

How an Environment's Moisture Heterogeneity Affects a Community's Traits

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Abstract

A plant's functional traits, which aid with survival, growth, and reproduction, are shaped by different abiotic and evolutionary elements. Some communities have a larger degree of variation in their functional traits, and this study aimed to see if this variation is directly linked to the level of environmental heterogeneity. This was accomplished by looking at differing traits of plant communities at 5 different sites. The analyzed traits were SLA, LDMC, and plant height. These traits were plotted against the environmental variation (as determined by soil moisture or microclimate) to determine if there was a correlation between the two. The data indicate that there is a positive correlation between the log(sd of LDMC) and the mean sd of soil moisture, but there is no correlation between the log(sd of height) or log(sd of SLA) and the mean sd of soil moisture. This demonstrates that, in some cases, a wider range of functional diversity can be driven by greater environmental heterogeneity.

Background

An organism's niche and its functional traits are closely intertwined (Kraft et al. 2008). A plant's functional traits vary due to a multitude of different evolutionary and environmental factors; its niche can be thought of as the environment in which it functions and affects (Diaz et al. 1998). These traits serve to reflect the plant's ecological strategies (Reich et al. 2003). But, because of the multitude of different elements that form a plant's traits and environment—a causal model between the two is difficult to establish. One way that science has tried to accomplish this is by looking at how the organism's niche and functional traits help it to fit within its environment. But does the

plant have its functional traits so it can be successful within its environment, or does its function traits help to shape its environment? While this question has not been answered, it is know that there is definitely some relationship between the two.

An environmental filter is the determining factor of what environment a species can properly function in, thus so, it is pivotal in community assembly (Mayfield et al. 2009). As environmental variance expands, so does the range of the environmental filters—as there are certain species with ecological strategies that are needed to enter a community (Turlure et al. 2009), However, only a few studies have been conducted that look at the correlations between functional traits and environmental heterogeneity (Kröber et al. 2012). Are these larger environmental filters associated with wider community trait variances? Answering this question would determine is environmental filters are the driving force behind functional diversity. This study aims to find a linkage between trait variance and environmental variance in alpine environments. It plans to do this by looking at the functional traits of different organisms in plots with varying levels of environmental heterogeneity.

Research Question

How do varying levels of environmental heterogeneity affect the variation of functional traits?

Hypothesis

During the experiment there are three possible scenarios.

- 1) The data could indicate that there is a positive relationship between heterogeneity and functional traits. This situation is demonstrated in Figure 1.
- 2) The data could show that there is a negative relationship between heterogeneity and function traits. This concept is shown in Figure 2.
- 3) It is possible that the data shows that there is no relationship between heterogeneity and function traits. This concept is shown in Figure 3.

One of the traits that will be measured is plant height, which is associated with competitive abilities and reproductive size (Pérez-Harguindeguy et al. 2013). It will be recorded by measuring from the first portion of the above ground plant to its highest point. The second measured trait is Specific Leaf Area. SLA is an important trait as it is positively related to relative growth rate and mass-based light saturated photosynthetic rate (Pérez-Harguindeguy et al. 2013). Another measured trait will be Leaf Dry Matter Content, which can be used to determine plant resource acquisition (Pérez-Harguindeguy et al. 2013). Two environmental variables that will be measured are air temperature, which shows the temperature in which the plant is existing, and Soil Moisture Content, which is negatively correlated with root length and positively correlated with canopy height (Pérez-Harguindeguy et al. 2013)

Methods

Field Methods

I established five sites along an elevation gradient (all within meadows). These sites were located at: the Washington Gulch Road Site, Painter Boy, Pfeiler, Cinnamon, and Ben's

Alpine Site (Figure 1). At each of the five existing sites, I created a 40m x 10m rectangular plot—that was selected randomly. Within each of these plots, 5 different transects were made, each spaced 10 meters away from each other. Within each transect, I placed 9 DS1921G iButtons (Maxim integrated Products Inc.) in the shape of a straight line. These buttons were placed at the 0, 2.5, 4, 4.75, 5, 5.25, 6, 7.5, and 10 meter marks. These iButtons measured air temperature at the surface of the soil. These iButtons were wrapped with duct tape, then a nail was used to anchor it into the ground—the duct tape protected the sensitive software from the elements and the nail ensured that the sensor would not shift due to rain or wind.

At each site I identified all plants within the plot to determine its richness. Then on various days, the soil moisture content and soil temperatures at each iButton were recorded using a TDR Moisture Sensor Trime-Pico (IMKO), which determined the amount of moisture in the terrestrial environment. To do this, the TDR was placed (as close as the terrestrial environment allowed) into the soil next to each iButton at a 3cm depth, and took a reading. The probe data was only taken at least 12 hours after rainfall and over 48 hours past a previous measurement of the site. This data was used to determine site heterogeneity.

Lab Analysis

The soil and moisture data required no lab analysis, as no samples were taken. But the Leaf Dry Matter Content and Specific Leaf Area needed to be calculated. SLA was found by scanning the leaves to find their surface area, then dividing it by the leaves' dry mass.

LDMC was found by calculating the leaves' wet weight, drying the leaves for three days, and then calculating their dry weights.

Statistical Analysis

Once the soil moisture and temperature were measured, I organized the data into Microsoft Excel, which I then transferred to R, where I used RConsole and RStudio to calculate the 4 different dates' mean soil moisture sd at each site's transect. I then analyzed the relationship between sd_SM and sd_AT across plots as a linear regression. However, due to the sporadic nature of the results, the data needed to be log-transformed to get all of the points closer together—in order to get a proper linear regression. This gave me both an R^2 value and the slope of the relationship between environmental and trait heterogeneity, allowing me to test my hypothesis.

Results

The data showed that the range of variation in soil moisture for the sites were: Road from 3.10-33.6%, Baldy from 5.11-22.80%, Pfeiler from 8.06-38.50%, Painter Boy from 5.44-35.25% (Figure 5). The site with the largest sd of soil moisture was Baldy with 3.98%, and the largest was Cinnamon with 6.62%.

I found no significant relationship between the log(sd of height) and the mean sd of soil moisture ($p=0.22$; $F_{1,23}=1.58$, $R^2=0.023$)(Figure 6). The lack of a linear relationship means that the first and second hypotheses were rejected.

I next found that there was not a significant relationship between the log(sd of SLA) and the mean sd of soil moisture ($p= 0.26$; $F_{1,23}=1.31$, $R^2= 0.013$)(Figure 7). This means that the results reject the first and second hypotheses.

I did find a significantly positive relationship between the log(sd of LDMC) and the mean sd of soil moisture ($p= 0.0011$; $F_{1,23}=13.86$, $R^2= 0.35$) (Figure 8). This result rejects Hypothesis 2 and 3 and is consistent with Hypothesis 1.

Discussion

The above results indicate that both the log of SLA and height had no correlation with soil moisture. These data supports the third hypothesis. However these results could also be due to the fact that there was not a large enough sample size to detect a true effect, or because there data contained too many outliers.

The results also indicated that the log(sd of LDMC) positively correlated with the mean sd of soil moisture. Therefore, this relationship was consistent with Hypothesis 1. This potentially could be because LDMC is directly related to the plant's water content. Thus, the wetter environments would have plants with higher water content, and the drier environments would have plants with lower water content—aligning itself with the soil

moisture. This relationship between means would then lead to a similar relationship between standard deviations.

Another possible explanation from the plant height's lack of a correlation is because height has less to do with moisture and more to do with exposure to sunlight and temperature (Pérez-Harguindeguy et al. 2013). Therefore, this trait could have a positive correlation to an environmental factor other than soil moisture—temperature. Similar to height, another reason SLA had no correlation is because may be dictated by photosynthetic material and nitrogen content, not soil moisture (Pérez-Harguindeguy et al. 2013). Thus, if these abiotic conditions had been taken into effect, a correlation could have been observed. However, other data that is still being collected, such as the information stored on the iButtons, will be used to analyze correlation between soil moisture and traits.

The data found in this study differs from some previously published articles. A 2012 study conducted on montane trees in South-East Asia found no correlation between soil moisture and mean LDMC (Moles et al. 2014). Furthermore, a 2014 meta-analysis study found a positive relationship between mean plant height and mean annual precipitation (a proxy for soil moisture), which was contrary to this study's findings (Kröber et al. 2012). However it is possible that a relationship exists between variances even if none exists between means. However, there are many differences between the studies, such as location, organisms studied, and time spent collecting data that could have caused the discrepancies in the results.

This experiment could be improved by having a larger sample sizes that contained more transects and iButtons, but it could have also been improved by have sample sites it a variety of different valleys, or higher sample sizes. It could also be improved by looking at more traits, such as seed mass or SDMC.

I investigated the role environmental filters play in controlling the environment that a species inhabits. This experiment showed that a larger environmental filter, such as a greater range of soil moisture, allows the organisms to have a more diverse span of Leaf Dry Matter Content functional trait values. This is due to the fact that the larger filter creates a multitude of environments, all within the plant community, that different species of organisms are able to be successful in. Thus, higher functional diversity may sometimes be driven by larger environmental filters and more environmental heterogeneity.

Figures

Figure 1

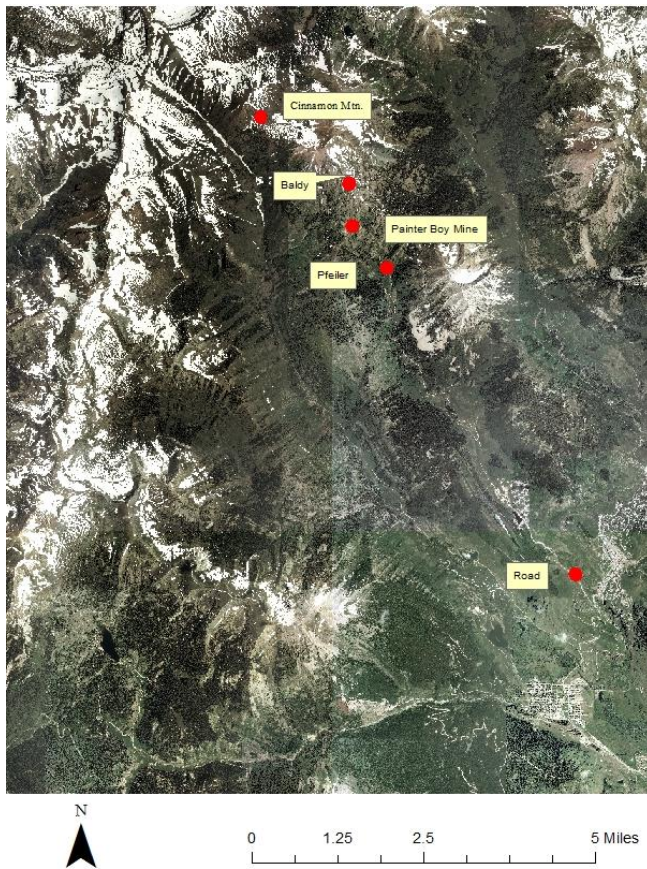


Figure 1. An aerial view of the Washington Gulch sites ($38^{\circ} 57' \text{ N}$ / $107^{\circ} 2' \text{ W}$).

Figure 2

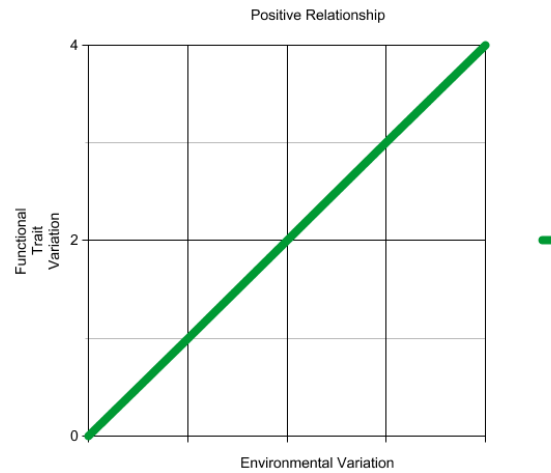


Figure 2. Hypothesis 1: a positive correlation between the x-axis (environmental variation) and the y-axis (functional trait variation).

Figure 3

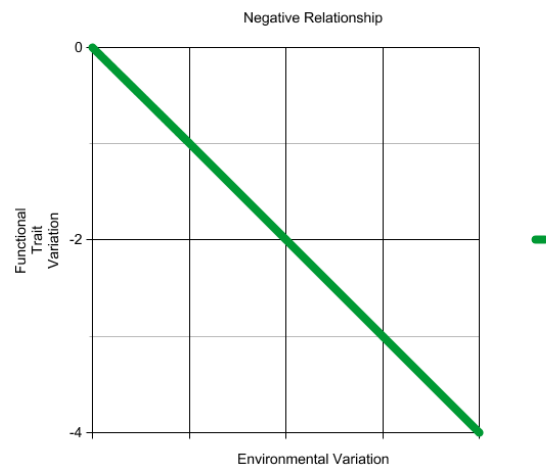


Figure 3: Hypothesis 2: a negative correlation between the x-axis (environmental variation) and the y-axis (functional trait variation).

Figure 4

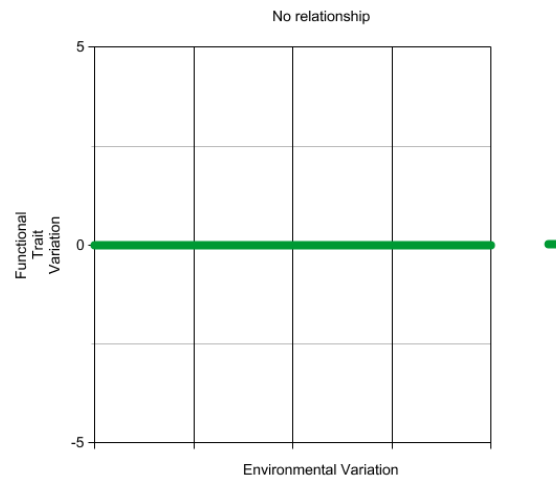


Figure 4: Hypothesis 3: no correlation between the x-axis (environmental variation) and the y-axis (functional trait variation).

Figure 5

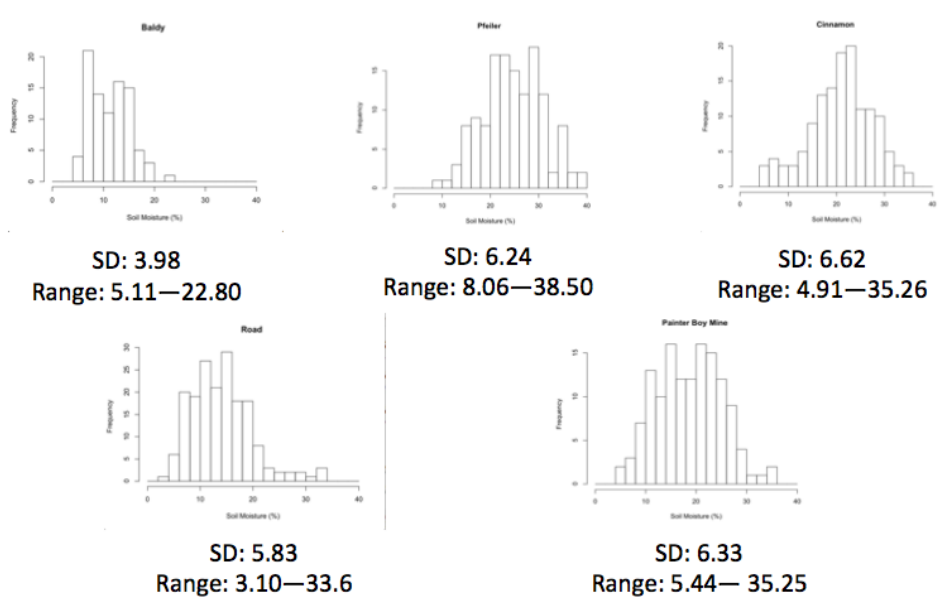


Figure 5. Histograms of the soil moisture sd % at each site, as well as each site's sd and range for moisture %.

Figure 6

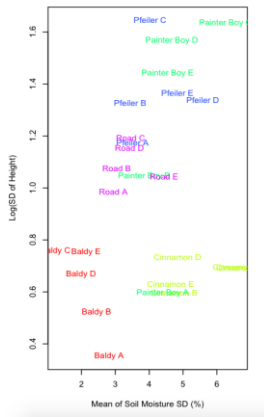


Figure 6. Relationship between the mean soil moisture sd %, which represents the x-axis, and the log(sd of plant height), which represents the y-axis. Each point represents a different transect at each site.

Figure 7

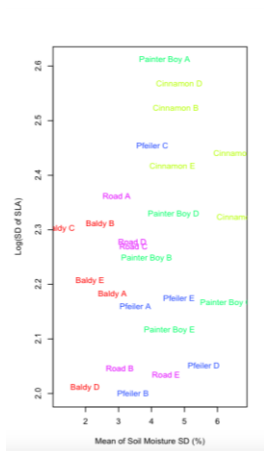


Figure 7 Relationship between the mean soil moisture sd %, which represents the x-axis, and the log(sd of SLA), which represents the y-axis. Each point represents a different transect at each site.

Figure 8

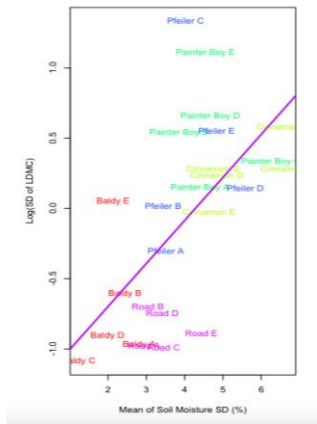


Figure 8 shows the positive relationship between the mean soil moisture sd %, which represents the x-axis, and the log(sd of LDMC), which represents the y-axis. Each point represents a different transect at each site, and the line represents the data's overall trend.

Literature Cited

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