

Does it stay or does it go: exploring seasonal influences on nutrients across topography in a
Colorado mountain watershed

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Full-time Independent Research

Summer 2017

Rocky Mountain Biological Laboratory

Abstract

Climate change is a current issue that impacts ecosystems and the natural processes within them. Through the variance of factors such as, temperature, precipitation and hydrology due to climate change key processes such as nutrient cycling are affected. This study focused on the movement of nitrogen in a Colorado mountain watershed. Through the measurement of various forms of nitrogen, i.e. nitrate and ammonium (NH_4^+ & NO_3^-) which are available to aid plant growth, found throughout the cycle and potential effects of climate change can be realized. Nitrogen amounts were compared with NDVI data, soil water content, near infrared photography and microclimate data to find any correlations that affect the nitrogen cycle and the amount of available nitrogen in the ecosystem. This study looked at a different way to view the Colorado mountain watershed. Over time NDVI values changed at both sites (Lower Montane and Lower Sub-Alpine). How NDVI changes over time varies and depends on the site specific conditions.

Introduction

Climate varies annually which drives many factors such as temperature, soil conditions, hydrology and nutrients (Sundqvist et al., 2013). These factors affect ecosystems and the interactions within them especially natural processes. This is becoming more of an issue in the wake of climate change which is causing varying temperatures, decreased ice, changing weather events and increased occurrence of non-native species due to altered site conditions (Walther et al., 2002). The study of these different factors across elevation gradients can yield insight into the effects of climate change on different ecosystems (Sundqvist et al., 2013). Plants, soil, hydrology and microbial interactions drive how nutrients are cycled through an ecosystem

specifically how they enter, are used and lost (Bohlen et al., 2001). Nutrient cycling is a key process in ecosystems and must be considered in the wake of changing environments.

Changing environments drive changing temperatures, precipitation and other factors that impact nutrient cycling. For example, as mean annual temperature decreases so do nitrogen cycling rates which causes plants to switch from inorganic to organic forms of nitrogen (Averill & Finzi, 2011). Nutrients are essential to the environment and its processes. Key elements for life are carbon, hydrogen, nitrogen, oxygen, phosphorous and sulfur. This study focused on the nutrient nitrogen, its different forms that it takes in the nitrogen cycle primarily ammonium and nitrate (NH_4^+ & NO_3^-) and how it moves through a Colorado mountain watershed. Nutrients can impact the environment by being present or absent. Without nutrients plants are unable to grow as successfully. Nutrients can also be transported, usually through surface or groundwater systems, to impact other ecosystems so, they are absent from their original ecosystem and present in another that is normally nutrient limited. An example of this is eutrophication of marine systems as nitrogen is a key limiting nutrient. The excess nitrogen, that becomes absent in one system and present in another, causes a rapid increase of algal populations which can lead to anoxic conditions that causes aerobic organisms, e.g. fish, to die off (Costanzo et al., 2001). The presence of nitrogen in a system provides the source for the interactions which form the nitrogen cycle, ammonification, nitrification and denitrification. An area's microclimate drives the nitrogen cycle. The microclimate, temperature, precipitation, soil moisture content and relative humidity affect how nitrogen moves through a system (Averill & Finzi, 2011). Communities and ecosystems respond similarly across a varying gradient due to similar factors that are influencing them (Sundqvist et al., 2013). At the same time communities and species

also respond differently because of other factors that change with elevation besides varying temperatures (Sundqvist et al., 2013).

Due to many factors influencing ecosystems it becomes difficult to measure natural processes such as nitrogen mineralization, which is an important environmental process (Duran et al., 2012). Methods to measure nitrogen mineralization and other types vary depending on site specific conditions but, by taking these conditions into account the methods can yield viable quantitative results over short or long time spans (Duran et al., 2012, Khanna & Raison, 2012).

Nitrogen changes forms from atmospheric nitrogen (N_2) as it goes through the nitrogen cycle into ones that can be taken up and used by plants (NH_4^+ & NO_3^-). Nitrogen can also be indirectly influenced by the changing environment because as temperature changes it can cause the timing of snowmelt to vary. The timing of snowmelt drives plants through their life cycle, i.e. when they sprout, flower or senesce (Steltzer et al., 2009). As the plant's life cycle shifts, e.g. into an earlier growing cycle or a later senescence the timing of nitrogen uptake can be influenced (Rayes-Fox et al., 2014). In the Colorado alpine forest range topography influences snowpack accumulation and indirectly soil water content, growing season length and the variation of plant communities and nutrients indirectly (Fisk et al., 1998). A possible relationship between plants and the nitrogen is that nitrogen cycling happened more frequently in the summer, during many plants growing season, than in the spring or fall (Bohlen et al., 2001). As the plants enter their life cycle they need nutrients and water to grow. So, nutrient uptake increases during the plants germination to flowering phase and decreases as the plant begins to senesce and apply energy to mature seed production. Also as the plant senesces the dead organic matter is decomposed into ammonium. One of the goals of this study is to understand the watershed from a different perspective. Studying one place in order to learn about others to see if there are similar patterns

and relationships that can be found in different ecosystems. Or in a similar ecosystem bound to the same regional characteristics but separated across an elevation gradient which causes different temperatures, precipitation, snowmelt timing and plant community dynamics. The research project addressed the following questions, as the environment changes and influences factors such as seasonality, timing and microclimate how do these changes influence nitrogen amount? Specifically how does seasonality and topography influence the presence or absence of nitrogen in a Colorado mountain watershed? Finally, will the results be applicable in other ecosystems and be a way to model future impacts of climate change?

Methods

Sites & Plots

The sites that I sampled are Lower Montane (Pumphouse) and Lower Sub-Alpine (Pfeiler) specifically, the slope and the toe slope areas (Figure 1). The slope is the hill slope and the toe slope is that transition area between the slope and the floodplain. Ten meter transects were set up in the ten by fourteen meter plots with a two meter buffer on both ends. Transects were laid out parallel to the slope and they were marked every two meters with colored whiskers that were staked in. Red whiskers were used on Pfeiler's slope (Figure 3) whereas purple whiskers were used on the slope of Pumphouse (Figure 2). Blue whiskers were used in the toe slopes of both sites and some were placed on wooden stakes to be more visible in certain vegetation. The toe slope of Pumphouse contains three transects perpendicular in Veratrum, the Monument plant and short willows, to that of the slope to more accurately follow and sample the water flow. The toe slope at Pfeiler contains two perpendicular transects to the slope that contain vegetation, veratrum and short willow, similar to Pumphouse to provide a better comparison between sites. Vegetation patches were selected randomly. At both sites at each point of the

transect NDVI was measured using the SpectroSense 2 meter (Skye Instruments, Inc., Powys UK) A converted canon camera was used to capture near infrared light while still including red and green surface radiance in order to quantify plant leaf area coverage. The whiskers represent the center of the photograph and area covered by the sensor. Soil water content is also taken at each point along the transects. Ion exchange resin strips (Membrane International, Inc., NJ USA) were placed at point 1 and 6 along the slope and toe slope to further study the presence of nitrogen, specifically ammonium and nitrate (NH_4^+ & NO_3^-) and how it moves through a watershed. They were taken out over an interval throughout the study to measure how nitrogen levels change throughout the season. Lastly soil cores were taken and divided into depths of 0-5 cm, 5-15 cm and 15 cm < at alternating points throughout the season to lessen the impact on the ecosystem. They were taken at points 1 & 4, 2 & 5 and 3 & 6. Double soil cores were taken for nutrient analysis and microbial biomass analysis that will be performed at the Lawrence Berkeley National Laboratory (LBNL).

Resin Strips

Ion exchange resin strips provided soil nutrient amounts through the analysis of anion and cation concentrations specifically, NO_3^- , NH_4^+ & NO_2^- (Qian & Schoenau, 2005). The resin strips were prepared at the LBNL before they were installed in the field. A hori hori knife was used to create a slit in the soil and the resin strip attached to a zip tie was placed in the soil so that it was completely covered. The cation resin strips were placed to the north (left) of transect points 1 and 6 while the anion resin strips were placed south (right) of transect point 1 and 6 with respect to the river in each plot. The resin strips were placed at points 1 and 6 to account for spatial variation of nutrients and to explore the position of nutrients on a hillslope. The anions and cations collected on the resin strips were analyzed using a weak acid or salt solution to

separate them from the resin strips. After the anions and cations are in solution an indicator is added and the resulting color is read by a photo spectrometer in order to determine the concentration of the ions. The analysis was performed at LBNL.

SpectroSense Meter

The SpectroSense 2 meter was used to measure the reflectance of red and near infrared light at each transect point. The two different wavelengths of light energy are read by the 2-channel sensors. The measurements are taken in units of $\mu\text{mol}/\text{m}^2/\text{sec}$ this represents the amount of energy per unit area over time. These measurements, 04h (umols): CH1_I, 05h (umols): CH2_I, 02h (Rel 1): CH1_R and 03h (Rel 2): CH2_R, were used to calculate the Normalized Difference Vegetation Index (NDVI) that represents the greenness of the area measured. The

formula used to calculate NDVI was $NDVI = \frac{(NIR - R)}{(NIR + R)}$ Near Infrared light (NIR) and red light

(R). This formula is further broken down into $NDVI = \frac{(CH2_R / CH2_I) - (CH1_R / CH1_I)}{(CH2_R / CH2_I) + (CH1_R / CH1_I)}$ where

the values given by the SpectroSense 2 meter are input into this formula.

Measurements were taken in full sunlight as partial sunlight can influence the data.

Hydrosense Soil Moisture Probe

The hydrosense soil moisture probe (Campbell Scientific, Inc., UT USA) measured the soil moisture content volumetrically, i.e. the volume of liquid water per volume of soil. An electromagnetic pulse was sent from one prong to the other. The time that it took to reach the other prong is measured and the Time Domain Reflectometry (TDR) approach was utilized. This measured the capacity of the soil to transmit electromagnetic pulses and the time was converted

into percentages of soil moisture content. When the soil moisture content was measured the dummy probe was inserted first so as to not damage or break the hydrosense soil moisture probe in dry soils or rocky areas.

Soil Cores

Soil cores were taken with a hand soil corer with a diameter of 3 cm (AMS, Inc., ID USA). Cores were collected once a week at each site while varying points, i.e. 1 & 4 week 1, 2 & 5 week 2 and 3 & 6 week 3. Each core was divided into three depth measurements of 0-5 cm, 5-15 cm and >15 cm. Soil cores were used to measure soil nitrogen at a specific point in time. A nutrient analysis and microbial biomass was performed at LBNL using a weak salt solution or water to determine nutrient concentrations.

Geographic Information Systems

ArcMap 10.4.1 (Environmental Systems Research Institute, Inc.) provided elevation, slope and aspect data at each point at both sites. The data was found using the aspect, slope and hillslope tools in ArcMap 10.4.1. The Digital Elevation Model (DEM) inputted into the tools was created from Lidar data flown for the Department of Energy (DOE) project (Wainwright et al., 2017).

Data Analysis

We performed a repeated measures analysis of variance with NDVI as the response variable and site (pumphouse vs. pfeiler) and date of data collection as the explanatory variables. We used the software JMP® 13.0.0 (SAS Institute, Inc., 2016).

Results

When observations were pooled across study weeks, the sites, Lower Montane (Pumphouse) and Lower Sub-Alpine (Pfieler) did not differ ($F=0.0525$, $P=0.8225$). NDVI changed significantly over time for both sites considered together ($F=9.0600$, $P=0.0032$). However, the way that NDVI changed over time varies between the two sites ($F=11.3961$, $P=0.0014$; Figure 4). How NDVI changed over time varies and depends on the site (Figure 4).

Can you repeat the test in JMP and put results here for soil moisture?

Eventual data will include nutrient analysis through soil cores, microbial analysis through soil cores, anion (NO_3^-) and cation (NH_4^+) analysis through resin strips and plant coverage quantified using the NIR photos.

Future: The soil cores have been shipped to Lawrence Berkeley National Laboratory where the nutrient and microbial biomass analysis will be performed ideally in the next couple of weeks. There is still 2 more weeks of collection for resin strips that will be shipped to Lawrence Berkeley National Laboratory for nutrient analysis. Once I have the results I will perform statistical tests to see if there is significance between the sites and if there are any correlations.

Discussion

Potential causes of the NDVI changes over time include the growing season and phenophases of the plants at the sites. As plants grow and enter different phenophases characteristics such as leaf expansion (CITATION) influence the area the plant covers and also the area present to reflect NIR light influencing greenness and the NDVI values. Other influence on plant area coverage include water availability, competition or nutrient availability. Variance due to site factors could include the timing of snowmelt, which drives the plants life cycle and phenophases (Steltzer et al., 2009). The Lower Sub-Alpine had full snowmelt later than the

Lower Montane site as it is approximately 1,200 feet higher than the Lower Montane site.

Besides snowmelt, temperature which is possibly the principle driving factor could influence the plants life cycle by driving snowmelt, thawing the ground and becoming warm enough where frost will not kill the plants (Steltzer et al., 2009).

Research Sites 2017

Elizabeth Ballor



Figure 1: Vicinity map of the two sites, Lower Montane (Pumphouse) and Lower Sub-Alpine (Pfeiler). The difference in elevation is approximately 1200 ft.

Lower Montane Site 2017

Elizabeth Ballor

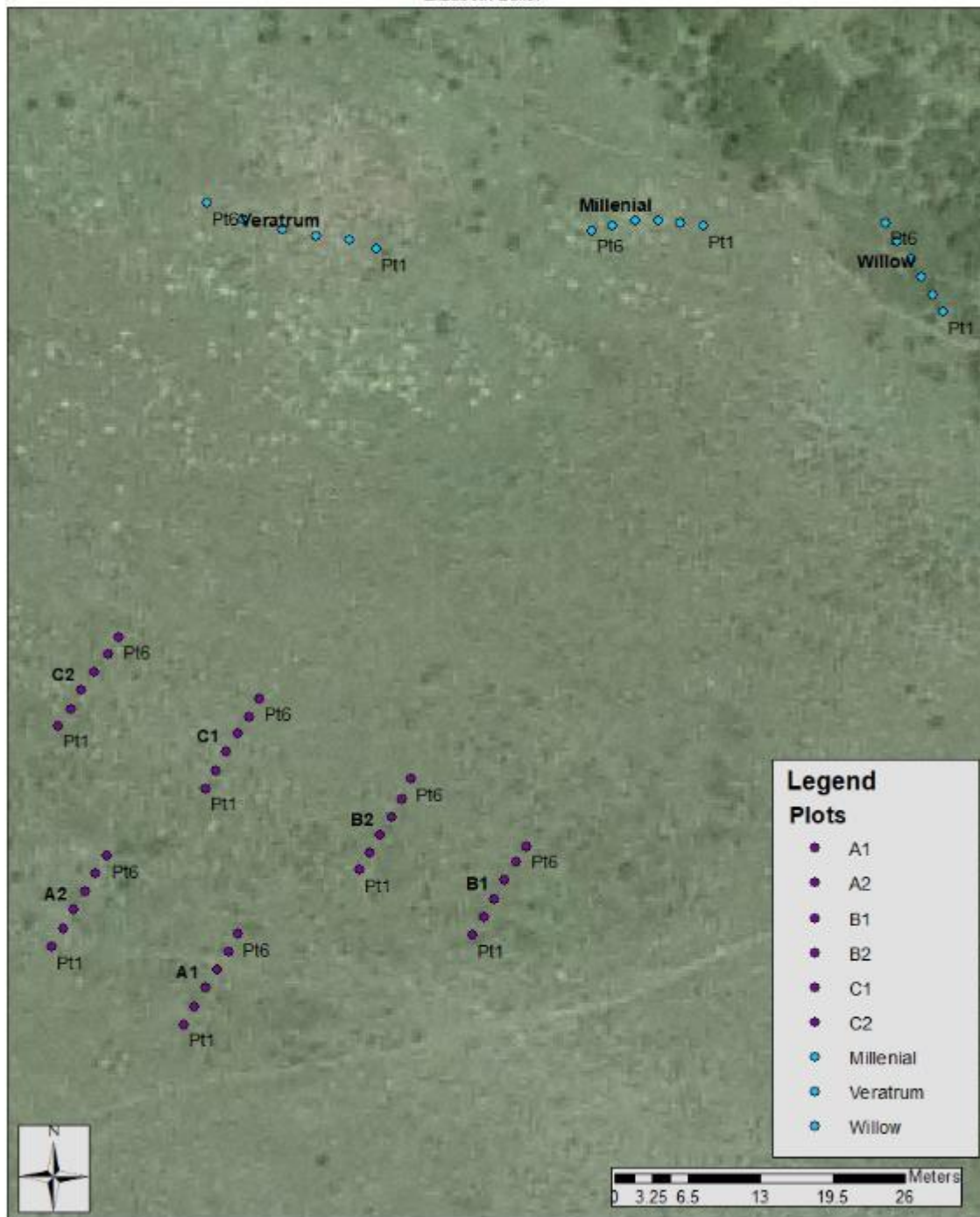


Figure 2: Map of the Lower Montane (Pumphouse) site and the transects that were laid out.

Lower Sub Alpine Site 2017

Elizabeth Ballor

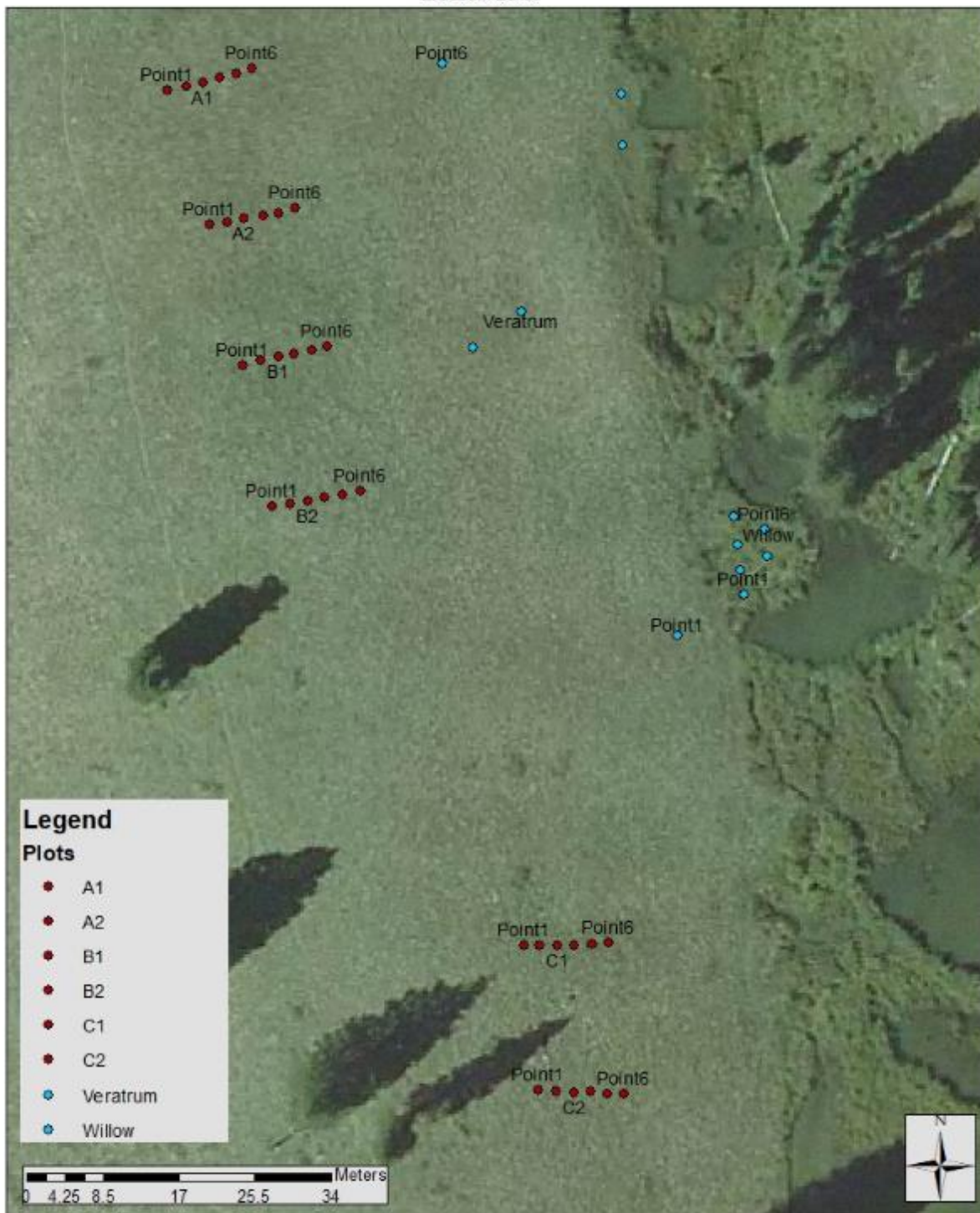


Figure 3: Map of the Lower Sub-Alpine (Pfeiler) site and the transects that were laid out.

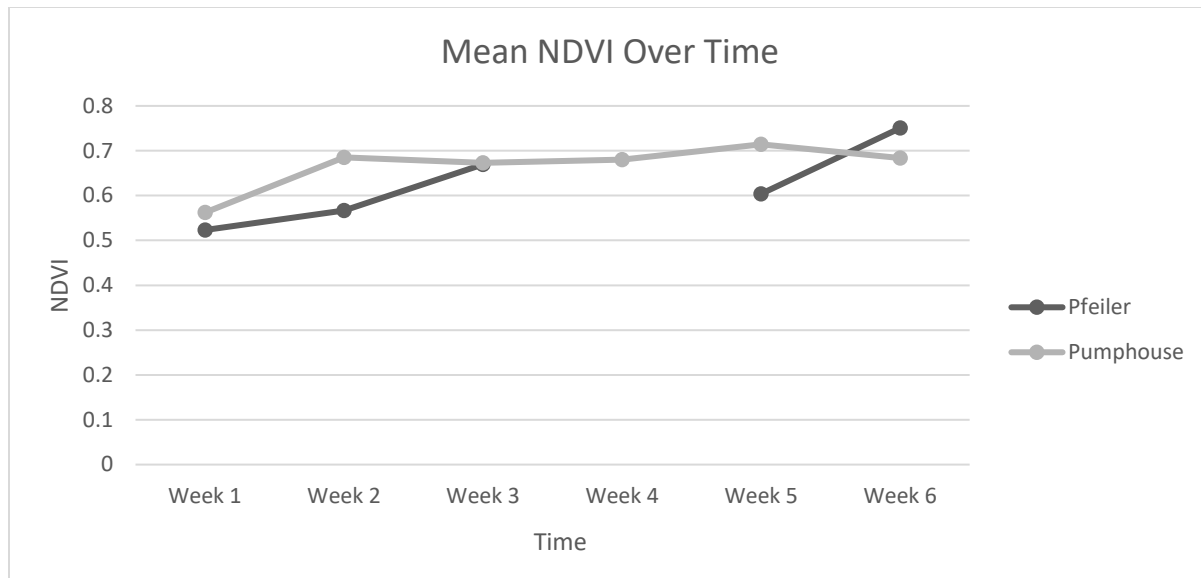


Figure 4: Mean NDVI (0-1 scale of greenness) over time at both sites. Values were averaged from each point for each site. There was no data for week 4 at Pfeiler as the weather was too cloudy the entire week.

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