The Effects of Changes in Soil Moisture on the Biodiversity of Herbaceous Plants

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Introduction

Biodiversity is an important aspect of scientific research at the moment, because climate change and anthropogenic activity has severely impacted the planet. Biodiversity has been defined multiple ways in scientific literature (Harper et al. 1994), so finding the 'right' way to measure it can be difficult. Understanding what factors influence biodiversity is important in improving our knowledge of ecology. It has been shown that diversity is a function of nutrient supply (Cowling et al. 1996), and there are multiple examples in the literature that looks at potential mechanisms for changes in diversity.

One of the abiotic factors that has been researched many times is soil moisture, or related variables such as the water table. Water is a vital part of plant health, so it is understandable why it has been chosen so many times to be studied. Without water, plants are unable to photosynthesize or respire, and they lose cell turgidity which leads to wilting and eventual death. Therefore, understanding the effects of soil moisture change will lead to an improved knowledge of plant ecology.

Previously, it was shown that soil moisture and temperature had a positive effect on bacterial biodiversity (Papatheodorou et al. 2004). And while bacteria and plants are dissimilar, they both rely on water for survival. A study found that plant diversity was determined based on a measure of soil (Olff and Ritchie 1998). Furthermore, it was found that there was a significant positive correlation between soil moisture and plant biodiversity (Xu et al. 2015), and that the distribution of plants was based on water availability (García‐Baquero et al. 2016). However, many other studies show different effects of soil moisture. For example, it was determined that soil moisture did not have a significant effect on diversity unless it was part of an interaction with another variable (Xiong et al. 2003), such as an addition of nitrogen to the research site (Smith et al. 2016). Other researchers have even suggested that due to climate change's impact on plant diversity, some plants that existed as few as five years ago may now be extinct due to climate change's induced prevalence of drought (Thuiller and Lavorel n.d.).

For the purpose of this study, biodiversity is being studied based on species abundance and evenness (Harper et al. 1994). Diversity is not just based on how many individuals there are, but what species they are (Peng et al. 2018).

Based on the information already present in the literature, I decided to further investigate if soil moisture had a direct effect on plant biodiversity, as there are conflicting conclusions in scientific literature on what exactly the role of soil moisture is on plant biodiversity. Because of these varying results, it is important to do more research to obtain a better understanding of how abiotic factors influence diversity. For the purpose of this study, biodiversity is being studied based on species abundance and evenness (Harper et al. 1994). Diversity is not just based on how many individuals there are, but what species they are (Peng et al. 2018). And based on the previous literature, I believe that if there is a higher soil moisture, then there will be higher plant biodiversity because a higher soil moisture will give plants increased access to water which will decrease competition.

Methods

Study Site

This study was conducted at Pandapas Pond (coordinates: 37.281944, -80.46917), which is part of Jefferson National Forest, and it is located near the Virginia Tech campus. The Pandapas area is a palustrine system that has a manmade pond surrounded by mountains. There are multiple streams in the area surrounding Pandapas Pond which made this an ideal location. Having multiple streams ensured that a possible confounding variable at what stream site would not affect the overall results. For this study, one of the streams marked on the map was not used, as one side has a wide trail right next to it, and the other side was too steep to be able to obtain data. Therefore, two of the transects were established along the same stream, but with distance between them.

Study Design

This study is an observational study, and variables being measured are soil moisture, soil pH, light exposure, and the abundance of each species present along the transect. Before beginning any data collection, each stream was scoped out to determine how long the transects could be, and the longest the transect could be was 10 meters. The steepness of some of the areas around the streams combined with dense leaf coverings made it impossible and unsafe to go make the transect longer than 10 meters. To begin data collection, the first transect was mapped out using the transect measuring tape that was held in place with a stake. Then, flags were placed along the tape at the 2, 4, 6, 8, and 10 meter locations. A smaller tape measure was then used to measure 0.5 meters away from the flag along the transect in both directions, and 1 meter away from the flag perpendicular to the transect in both directions. This created a 2 meter by 1 meter plot for data collection. This process was repeated in four other locations for a total of five transects.

In each plot, the 3 way soil meter that measures soil moisture, pH, and light intensity (manufacturer: Executive Deals, ASIN: B07D41LH88)) was used at the center of the plot (where the original flag was placed) to measure soil moisture, soil pH, and light availability. After obtaining this data, a reference database was created, and pictures were taken of all of the species present in the plot, and a count of how many present was taken. If there was already a picture of a species from a previous plot, then a new picture was not taken. For this study, the phone app snapchat was used to take the pictures because it allows the user to write on the picture, and the picture can then be saved to the phone's camera roll. As an example of how each species was labelled, the first species (species A) was labelled as SpecA on the picture. Abundance was only measured for herbaceous species to simplify data collection.

The control variables in this study are soil pH and light intensity. Soil pH varied slightly among plots, and light intensity varied between transects, but were often similar within a transect.

Data Analysis

To analyze the data, version 1.2.5001 of R was used, and the packages used were vegan and lme4. Vegan was used to calculate the Shannon Diversity values of each plot, and lme4 was used to calculate the statistics. To test the hypothesis that increasing soil moisture leads to an increase in plant diversity, I used a linear mixed model with biodiversity as the response

variable, soil moisture, distance from the stream, and their interaction as fixed effects, and transect as a random effect. To test the significance of fixed effects, I used likelihood ratio tests comparing the model to simplified versions with single terms deleted. Based on a significant interaction between soil moisture and distance from the stream (see results), I also examined the effect of soil moisture separately at each distance from the stream.

Results

Effect of Stream Distance on Soil Moisture

When determining how the study would be conducted, it was assumed that soil moisture would decrease as distance from the stream increased. This was confirmed in my study as there was a significant, negative relationship between the distance from a stream and the soil moisture ($t = 4.143$, $p=3.42x10^{-05}$, Fig 1).

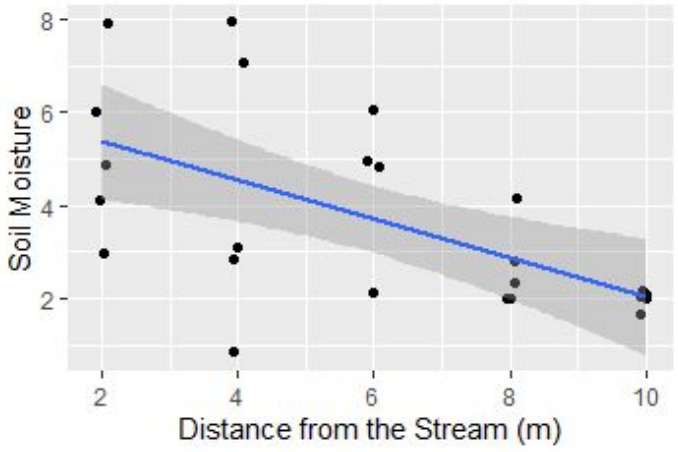

Figure 1: The effect of distance away from a stream on the soil moisture across all Pandapas Pond transects.

Effect of Soil Moisture and Distance from Stream on Diversity

Overall, there was not a significant relationship between soil moisture and diversity values ($X^2=0.68$, $p=0.41$, fig 2), and there was not a significant relationship between stream distance and diversity ($X^2=1.53$, $p=0.22$, fig 3). However, diversity was affected by the interaction between stream distance and soil moisture ($X^2=8.67$, $p=0.003$, Fig 2). Additionally, when looking at the effects of soil moisture on diversity separate for each distance from the stream, at two of the intermediate distances, there is a significant relationship between soil moisture and diversity. There is a significant negative relationship at distance 6 ($t=-8.25$, $p=0.014$, fig 4.D6) and at distance 8 ($t=-8.54$, $p=0.0033$, fig 4.D8). There was not a significant relationship at distance 2 ($t=1.097$, $p=0.35$, fig 4.D2), distance 4 ($t=-0.817$, $p=0.47$, fig 4.D4), or distance 10 ($t=-0.205$, $p=0.85$, fig 4.D10).

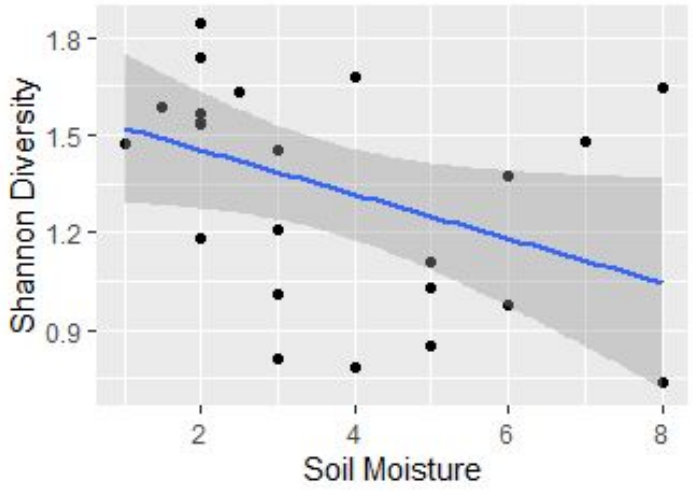

Figure 2: The effect of soil moisture on Shannon Diversity across all transects.

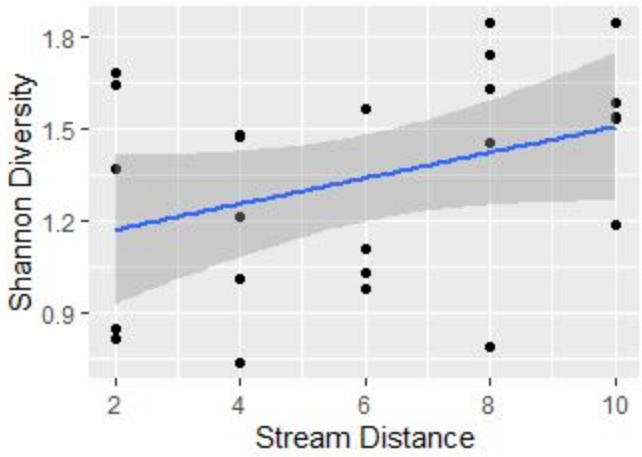

Figure 3: The effect of Stream distance on Shannon Diversity across all transects

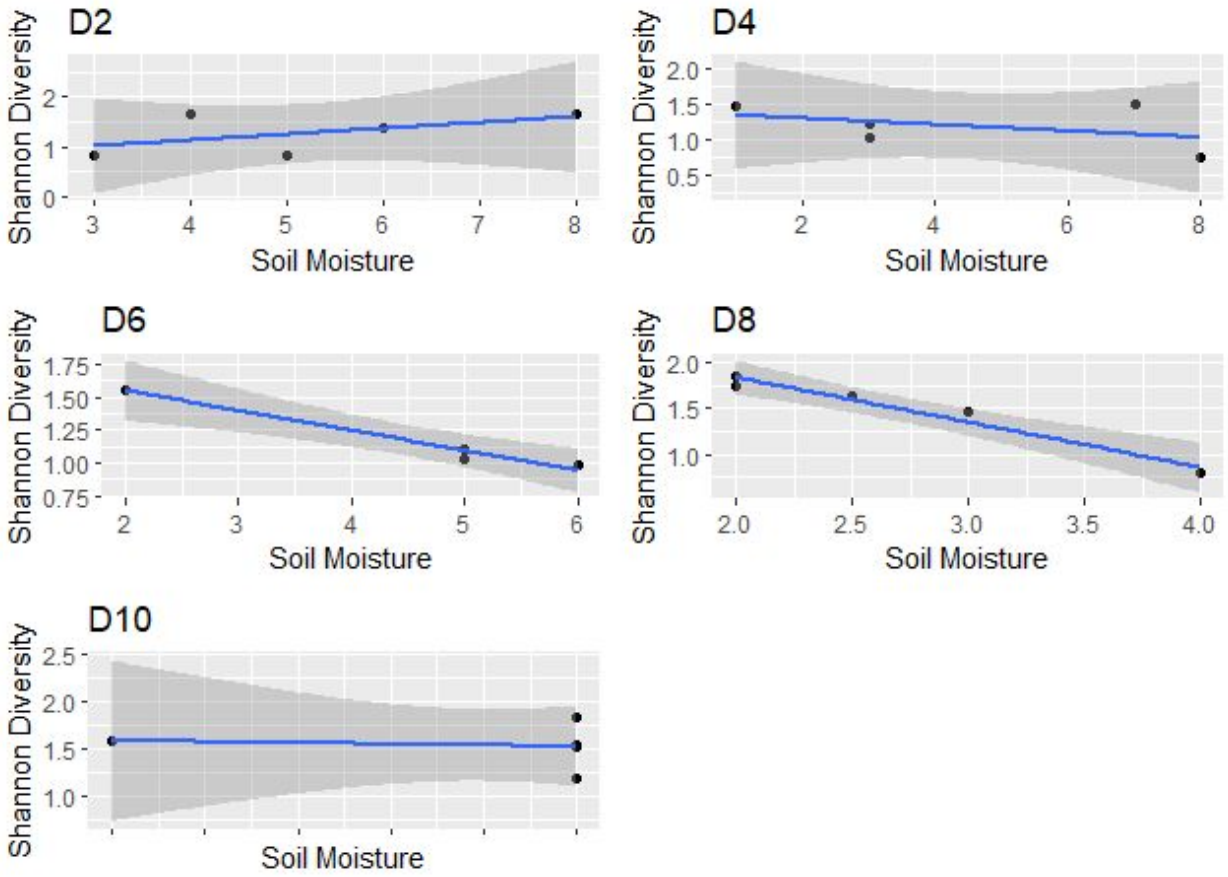

Figure 4: The effect of soil moisture on Shannon Diversity values at each location along the transect. The D refers to distance, and each number refers to how many meters away from the stream the data is from (D2 is 2 meters away from the stream).

Effect of Soil Moisture on Total Species Abundance

There was no significant effect of soil moisture (X^2=0.11 p=0.74), stream distance (X^2=1.71m p=0.19), or the interaction between the two (X^2=1.54, p=0.22) on the total species abundance overall or at each individual distance. Thus, the total number of species present is correlated neither with the soil moisture nor the distance from the stream.

Discussion

The purpose of this study was to determine if there was an effect of soil moisture on plant biodiversity, and it was hypothesized that soil moisture would have a positive effect on plant biodiversity due to the higher access to water that higher soil moisture would provide. The results showed that overall soil moisture does not have an effect on diversity. However, at intermediate distances from the stream, soil moisture had a negative effect on plant diversity.

The data did not support the hypothesis. Either there was no relationship between soil moisture and plant diversity, or there was a negative relationship between soil moisture and plant diversity. Because no other study had similar results to the ones found in this study, there is no possible mechanism that can be found in literature. Possible explanations are based on speculation. One possible reason for these results is that the densest perceived leaf covering

occurred at the 6 and 8 meter distances. If there is a higher amount of leaf cover, then there is going to be less diversity because the leaves block sunlight from any low ground plants which reduces diversity by killing off plants. But, the leaf cover could contribute to increased soil moisture because the water that evaporates out gets condensed underneath the leaves which keeps the water in the soil.

Previous studies found either no effect or a positive effect of soil moisture on plant diversity. One study found no significant relationship between soil moisture and plant diversity when soil moisture was the only variable being tested, but found that soil moisture impacted diversity in concert with other variables (Xiong et al. 2003). However, studies that found a significant effect, only ever found a positive one, such as a study that looked at the water table and soil moisture, and they found a strong positive interaction between soil moisture and plant diversity (Xu et al. 2015). A possible explanation for this deviation from the literature could be that leaf covering is a possible confounding variable. Therefore, further research looking at how leaf cover affects soil moisture and diversity is needed to determine if that is what happened.

Possible caveats to the results found in this study are drought and dense leaf coverings. Data was collected after a short period of drought that could have killed plants that would have been present if there had been more rain. Additionally, there were multiple places that had extremely thick leaf coverings that could have killed or prevented the growth of some plants. Additionally, data was collected in the fall, so some annuals may have already died that would have been there had data been collected in the spring or summer. Additionally, this study was limited by only having data collected at five transects at one site. Having a greater number of longer transects would have increased the accuracy of the data.

In the future, studies should increase the size and number of transects. Additionally, it would be interesting to see if the type of environment has an effect, so research should be conducted in different biomes. Because this study only looked specifically at herbaceous species, there should also be future studies that look at other types of plants, such as trees, as well as studies that utilize all types of plants. Furthermore because there may be differences due to the type of plant being studied, separating the plants into different categories and comparing them should be considered.

It is important to understand how soil moisture impacts plant diversity, because climate change will change the soil moisture due to increased drought. As drought becomes more common, it is important for scientists to have a concept of expected ecological changes. Having a better understanding of how an ecosystem is affected by changes in soil moisture will prepare us for when soil moisture decreases. Due to the importance of plants in ecosystems, it is vital that there is data that will lead to the proper conservation management.

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