

Vegetation Pattern Dependency Along the Southwest-Facing Hillslope of the Upper East River Watershed

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Introduction

Montane and subalpine vegetation is the result of a complex interaction between historic and current natural processes as well as human activities. It is impossible to contribute the responses of vegetation to a limited set of conditions (Reice 1994). Little is known, however, about the role of lithology under the varying influence of vegetation dynamics across large watershed areas (Istabbulluoglu et al., 2010). However, the past fifty years has witnessed an increasing number of studies exploring these dynamic relationships, in part due to motivation to enhance land restoration and management techniques (McDermott et al., 2007).

Microclimate is a local area that is distinct from the surrounding landscape. Factors that contribute to a microclimate include slope, aspect, soil type, vegetation types, average air temperatures, elevation, and a variety of other similar environmental conditions. The amount of groundwater present and accessible is crucial for controlling microclimate and acts as an important resource for vegetation in semiarid landscapes (Miller et al., 2010). Groundwater both affects and is affected by microclimate. The ability of plant roots to access this resource is a function of rock permeability and porosity. Geologic porosity determines overall water storage capacity while permeability establishes the rate of flow of liquids through the geologic unit (Birkeland, 1999). Therefore, a substrate's geologic unit is paramount in determining the type of vegetation that can survive in a particular location given that it controls the level of access plant roots have to water.

Vegetation boundaries have been described as being multi-scalar or hierarchical entities. That is, that environmental conditions act as site-dependent filters of varying degree to create a present landscape (Yarrow et al., 2008). To begin to understand relationships between vegetation distribution patterns and a biotic environmental factors and the potential hierarchy of these a biotic factors upon vegetation location, a pilot project was launched at the Rocky Mountain Biological Laboratory in Gothic, Colorado.

The study area for this project was the southwest-facing hillslope of the Upper East River Valley, just downstream of the Gothic townsite. The site was selected primarily for ease of access, presence of five distinct vegetation distributions, and relatively consistent orientation of the aspect in a southwest-facing direction. Within the study area, nineteen distinct lithologic units were present in the substrate.

Methods

Mapping of vegetation units was performed to obtain primary data of vegetation locations along the southwest-facing aspect of the Upper East River watershed, downstream from the Gothic townsite. A specialized field-hardened laptop (Trimble, Denver, Colorado), programmed with ArcMap10 (Esri, Redlands, California) and an internal GPS unit, was used to make outlines of the vegetation patterns along the southwest-facing hillslope were mapped. Five vegetation mapping units were defined for the scope of this project: (1) aspen, (2) mixed conifer tree stands, (3) sage brush dominated hillslopes, (4) wet meadows, and (5) mesic meadows of mixed forbes and grasses. Field days consisted of walking along the face of the Upper East River's southwest-facing slope and recording the locations of one of the five vegetation map units. Map units were determined based upon the presence of at least 50% of signature vegetation types, such as Corn lilies (*Veratrum album*), or various willow species, which signified the location of wet meadows. Wet meadow locations were indicative of a water table that is high enough to support highly water-dependent plant species. Dry meadow vegetation units were identified based upon the

presence of various flowering species that changed throughout the summer season. Some of the dry meadow species included lupin (*lupinus argenteus*), larkspur (*delphinium*), and mixed sunflower species (*Asteraceae*). Sage communities were mapped based upon the presence of large sage brush species typically located in drier areas with steeper slopes. The conifer unit on our vegetation map encompassed any of the common conifer species within our study site, such as engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). Finally our aspen map units included only areas with a minimum of 50% aspen tree stands (*Populus tremuloides*). Field mapping was done at a scale of 1:3000 to 1:5000. These outlines of were then transferred to a desktop in the Barclay computer laboratory on a weekly basis.

Previous outlines of mapped units were traced in the laboratory with greater accuracy using 2-m aerial photographs collected in 2009 through the National Agricultural Imagery Program (NAIP). Using the ArcMap *Edit* and *Create New* (Esri, 2009) Feature functions, each outline created in the field was filled to create a vegetation polygon with a unique identification number that corresponded to one of the five vegetation mapping unit types. Due to limited road access and safety, some outlines of mapping units were performed exclusively through analysis of aerial photographs in the laboratory.

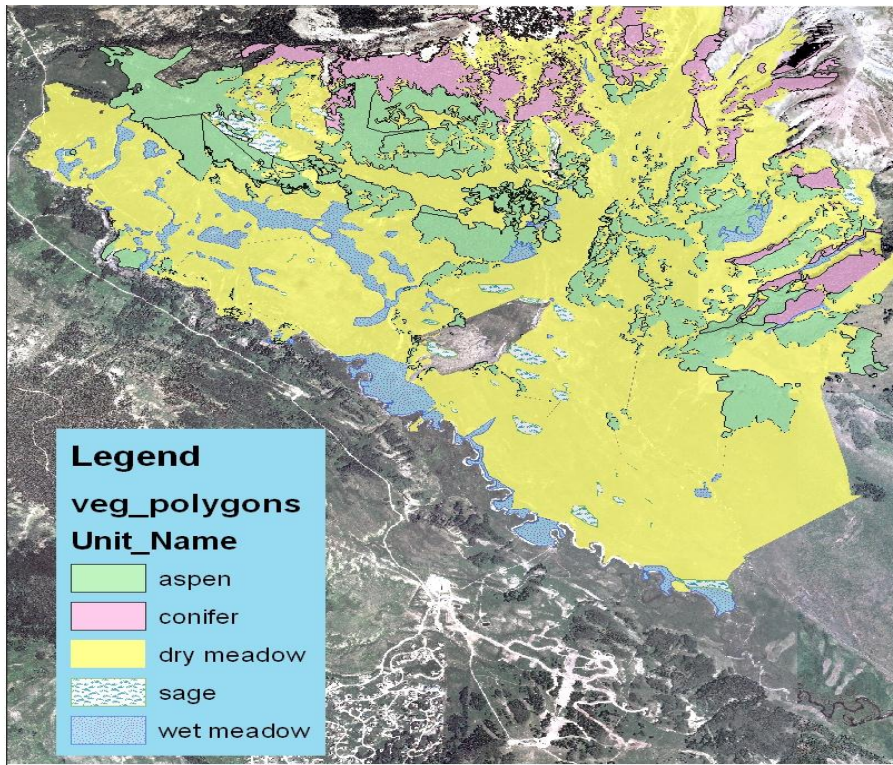
Once all of the vegetation polygons were finalized, the resulting map was overlain with a digitized geologic map of the Gothic Quadrangle, Gunnison County, Colorado. The geologic map was published by the U.S. Geologic Survey in 1991, and contains labeled polygons that depict the lithology of the Upper East River Valley. The geologic survey also includes a description of each lithologic unit found on the map. To ensure that the geologic map had the same coverage area so that the rate of occurrence of vegetation units across each lithologic unit could be calculated, ArcMap's *Extract by Mask* (Esri, 2009) tool was used with the vegetation map as the input feature.

Using this montage map image, the areas of each vegetation unit were calculated using Arc Analysis Tools. The percent occurrence of each vegetation map unit was compared to the overall area of study and then to the area covered by each lithologic unit present. All calculations were made in a Microsoft Excel spreadsheet.

Results

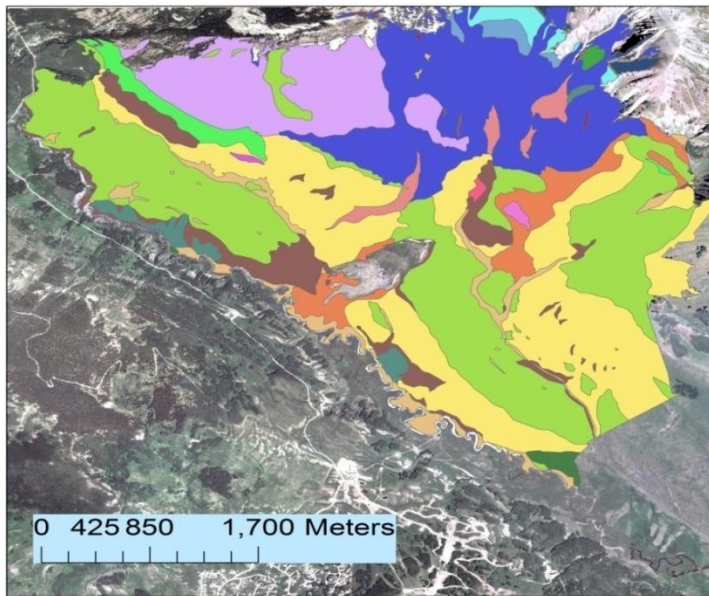
The final image of the vegetation units across our study area produced the image found in Figure 1. The total area of study was 165056683.5 m².

Figure 1



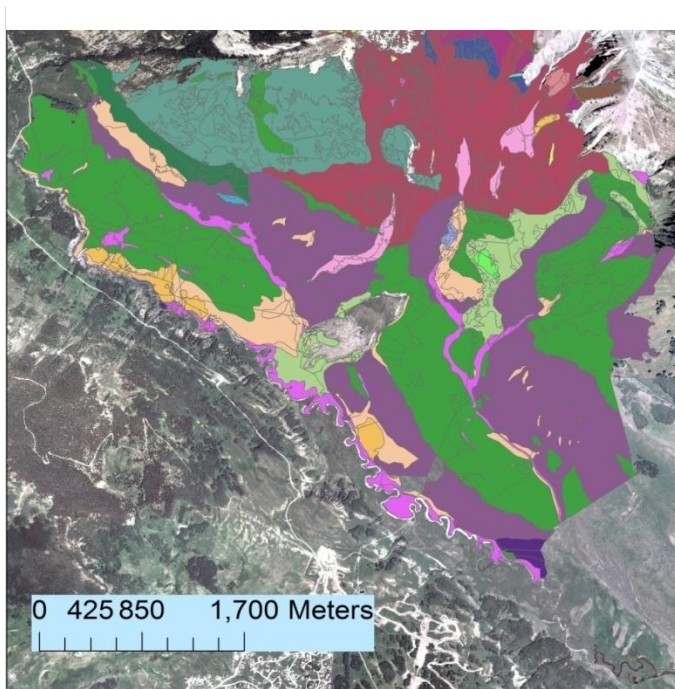
The final image of the geologic map of the Gothic Quadrangle (U.S. Geologic Survey, 1991) clipped to the exact area of study produced the image found in Figure 2. Each colored unit represents one of the nineteen geologic units identified within our area of study.

Figure 2



The final image of the Gothic Quadrangle geologic map overlain with the vegetation distribution map is found in Figure 3. Each unit represents the intersection of a geologic unit with one of the vegetation units.

Figure 3



Dry meadow communities were found to have the highest rate of occurrence at 63.505%, followed by aspen communities at 20.86%.

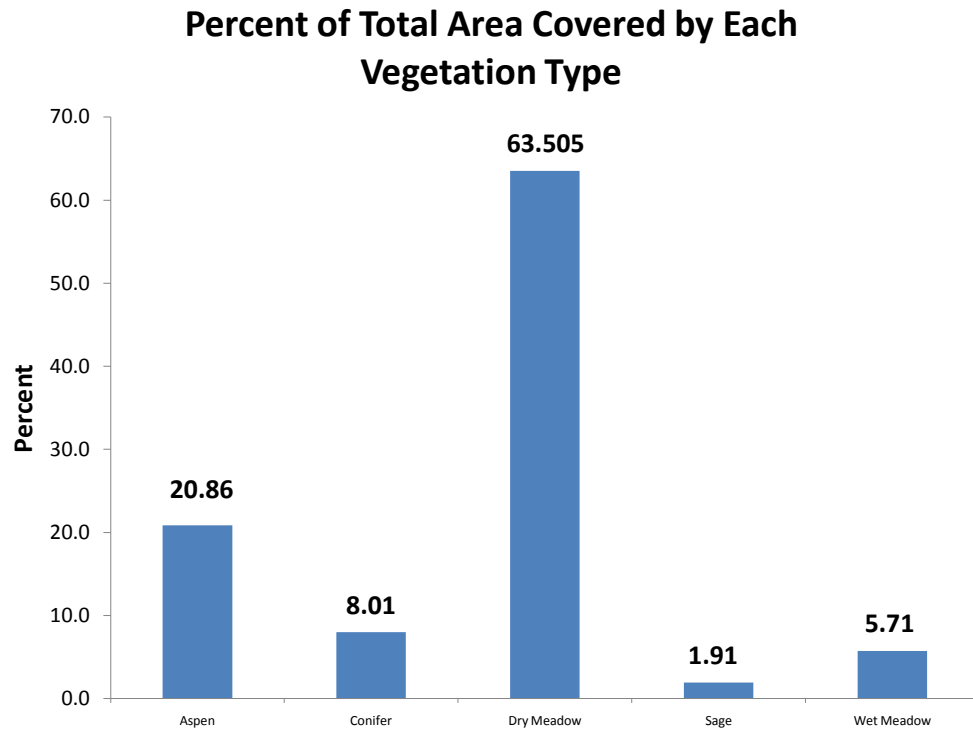


Figure 4 shows the rate of occurrence of each vegetation type was calculated across each lithologic unit present within the study area and plotted on a bar graph.

Figure 4

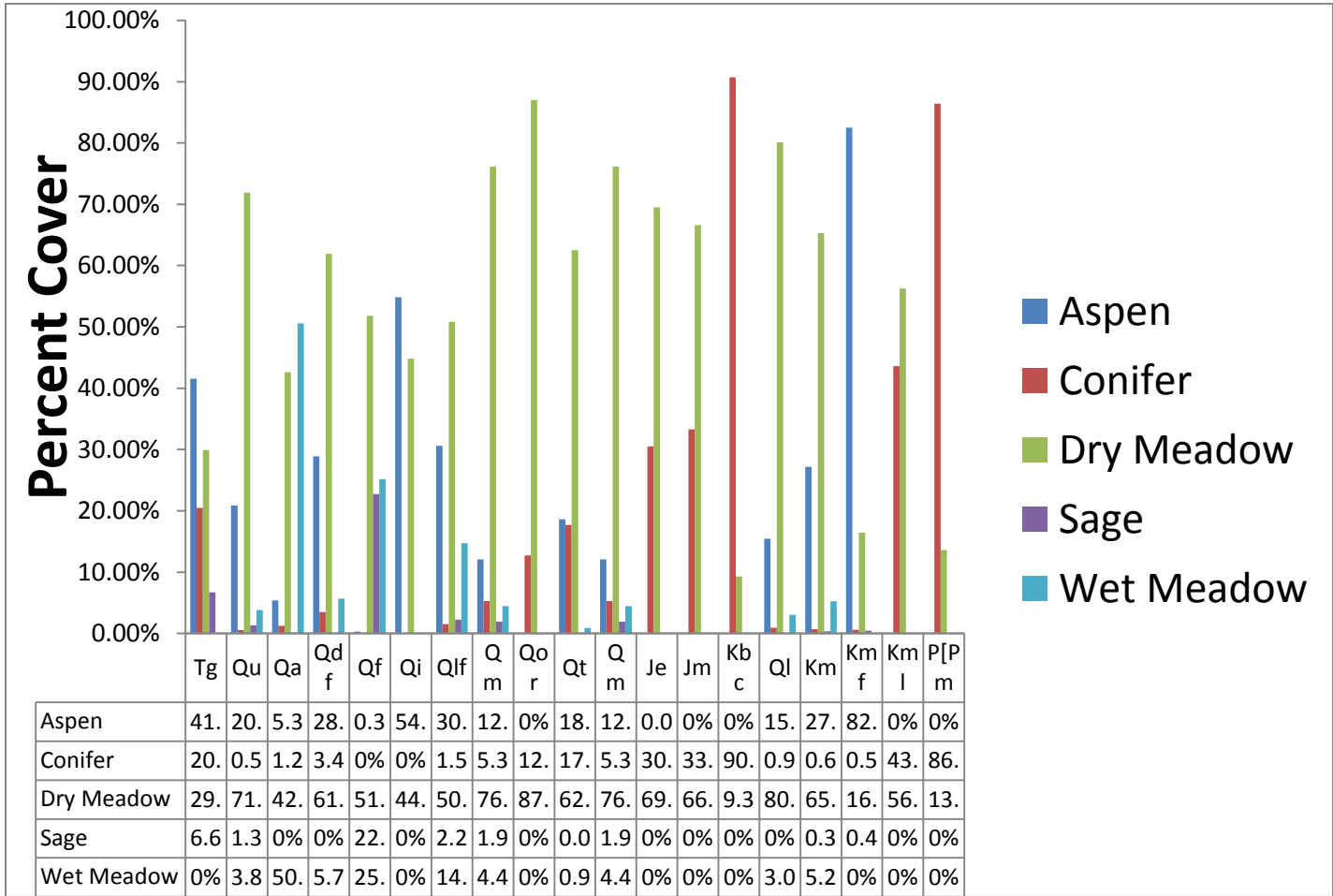


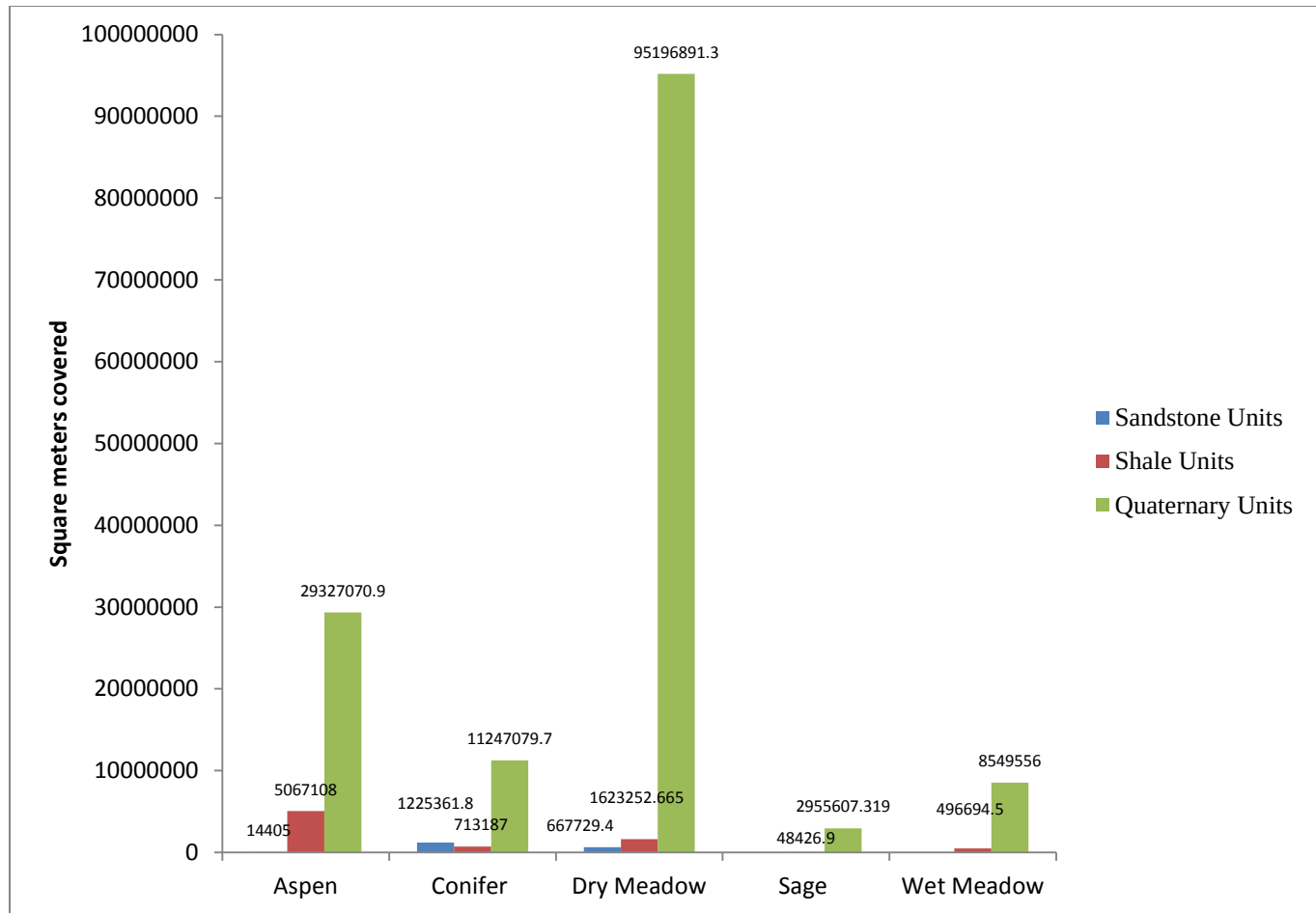
Figure 5 shows the categorization of each geologic unit into one of three subdivisions based on a broad type of lithology.

Figure 5

Sandstone Units	Shale Units	Quaternary Units
Je	Kml	Qa
P[Pm	Kmf	Qdf
Kd	Km	Qf
	Jm	Qi
	Kbc	Ql
		Qlf
		Qm
		Qor
		Qt
		Qu
		Tg

Dry meadows had the highest rate of occurrence across the three subdivisions of lithologic units, sandstone, shale and Quaternary as shown in Figure 6.

Figure 6



However, there are strong correlations with aspen units to shale lithologic units, while conifers demonstrate a greater affinity for sandstone geologic units.

Discussion

Topology errors with polygon features that were created for each unique vegetation unit within the study system initially created difficulties in comparing total lithologic areas to total vegetation unit areas. Common topological polygon errors range from unclosed polygons, gaps between polygon borders, or overlapping polygon borders (Infiniti). Essentially, polygon feature boundaries do not meet perfectly. Although all significant topology errors were corrected before calculating final vegetation and lithologic area ratios, ArcMap's *Merge* function (Esri, 2009) would remove any remaining topology error. Given the time frame and scale of this project, minor topology errors on the overlain map image were left unaltered, but will be fixed before any further analysis.

One difficulty in analyzing the percent occurrence of vegetation using the bar graph (see figure entitled 'Percent of Total Area Covered by Each Vegetation Type') is that the edge of a lithologic unit may extend into the study area and therefore not well represent the variety of

vegetation that is capable of thriving upon that geologic unit. Therefore, large, interior lithologic units were the focus of this study. These consist of undifferentiated moraine deposits (Qm), undifferentiated surficial deposits (Qm), Maroon Formation (P[Pm]), and the intrusive Grandiorite (Tg) (US Geologic Survey 1991).

To further analyze the rate of occurrence of each vegetation unit across all geologic units within our area of study, geologic units were categorized into three broad units: sandstone, shale, and Quaternary. The primary focus of this division is the level of permeability and porosity that each geologic subdivision possesses. Sandstone formations are generally composed of fine-grained materials and allow for the percolation of fluids. They also are relatively porous and can therefore store large amounts of water (Birkeland, 1999). These qualities make them valuable aquifers and reservoirs for energy sources. Shale units in our study area are primarily composed of mud rock that accumulated when the Cretaceous epeiric North American Inland Sea was established and waters had sufficiently deepened to allow for the deposition of black mud (Pierce, 2003). Clay particles in the mud compacted over thousands of years, leaving very limited pore space for water to permeate. Conduits between pore spaces were similarly compacted over time, thus limiting the overall level of permeability in shale units. Quaternary units comprised our final subdivision of lithologic units. Quaternary units possessed the greatest degree of permeability and porosity. They are primarily undifferentiated alluvial, glacial, and landslide deposits that have had little time for compaction (U.S. Geologic Survey, 1991). They are therefore the most porous and permeable division of the three.

Although the dry meadow vegetation unit was most abundant across the sandstone, shale, and Quaternary units, aspen unit abundance was found to have a strong correlation with shale units. Additionally, of the three sandstone units, each hosted only dry meadow and conifer species with only a minor occurrence of aspen in one of the units. Of the four lithologic units classified as a shale unit, those with an aspen population were found to occur in much greater numbers than the conifer units within the same lithologic unit. These significant findings are indicative of the potential correlation between access to groundwater and species preferences.

The data suggests that there is a possibility that aspen trees prefer shale lithologic units due to their low permeability. This results in groundwater being unable to move and is therefore more confined to a set area. The species *Populus tremuloides* has been found to have inhibited growth in situations of reduced root water flow (Wan et al., 1999). It is therefore probable that aspen prefer shale geologic units because of their ability to trap groundwater and prevent it from migrating unlike the more porous sandstone and Quaternary units.

We would like to explore these relationships between rock types and vegetation distributions further by considering slope, elevation change, and aspect across our area of study. Slope in particular greatly affects the flow rate and direction of groundwater (Birkeland, 2003). Changes in elevation alter microclimate and the intensity of sun exposure. This in turn affects evaporation rates (Miller et al., 2010). The elevation change of 3,000 feet within our study area was not considered when analyzing this data. Aspect also controls sun exposure by determining the length of exposure by a given orientation (Miller et al., 2010). Although our aspect is fairly consistent in a southwest-facing direction, further analysis of a digital elevation model would confirm any significant deviations from this orientation. Using the same data, we would like to analyze slope from digital elevation models due to our observational analyses that suggest that it is another key factor in determining vegetation distribution within this system.

Given the lack of previous data relative to this study, the primary focus of this pilot project was to obtain preliminary data to allow for further analysis of how and which biotic factors affect vegetation distribution across our area of study. Analyzing correlations between slope gradients and vegetation types is our next proposed focus to this study.

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