

Effects of Light Availability on Aspen Understory Species

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Abstract:

Trembling aspen (*Populus tremuloides*) is a keystone species found throughout North America. *P. tremuloides* is a successional species which aids the regeneration of ecosystems after disturbance. However, climate change is altering aspen forest dynamics. Aspen forest die-off in the American Southwest is predicted to increase in the next few years as temperatures and drought increase. As forests change, so does their understory. Forest die-off will affect the understory plant communities, which play crucial role on regional biodiversity. In this study, the effect of aspen canopy light transparency was measured to find its impact on species richness and abundance of aspen understory shrub, grass and forbs in the Gunnison National Forest (Colorado). The hypothesis is that aspen understory forbs will decrease in richness and abundance, aspen understory shrub and grass species will increase in richness and abundance with increasing canopy light availability in the form of LAI. Aspen overstory and understory photographs were taken. The overstory photographs were analyzed for LAI and the understory photographs were analyzed for richness and abundance. The results of the analysis did not express any negative relationships between forbs and light availability. The results did not show any positive relationship between grasses/shrubs and light availability. Indicating that LAI does not affect understory species richness and abundance.

Introduction:

From as south as central Mexico to north as northern Canada, and as high as alpine Colorado, trembling aspen, *Populus tremuloides*, is the most widely distributed native tree

species in North America (Barnes 1975). *P. tremuloides* contributes to significant biological understory plant diversity in low diversity landscapes (Krasnow and Stephens 2015). *P. tremuloides* is a keystone species in forests throughout northern and western North America, also creating a home for insects and food for ungulates. In short, *P. tremuloides* is an extraordinarily successful and ecologically important species (Clair and Lindroth 2013). Despite aspen's wide distribution and broad environmental niche, many *P. tremuloides* populations are currently declining. These declines are attributed to rising temperatures and drought caused by global warming (Krasnow and Stephens 2015). Although much research has been focused on *P. tremuloides* drought induced tree mortality, the multifaceted consequences of widespread tree mortality have been studied much less (Anderegg 2012). Recent research has indicated that tree health can transform regional land cover and alter existing ecosystems (Anderegg 2012).

Understory vegetation is a vital component of forest ecological function and biodiversity. Understory plant communities play an important role in both the influence ecosystem properties above and below ground (Mcintosh 2016). Dense understories can predict future successional trajectory of forests by delaying tree regeneration and growth (Mcintosh 2016). *P. tremuloides* understory is rich in number and species of plants and animals in comparison to coniferous forests. Aspen forests produce and abundance of forage, up to ten times more forbs, shrubs and grass species (U.S Forest Service 2004). Understory aspen communities can indicate stability or succession. Richer soils, higher forb diversity and water abundance are markers of stability. Low soil moisture, low forb diversity, and the presence of conifers are some markers of invasion (Lagenheim 1962). In the Gunnison National Forest (Colorado) a mature and stable aspen stand is very dense, with an average bare cover of only 2% (Lagenheim 1962). Aspen understory is mostly covered by forbs, such as *Ligusticum porteri*, *Heracleum panatum* which are both tall

members of the Apiaceae family which provide a variety of uses to animals and the forest itself (Lagenheim 1962).

As *P. tremuloides* range contracts in the American Southwest due to climate change induced drought. A direct effect of drought is crown thinning and decreased regeneration, which in return allows more sunlight to penetrate the overstory (Worrall 2013). As microenvironmental conditions change, the understory species may also begin to change, and potentially lead to decreased or different types of understory biodiversity. In the state Colorado, as the southern portion of the state is affected by sudden aspen decline. There less foraging available for ungulates to keep a steady diet. Leading to ungulate migrations to the northern part of the state (Buck 2012). The broader impact of this change, beyond its immediate effect on ecosystem services and biodiversity, may also include potential negative impact on eco-tourism and on the North American paper industry.

The focus of this study is to understand the effect of canopy cover variation on understory plants as aspen forests decline. Decline is associated with loss leaf flushing and eventual whole-stem mortality, a process which dramatically increases light penetration to the forest floor. This in turn may lead to the introduction of drought tolerant shrubs and grass species into to mature aspen stands, which are likely to decrease soil resource availability, with strong potential feedbacks on plant community dynamics. The study examined 3 hypotheses related to these mechanisms.

Hypotheses:

- 1) As light transparency increases, aspen understory forbs will decrease in richness and abundance.

- 2) As light transparency increases, richness and abundance of more drought tolerant shrubs and graminoids will increase.
- 3) As light transparency increases, total bare ground cover will increase.

Methods:

Site location: To test the hypotheses, 80 sample sites from Benjamin Blonder's aspen remote sensing study were selected. Blonder's Aspen remote sensing plots are composed of four major watersheds (Coal Creek **Map. 1**(N38.863798826, W107.051712635), Slate River **Map. 2**(N38.9096473867, W107.022222921), Washington Gulch **Map. 3**(N38.9224503177, W106.994864722), East River Watershed **Map. 4**(N38.9506819019, W106.963923955)), each watershed consists of seventy survey sites. All four watersheds were chosen for their diverse topography and location. The study sites are in the Gunnison National Forest, Colorado and were all easily accessible from the Rocky Mountain Biological Laboratory. The 80 study sites were randomly chosen using a random number generator provided by the University of Utah's Mathematics department <http://www.math.utah.edu/~pa/Random/Random.html>. Each study site has a unique four-digit code which makes it easily identifiable. Each Study was visited between 9th of June and 16th July 2018.

Species key: A total of nine indicator species were chosen to differentiate between understory types. There are three understory categories. The three categories were formulated by observing the most dominant understory species at three different undergrowth areas. Those undergrowth

areas are mature aspen stands, ecotonal stands with fescue and ecotonal stands with sagebrush.

Mature aspen stands are dominated with forbs, ecotonal stands with fescue have an abundance of drought tolerant fescues, and ecotonal stands with sagebrush contains drought tolerant shrubs.

The first category are forbs, which consist of: *Ligusticum porteri*, *Osmorhiza occidentalis*, *Lathyrus leucanthus*, *Lupinus sericeus*, *Erigeron elatior*, *Thalictrum fendleri*, *Fragaria ovalis* and *Helianthella quinquenervis*. The second category are graminoids which are: *Bromus ciliata* and *Festuca thurberi*. The third and final category are shrubs which include: *Symphoricarpos oreophilus* and *Rosa woodsii*. A morphological key (Species Table.1) was created which was used to differentiate between understory species richness.

Light availability: Aspen Leaf Area Index was measured at each site. Using a 24MP C digital camera (Canon EOS 6D) with a wide-angle lens (Canon, 17-40mm f/4L), one digital photograph of aspen overstory was taken with the lens set to 17mm and placed one meter above ground. The camera was placed with tree obstructions minimized, away from stems, sun not directly overhead and no understory obstructions. Once all 80 photographs were collected, aspen canopy light transparency as analyzed using Hemisfer <https://www.wsl.ch/en/services-and-products/software-websites-and-apps/hemisfer.html>, Hemisfer is a computer program that allows its users to measure light transmission into the forest floor via leaf area index (LAI) variable. LAI is a dimensionless quantity that measures plant canopy light transparency, the higher LAI the more canopy cover there is (Breda 2003).

Plant community assessment: Mature Aspen understory plant communities were measured for diversity and abundance. A square meter quadrant made of PVC tubing was laid out at each chosen site. The square meter quadrant was divided into nine regions. Using a 24MP high resolution camera (Nikon D3400 DSLR) with a (Nikon 18-50mm) wide angle lens, a picture of

the square meter quadrant was taken with the lens set to 17mm. The photograph was taken from a distance that allows the sides of the quadrant to line up with the top and bottom sides of the photograph. Using this technique allowed the camera to capture precise details of the vegetation enough to distinguish species diversity and approximate cover. From each photo I estimated approximate percent cover of species as a proxy for abundance, richness was calculated as the number of species with non-zero cover percentages using the species key. Richness and abundance was calculated one region at a time and at the end richness and abundance was compiled. All 80 photos were analyzed using a high definition screen, in the RMBL computer lab.

Statistical analysis: From the beginning of the experiment all the data was collected using pre-typed data sheets, then compiled and simplified into a standardized data sheet. Using R-Studio, I fit a linear regression models comparing leaf area index to all these types of undergrowth, using individual sites as a replicate. I generated one model for each watershed, and for each undergrowth type (a total of twelve models). The linear models can express what type of relationship leaf area index and understory vegetation have at each site. All the results were compiled into simple data tables and figures that were visualized scatter plots with the ggplot2 package (REF).

Results:

Forb Richness Vs. Leaf Area Index: Forb richness increased as leaf area index (LAI) increased (Figure. 1) in Slate River. However, it is a non-significant relationship (Table.1, Estimate Std: 0.3424, P-Value: 0.41). In Coal Creek, as LAI increases forb richness decreases (Figure.1), but the relationship between LAI and forbs at Coal Creek is not significant (Table.1, Estimate Std: -

0.08, P-Value:0.52). At Washington Gulch as LAI increases forb richness increases (Figure.1), the relationship at Washington Gulch is not significant (Table.1, Estimate Std:0.03, P-Value: 0.87). At Middle East River Valley, as LAI increases forb richness decreases (Figure.1), it is a significant relationship, however it supports the null hypothesis (Table.1, Estimated Std:-0.38, P-value: 0.02).

Graminoid Richness Vs. Leaf Area Index: Graminoid richness increased as LAI increased (Figure. 2) in Slate River. However, it is a non-significant relationship (Table.2, Estimate Std: 0.2605, P-Value: 0.27). In Coal Creek, as LAI increases graminoid richness increases (Figure.2), but the relationship between LAI and graminoids at Coal Creek is not significant (Table.2, Estimate Std: -0.04, P-Value:0.47). At Washington Gulch as LAI increases graminoid richness decreases (Figure.2), the relationship at Washington Gulch is not significant (Table.2, Estimate Std: -0.13, P-Value: 0.20). At Middle East River Valley, as LAI increases graminoid richness decreases (Figure.2), the relationship is significant (Table.2, Estimated Std: -0.19, P-value: 0.03).

Shrub Richness Vs. Leaf Area Index: Shrub richness decreased as LAI increased (Figure. 3) in Slate River. However, it is a non-significant relationship (Table.3, Estimate Std: 0.013, P-Value: 0.88). In Coal Creek, there were no shrubs present at any of the randomly selected survey sites. In Table.3, “NA” was typed in to substitute the absence of values. In the Washington Gulch watershed, there were no shrubs present at any of the randomly selected survey sites. In Table.3, “NA” was typed in to substitute the absence of values. In Middle East River Valley, as LAI increases shrub richness increases (Figure.3), the relationship is not significant (Table.3, Estimated Std: -0.09, P-value: 0.15).

Total Bare Ground Vs. Leaf Area Index: Total bare ground decreased as LAI increased (Figure. 4) in Slate River, it is a non-significant relationship (Table.4, Estimate Std: -0.62, P-Value: 0.49).

In Coal Creek, as LAI increased total bare ground increases (Figure.4), the relationship between total bare ground and LAI is not significant (Table.4, Estimate Std: 0.22, P-Value:0.54). Total bare ground coverage increases as LAI increases in Washington Gulch (Figure.4), however it is not a significant relationship (Table.4, Estimate Std: 0.36, P-Value: 0.43). In Middle East River Valley, as LAI increases, total bare ground coverage decreases (Figure.4), the relationship is not significant (Table.4, Estimated Std: -0.45, P-value: 0.20).

Total Forbs Vs. Leaf Area Index: Total forb abundance increased as LAI increased (Figure. 5) in Slate River, it is a non-significant relationship (Table.5, Estimate Std:4.47, P-Value: 0.095). In Coal Creek, as LAI increased total forb abundance decreases (Figure.5), the relationship between total forb abundance and LAI is not significant (Table.5, Estimate Std: -0.3993, P-Value:0.46). Total forb abundance increases as LAI increases in Washington Gulch (Figure.5), however it is not a significant relationship (Table.5, Estimate Std: 1.97, P-Value: 0.18). In the Middle East River Valley, as LAI increases, Total forb abundance decreases (Figure.5), the relationship is not significant (Table.5, Estimated Std: -0.18, P-value: 0.97).

Total Graminoid Vs. Leaf Area Index: Total graminoid abundance increased as (LAI) increased (Figure. 6) in Slate River, its relationship is not significant (Table.6, Estimate Std:1.3, P-Value: 0.51). In Coal Creek, as LAI increased total graminoid abundance increases (Figure.6), the relationship between total graminoid abundance and LAI is not significant (Table.6, Estimate Std: 0.028, P-Value:0.74). Total graminoid abundance increases as LAI increases in Washington Gulch (Figure.6), however it is not a significant relationship (Table.6, Estimate Std: 0.01, P-Value: 0.90). In the Middle East River Valley, as LAI increases, total graminoid abundance decreases (Figure.6), the relationship is not significant (Table.6, Estimated Std: -0.48, P-value: 0.43).

Total Shrubs Vs. Leaf Area Index: Shrub abundance stays constant as Leaf Area Index (LAI) increased (Figure. 7) in Slate River. However, it is a non-significant relationship (Table.7, Estimate Std: 0.000, P-Value: 0.88). In Coal Creek, there were no shrubs present at any of the randomly selected survey sites. In (Table.7), “NA” was typed in to substitute the absence of values. In Washington Gulch, there were no shrubs present at any of the randomly selected survey sites. In (Table.7), “NA” was typed in to substitute the absence of values. In Middle East River Valley, as LAI increases, shrub richness increases (Figure.3), the relationship is not significant (Table.3, Estimated Std: 0.41, P-value: 0.08).

Discussion:

The purpose of the study was to understand the effects of canopy light transparency on aspen understory species. The study hypothesized that as aspen canopy light transparency increases, forbs will decrease, and graminoids and shrubs will increase in richness and abundance. After all the data was collected and analyzed using linear models, the results were compiled. There are seven linear models in total. Each model expressed the effect that LEI had on understory species in each watershed. No significant relationships between forb, graminoid, and shrub richness and LAI in all four watersheds except for one watershed. The first exception was for forb richness Vs. LAI (Table. 1)(Figure.1) expressed a negative significant relationship. Indicating that as LAI increase forb richness increases in the Middle East River valley, accepting the null hypothesis. The second exception was for graminoid richness Vs. LAI (Table.2) (Figure.2) expressed a negative significant relationship. Which indicates that as LAI increases, graminoid richness increases in the Middle East River Valley, accepting the proposed hypothesis. In summary, all but two of the sixteen statistical analyses had no statistical significance. Since we found very few or no significant relationships, the null hypothesis was accepted for all our hypothesis. In

summary, as LAI decreases forbs do not decrease in richness and abundance. Also, as LAI increases graminoids and shrubs do not increase in richness and abundance.

My findings suggest that while there are consistent linkages between aspen forest structure and understory, LAI is not a primary variable driving this relationship. Rather, LAI belongs to a larger category of biotic and abiotic effects determining understory species growth and succession. Different LAI calculating software would be used instead of only calculating the center portion of the photograph, the entire photograph could be analyzed. LAI could be measured using ForestCrowns: A Transparency Estimation Tool for Digital Photographs of forest canopies. Provided by the USDA Forest Service <https://www.srs.fs.usda.gov/compass/2016/11/02/urbancrowns-and-forestcrowns-tools-to-assess-tree-crowns-and-forest-canopies/>. Forest crowns allows you to analyze the entire photograph instead of just one portion.

A key factor that could be affecting aspen understory species and growth and succession is cattle browsing. In the Gunnison national forest, cattle grazing is common. Heavy grazing by cattle has resulted in retrogression in understory plant communities (Krueger 1974). Retrogression is the reverse in succession, in which an area is successively occupied by less developed vegetation (Krueger 1974). Cattle graze on graminoids, therefore potentially reducing the number of fescues in mature aspen understory stands. Another factor that could have a potential impact on forest understory growth and succession could be microclimate. The role of local understory variation varies with climatic conditions. Humidity and water availability can moderate climate by creating a thermal buffer and making it ideal for forb understory species to thrive better than others (Burton 2014). As Climate is changing, so are aspen forests however, the multi factored consequences of climate change on aspen have rarely been studied (Rodgers 1998).

This study could potentially provide a better understanding of aspen forest dynamics with future replications. A future replication of this study would include a richer data set. Instead of twenty sites per watershed, it would be best to collect data from all seventy sites. Seventy random sites throughout the Gunnison National Forest could be surveyed. The randomly picked can provide a richer data. The effects of elevation on understory plant richness and diversity have the potential to be better understood. A larger understory species key formulated from numerous past temporal studies would benefit the census. Different LAI calculating software would be used, instead of only calculating the center portion of the photograph, the entire photograph would be analyzed.

Aspen are a keystone which species provide a home and food for many animals. Aspen understory is dense (Anderegg 2012). Understory plant communities play an important role on the mechanisms of biotic and abiotic factors (Mcintosh 2016). Dense understories can predict future forest succession. To understand the effects of aspen forest change on understory species all the biotic and abiotic factors such as microclimate, soil composition and canopy light transparency should be studied to better understand aspen forest dynamics. The understanding of aspen forest dynamics can lead to better forest management practices. Which in return will lead to the conservation of aspen forests in the American Southwest.

Tables & Figures:

Species Table. 1

Forbs	Graminoids	Shrubs	Trees
<i>Ligusticum porteri</i>	<i>Bromus ciliatus</i>	<i>Symphoricarpos oreophilus</i>	<i>Populus tremuloides</i>
<i>Ligusticum grayi</i>	<i>Festuca thurberi</i>	<i>Rosa spp</i>	
<i>Lathyrus leucanthus</i>			
<i>Lupinus sericeus</i>			
<i>Erigeron elatior</i>			
<i>Thalictrum fendleri</i>			
<i>Fragaria ovalis</i>			
<i>Helianthella quinquenervis</i>			

Table. 1 Forb Richness Vs. LAI

Site	Estimate	Std.	P-value	Significance
Slate River	0.3424		0.419	No
Coal Creek	-0.08597		0.528	No
Washington Gulch	0.03113		0.877	No
East River valley	-0.3849		0.020	Negative

Table. 2 Graminoid Richness Vs. LAI

Site	Estimate	Std.	P-value	Significance
Slate River	0.2605		0.270	No
Coal Creek	0.06461		0.218	No
Washington Gulch	-0.12023		0.191	No
East River valley	-0.18722		0.0331	Negative

Figure.1

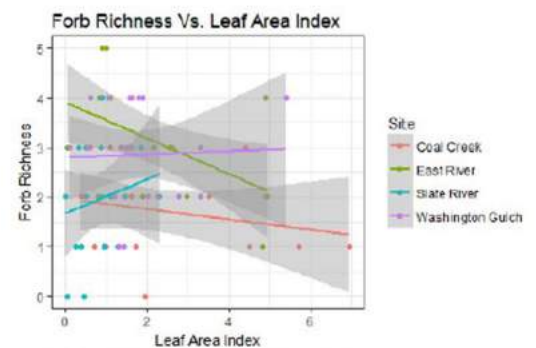


Figure .2

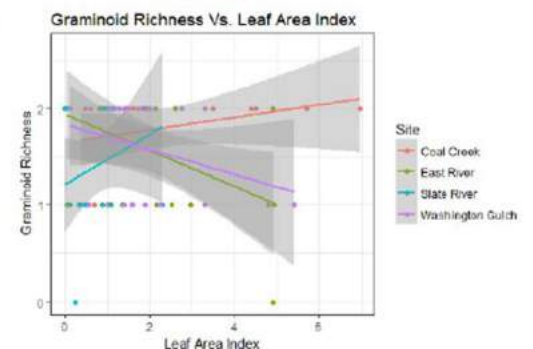
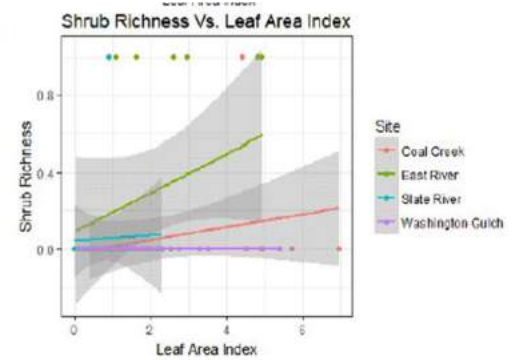
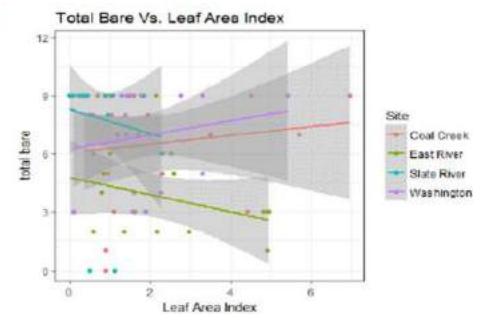


Table.3 Shrub Richness Vs. LAI

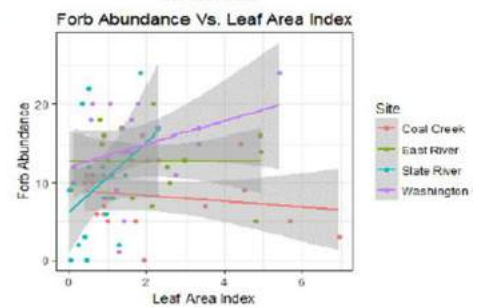
Site	Estimate Std.	P-value	Significance
Slate River	0.01381	0.879	No
Coal Creek	NA	NA	No
Washington Gulch	NA	NA	No
East River valley	0.12559	0.564	No

Figure .3**Table.4** Total Bare Vs. LAI

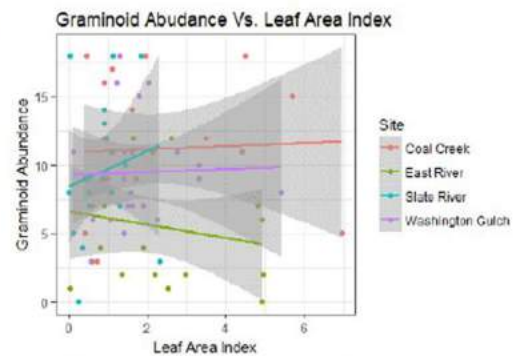
Site	Estimate Std.	P-value	Sginificance
Slate River	-0.6278	0.497	No
Coal Creek	0.2269	0.544	No
Washington Gulch	0.3664	0.431	No
East River valley	-0.4448	0.206	No

Figure .4**Table.5** Total Forbs Vs. LAI

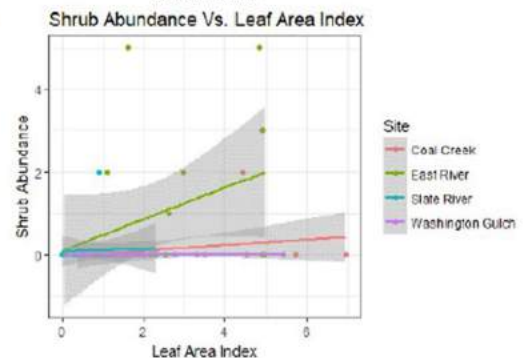
Site	Estimate Std.	P-value	Sginificance
Slate River	4.497	0.095	No
Coal Creek	-0.3993	0.4573	No
Washington Gulch	1.973	0.1772	No
East River valley	-0.1846	0.997	No

Figure .5**Table.6** Total Graminoid Vs. LAI

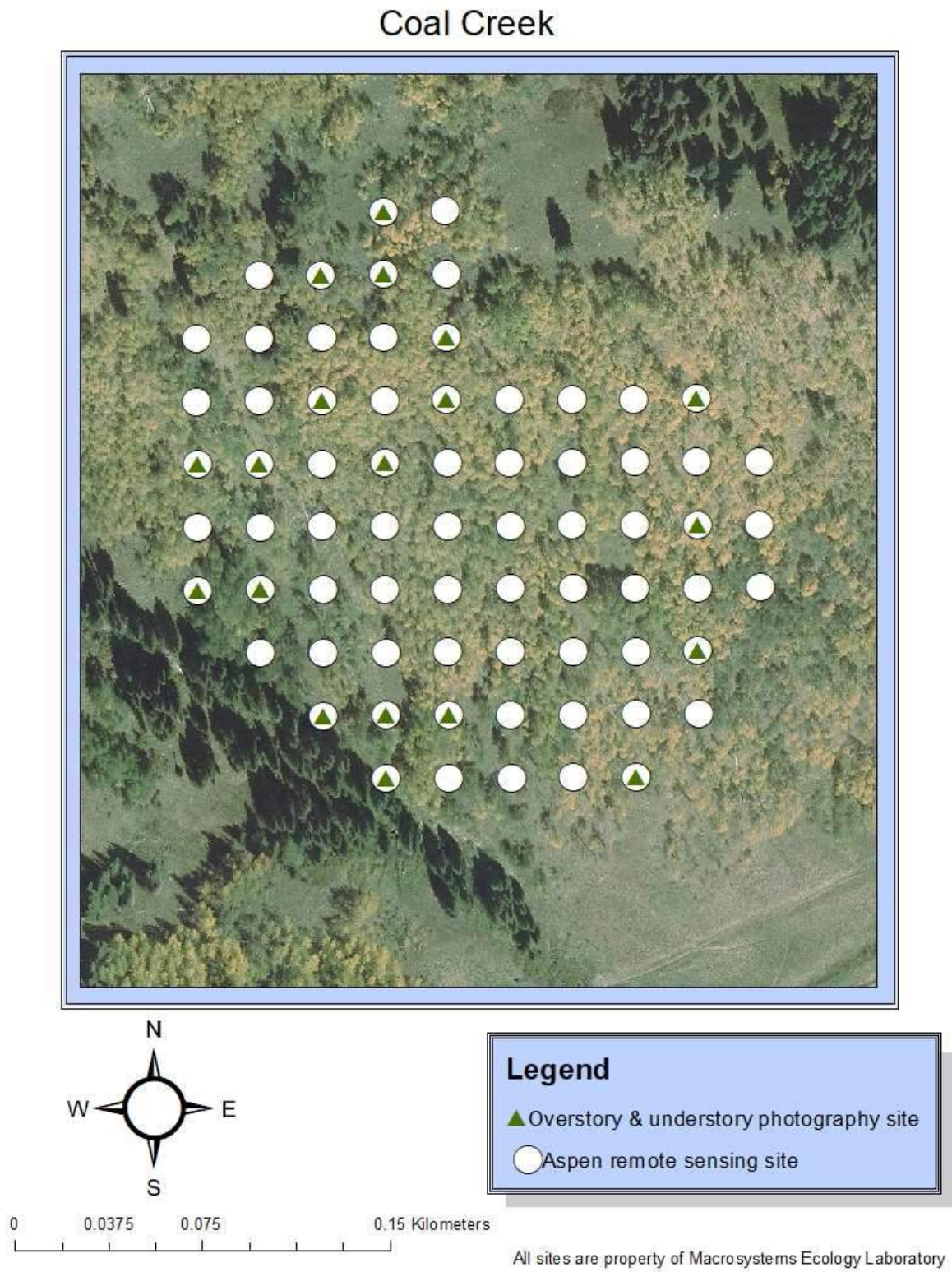
Site	Estimate Std.	P-value	Sginificance
Slate River	1.3	0.514	No
Coal Creek	0.0288	0.742	No
Washington Gulch	0.121	0.902	No
East River valley	-0.4853	0.4385	No

Figure .6**Table.7** Total Shrubs Vs. LAI

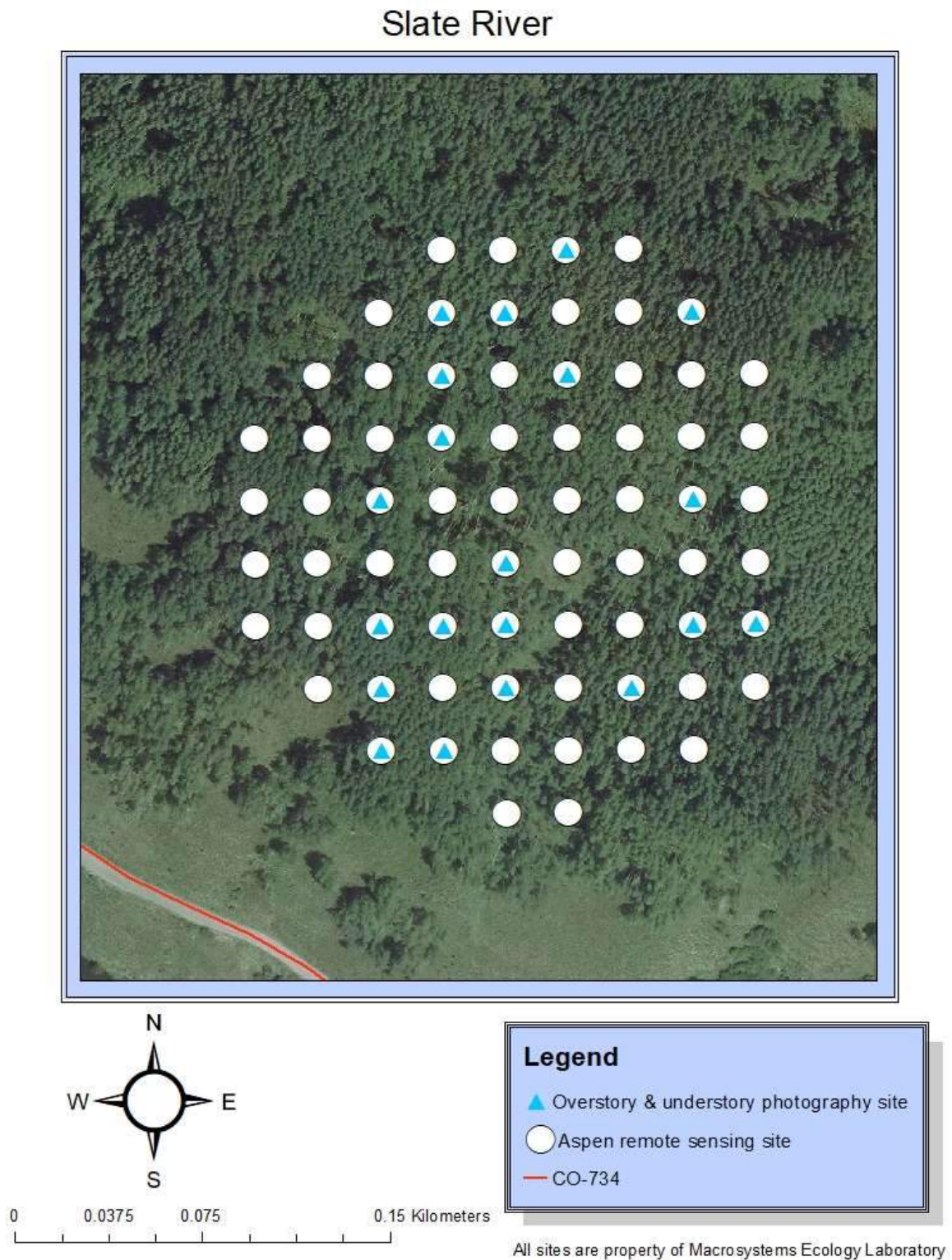
Site	Estimate Std.	P-value	Sginificance
Slate River	0	0.879	No
Coal Creek	NA	NA	No
Washington Gulch	NA	NA	No
East River valley	0.431	0.0872	No

Figure .7

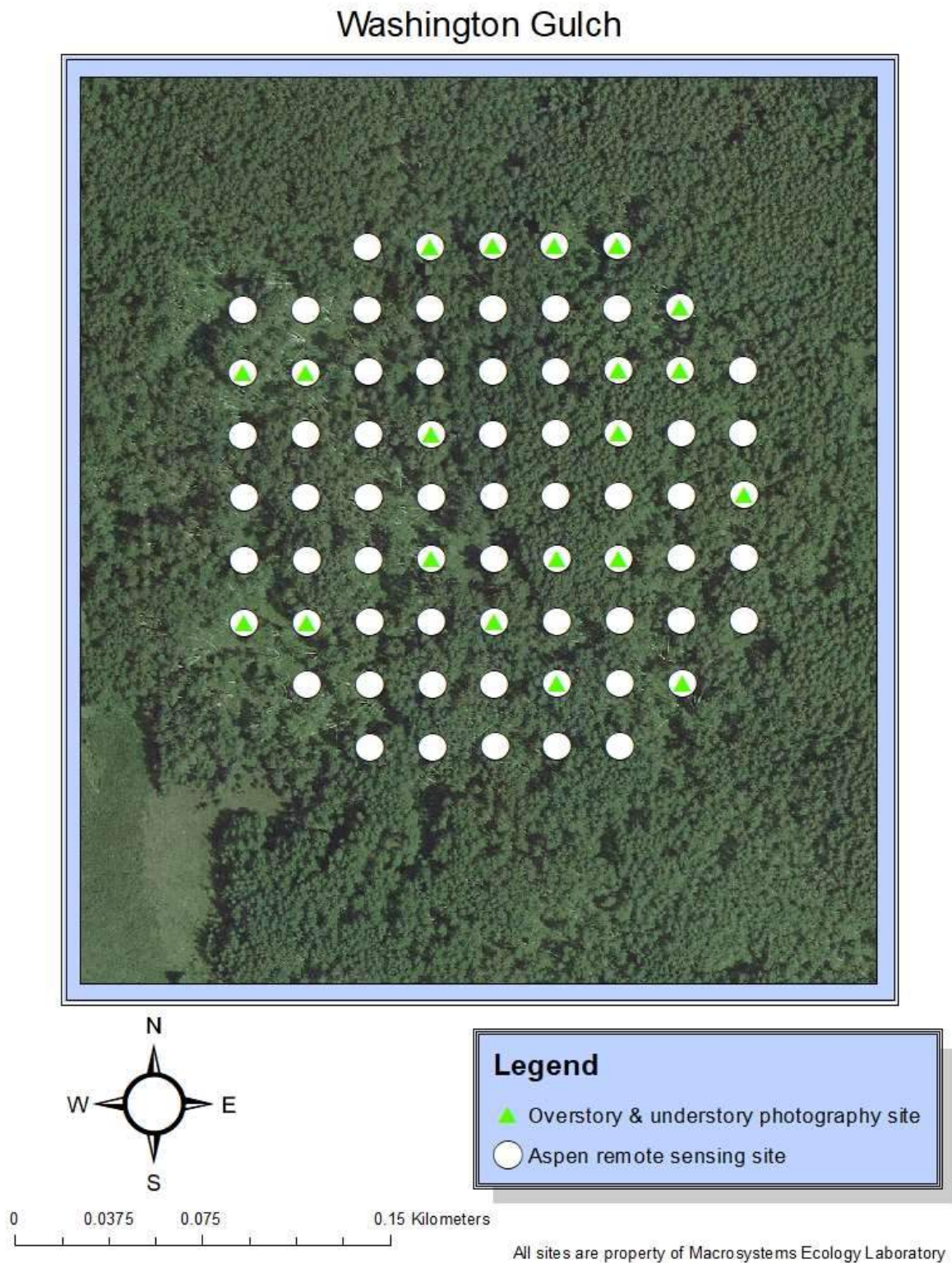
Map. 1



Map. 2

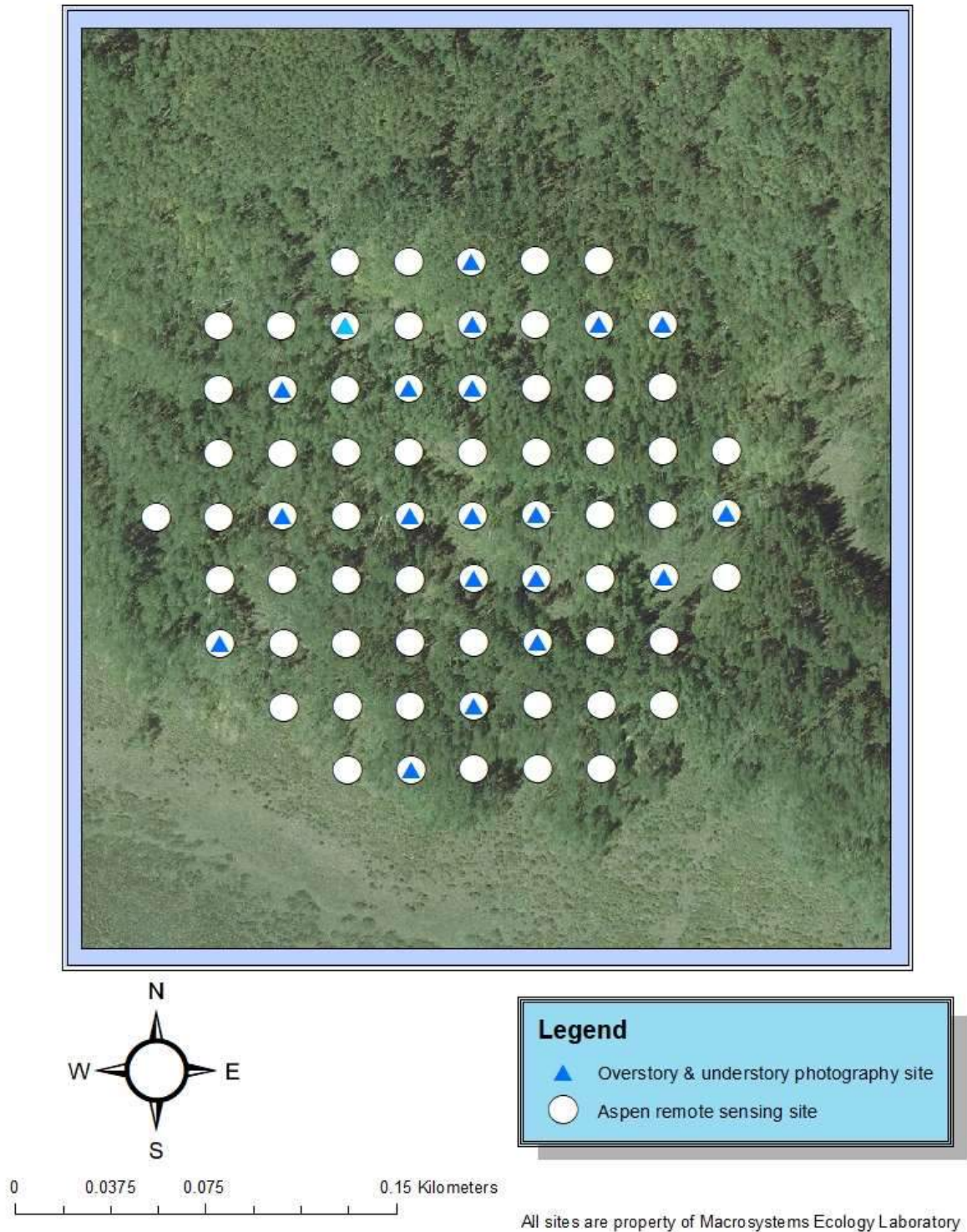


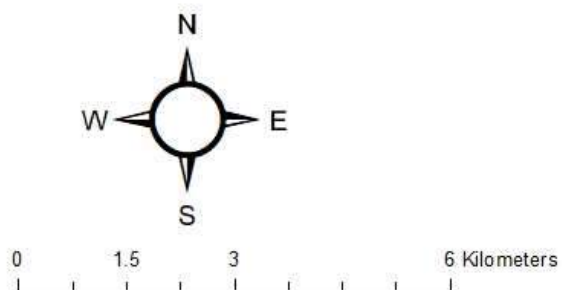
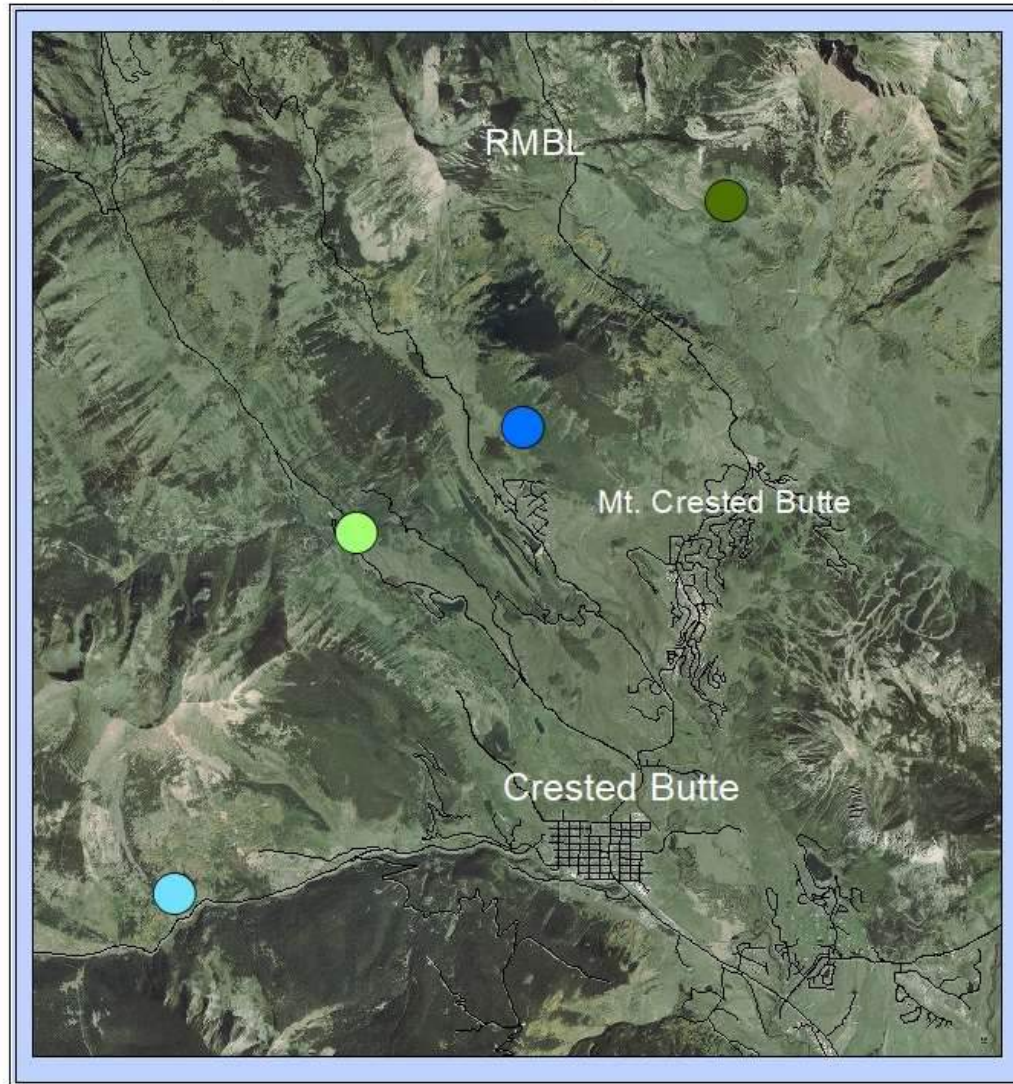
Map. 3



Map. 4

Middle East River Valley



Map of all watersheds:**Aspen Remote Sensing Watersheds****Legend**

-  Middle East River Valley
-  Washington Gulch
-  Coal Creek
-  Slate River

All sites are property of MacroSystems Ecology Laboratory

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