1.0

[1] IV_{200} is the average of relative density and relative basal area.

Table 3. Names and definitions of environmental variables measured on sample plots.

Variable	Description	Note
Elevation	Elevation (m)	from GPS
Slope	Maximum slope (^{o})	
TAspect	Transformed Aspect [1]	-1 x COS(45-Aspect)
TSI	Terrain Shape Index [2]	<1: dome; >1: cove
xDepth	Mean soil depth (cm)	to maximum of 100 cm; from 30 measurements
sDepth	standard deviation of depth	
pH	pH	
C	Soil Carbon (%)	total carbon
N	Nitrogen (%)	total nitrogen
C:N	Carbon:Nitrogen ratio	
P	Phosphorus (μg/g)	total exchangeable
Ca	Calcium (cmol(+)/kg)	
Mg	Magnesium (cmol(+)/kg)	
K	Potassium (cmol(+)/kg)	
Ac	Acidity (cmol(+)/kg)	total exchangeable
ECEC	Effective Cation Exchange Capacity	Σ(Ca,Mg,K,Ac)
BS	Base Saturation (%)	Σ(Ca,Mg,K)/ECEC
xLitter	Mean Litter Depth (cm)	depth to mineral soil
Clay	Clay (%)	particles < 2 μm
Silt	Silt (%) [3]	particles 2-50 μm
Sand	Sand (%)	particles >50 μm

[1] Aspect transformation based on Beers (1966), modified so that SW-facing slopes have value 1.0 and NE slopes have value -1.0. SW is direction of maximum radiation load.

[2] TSI is the mean slope (^{o}) from measurements taken in 4 cardinal directions from plot center (after McNab 1989).

[3] Percent silt is computed as 100-(Clay+Sand).