# Characteristics of a typical Nevada grazing area with riparian access

*Assessing the impact of perennial grazing on high-desert riparian ecosystem integrity by examining vegetation diversity and ground cover with UAS technology*

by Alexander Audet & Christopher Bargman

**Figure 1**. ***"The Plateau Site"*** - This study site falls within the *Inter-Mountain Basins Mixed Salt Desert Scrub* vegetation community.

## I. Topic:

Riparian vegetation and soil health is of great concern in the Great Basin since climate models show this ecosystem getting drier with climate change. These zones are a particularly delicate and important part of this ecosystem that provides fertile rangeland, wildlife habitat, fish habitat, abundant recreation, and water purification ecosystem services. Previous studies of rangeland have suggested that grazing has the potential to both increase or decrease the soil moisture content, and by extension ecosystem and soil health. **Here we utilized UAS methods to determine what if any impact grazing and land-use has had at two perennial grazing**

**sites, understanding each site in terms of vegetation diversity, vegetation density, and ground cover.** The two sites have opposing grazing-use and water availability patterns: Site 1, known henceforth as the Spring Site, is characterized by concentrated grazing in a lush spring riparian zone, while Site 2, known as the Plateau Site, exhibits more diffused grazing-use patterns as it is located a short distance from the riparian zone on top of a dry but grazable plateau.

To answer our research question, we found that we naturally stepped through a series of three analyses. First we determined how the ecological diversity compared between the neighboring dry upland and wet riparian sites. We had theorized that the wet riparian site would be much more diverse, emphasizing its ecological importance. Secondly, we asked if UAS methods can be a more efficient and comprehensive system for capturing the observed ecological conditions and differences between the sites than traditional ground field methods? Ground field methods (listed in the Nevada Rangelands Monitoring Handbook; Swanson et al., 2018) were used to test the validity of the UAS methods used to estimate vegetation diversity, vegetation density, and ground cover and determine their suitability as a replacement for ground survey methods. If UAS methods could be verified as accurate for measuring vegetation communities metrics, then we theorized we could place a greater degree of trust in our UAS based analysis to improve ground methods. Finally, using the UAS methods we had tested and ecological benchmarks, we sought to determine what measurable impacts grazing and land-use produce on the plant communities found on each site. These results are what we use to ultimately provide guidance on whether the sites are being overgrazed and how this impacts the ecological conditions of sensitive riparian and dry plant communities.

## II. Study Area:

The study area is set at two locations ~9 km south of the eastern extremity of the Carson River as it begins to outlet into the Lahontan Reservoir in Lyon County, NV (Fig. 2). Both sites are on BLM land with available grazing allotments and are ~2.25 kilometers apart. Site 1, known as the "Spring Site" is located at Churchill Springs (within Mill Canyon grazing allotment) and consists of a 1.22 ha polygon area; whereas, the drier upland location on the adjacent Adriance Valley grazing allotment, dubbed the 'Plateau Site', consists of a 1.47 ha polygonal study area (Fig. 3). Historical records of annual grazing AUN and the vegetation community types and their ideal peak conditions were requested at Reno BLM. Alison Agneray, the Great Basin Ecoregional Coordinator pointed us towards the NatureServe Explorer for understanding the vegetation communities and their benchmark conditions.

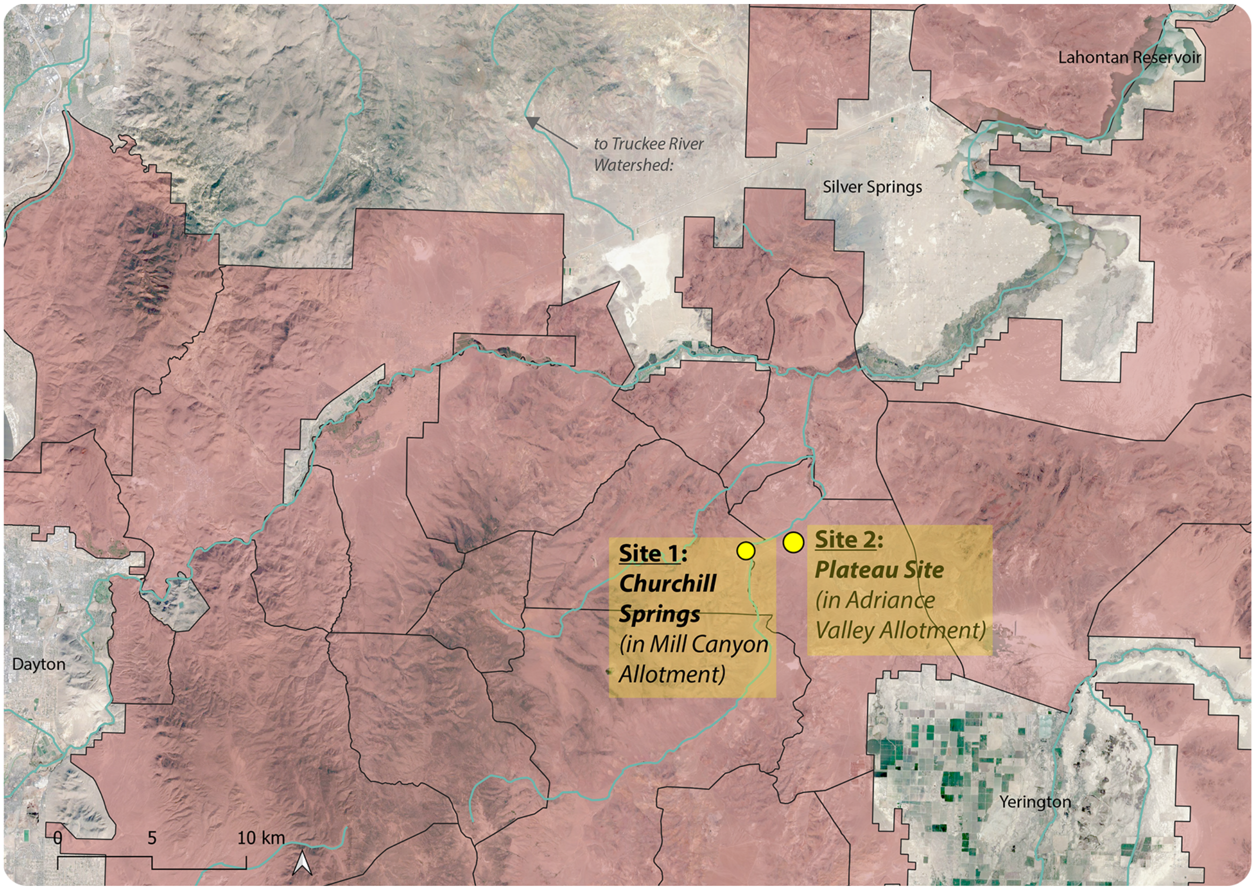



**Figure 2**. ***Study sites for project*** - Both study sites are within Lyon County, NV, approximately 9 km south of the Carson River. The sites are separated by only 2.25 km, but fall within two different grazing allotments.

**Mapped Community types:**

Previous work done on high desert ecosystem classification (from Nevada Rangelands Monitoring Handbook) has broken down Nevada into over a hundred different types. According to the "A Synthesis of Vegetation Maps for Nevada" (Nevada Natural Heritage Program, 2008), ecosystem classification for the Spring Site consists of a gradient changing from *Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland* to *Inter-Mountain Basins Big Sagebrush Shrubland* on the hill, then to *Inter-Mountain Basins Mixed Salt Desert Scrub* on the Riparian uplands. The Plateau site consists solely of *Inter-Mountain Basins Mixed Salt Desert Scrub.*

***1. Inter-Mountain Basins Big Sagebrush Shrubland***

*According to the ecological system definition from NatureServe Explorer, this system "occurs throughout much of the interior west U.S., typically in broad basins between mountain ranges, plains and foothills between 800 and 2500 m".*

***Floristic Summary:***

***Dominant Shrubs****: Artemisia tridentata ssp. tridentata, Artemisia tridentata ssp. wyomingensis, with scattered amounts of Juniperus spp., Sarcobatus vermiculatus, and Atriplex spp.*

***Shrubs found in disturbed stands:*** *Ericameria nauseosa, Chrysothamnus viscidiflorus, Purshia tridentata, Symphoricarpos oreophilus can be found to co-dominate these areas, sometimes growing more dense than non-disturbed stands.*

***Perennial herbaceous components:*** *These contribute less than 25% of vegetation cover.*

***Gramanoid Species:****Achnatherum hymenoides, Bouteloua gracilis, Elymus lanceolatus, Festuca idahoensis, Hesperostipa comata, Leymus cinereus, Pleuraphis jamesii, Pascopyrum smithii, Poa secunda, or Pseudoroegneria spicata.*

***2. Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland***

*According to the ecological system definition from NatureServe Explorer, this system "occurs in mountain ranges of the Great Basin and along the eastern slopes of the Sierra Nevada with a broad elevation range from about 1220 m (4,000 feet) to over 2135 m (7,000 feet)". Classification of this system is also defined as a mosaic of multiple communities that are "tree-dominated with a diverse shrub component".*

***Floristic Summary:***

***Dominant Trees:*** *Abies lowiana (= Abies concolor var. lowiana), Alnus incana, Betula occidentalis, Populus angustifolia, Populus balsamifera ssp. trichocarpa, Populus fremontii, Salix laevigata, Salix gooddingii, and Pseudotsuga menziesii*

***Dominant Shrubs:*** *Dominant shrubs include Artemisia cana, Cornus sericea, Salix exigua, Salix lasiolepis, Salix lemmonii, or Salix lutea*

***Herbaceous Layers:*** *often dominated by species of Carex and Juncus*

***Perennial Grasses:*** *Deschampsia cespitosa, Elymus trachycaulus, Glyceria striata, Iris missouriensis, Maianthemum stellatum, or Thalictrum fendleri*

***Introduced Forage Species:*** *often present in disturbed stands are Agrostis stolonifera, Poa pratensis, Phleum pratense, and the weedy annual Bromus tectorum*

### *3. Inter-Mountain Basins Mixed Salt Desert Scrub*

*According to the ecological system definition from NatureServe Explorer, this system is typified by "open-canopy shrublands of typically saline basins, alluvial slopes and plains across the Intermountain western U.S.".*

***Dominant Shrubs:*** *Typically open to moderately dense shrubland composed of one or more Atriplex species (Atriplex confertifolia, Atriplex canescens, Atriplex polycarpa, or Atriplex spinifera). Other shrubs present to co-dominant include: Artemisia tridentata ssp. wyomingensis, Chrysothamnus viscidiflorus, Ericameria nauseosa, Ephedra nevadensis, Grayia spinosa, Lycium spp., Picrothamnus desertorum, or Tetradymia spp.*

***Herbaceous Layers:*** *varies from sparse to moderately dense, dominated by perennial gramanoids.*

***Perennial Graminoids:*** *Achnatherum hymenoides, Bouteloua gracilis, Elymus lanceolatus ssp. lanceolatus, Pascopyrum smithii, Pleuraphis jamesii, Pleuraphis rigida, Poa secunda, or Sporobolus airoides*


**Figure 3. *Proposed Test Sites***: After researching the springs, the grazing allotments, and the relationship with the Carson River, the final proposed tests were chosen to be the Churchill Spring (1.) and a plateau Grazing site (2.).

## III. Methods

### *1. UAV Sampling Methods:*

Drone Flight

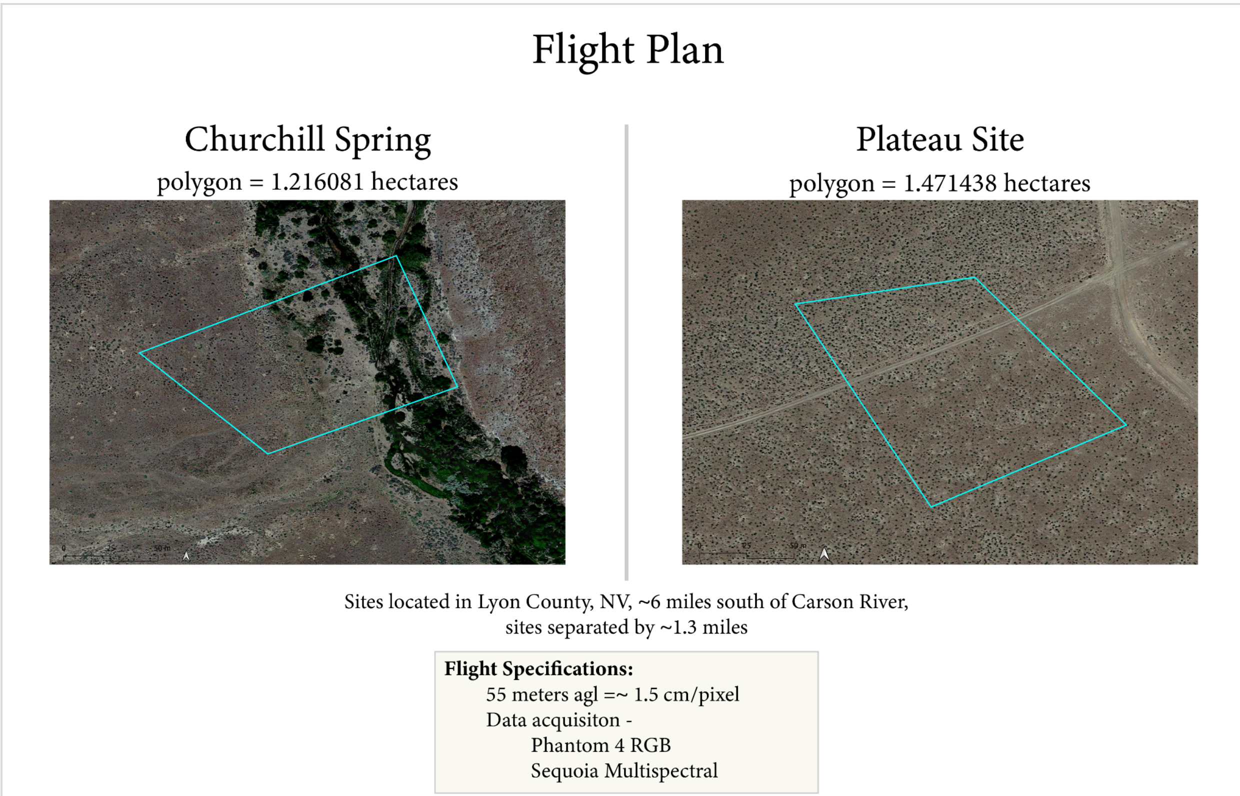



**Figure 4**. ***Flight plan*** - The Spring site on the left consists of a 1.21 ha polygon, while the Plateau site is a 1.47 ha polygon.

We used a Phantom 4 Pro drone with its default RGB camera and a multispectral Parrot Sequoia camera for our flights (Fig. 4). We prepared and controlled the flight through Drone Deploy At each site, we flew once by strapping the multispectral camera to the drone while still allowing it to use its RGB camera. The RGB camera obtained imagery at 0.69 cm/pixel ground sampling resolution (GSR) by flying at 55 m AGL. This height and resolution was chosen due both to constraints on flight time as well as the presence of tall trees in the flight area at the Churchill Spring site. The Sequoia camera was able to obtain 2.68 cm/pixel GSR resolution from 55 m AGL. Each flight used 80% side overlap and 90% forward overlap. A total of 1424 images were taken and enabled. images were taken; each image has 5 separate files accounting for red, green, blue, infrared, and red edge light spectrums. The entire study area is within class G airspace.

Five GCPs were used at each study site. They consisted of a single GCP in each corner of the flight plan polygon, plus a single GCP that roughly marked the center of the polygon. If the

GPS GCP data had been used, their spatial coordinates would have been refined by post-processed for differential corrections in Pathfinder Office using the COF1 CORS station in Fernley. However, since the precise spatial location and orientation of the orthomosaics and DEMs were not critical for the project analysis, they were not used to spatially correct the drone data. Instead, they were instead used as tie points in the orthoimage when georeferencing the Sequoia imagery to the RGB and DEM rasters.

### 2. *Ground Sampling Methods*

**Method 1:** ***Ground cover point samples*** (*Method 1 was not completed due to time constraints)*
Following the transect lines that cross our survey area, one stops every ~5 paces and records the ground cover at the base of one's feet. We had planned to target about 100 points per study site.
**Method 2:** ***Ground diversity plots***
We created a grid of evenly spaced points at 28 m spacing within QGIS. Then at the study sites, we located each plot center using the SW maps App, placed a pin in the ground and counted all species within a 12 ft radius greater than the palm of one's hand in area or over a foot tall.

**Selection of Survey Photos**

Excess photos were collected during the survey. Using R script, modified from a file created by Kenneth E Nussear, we isolated the photos taken at the correct altitude by filtering all photos outside of the first and last survey timestamps.

### 3. *UAV Data Processing*

a. Pix4D

For each site, we elected to create the normal 3D map product from the higher resolution RBD imagery to create an orthomosaic as well as both a DTM, and DSM. The DEMs were created using Pix4D's internal photogrammetry calculations. We also created a multispectral agricultural orthomosaic product from the Red, Green, NIR and RedEdge bands of the multispectral imagery at each site.

b. ArcGIS

Subtracting the DTM layer from the DSM layer using the Arc raster calculator tool, we calculated the nDSM, which gave us the above ground height of the vegetation, and this layer was added to the orthomosaic.

We combined the four multispectral bands into a composite using the ArcGIS Composite Bands processing tool. Then, we georeferenced the multispectral orthomosaics to the RGB imagery using ArcGIS Pro's georeferencing tool. We performed a third order polynomial transformation at the spring site with 19 control points and a second order polynomial transformation at the plateau site with 12 control points to reach a similar residual (<0.1 m) for the control points.

After georeferencing, we performed the ground cover image classification. We used the RBG bands to draw training polygons that would classify the images into vegetation and non-vegetation categories including shadow, bare ground, rock, tumbleweed, and miscellaneous categories. These training polygons were used to create a signature file using the Create Signature File tool from the RGB and georeferenced multispectral bands (at the spring site), then the classification layer was created using the RGB and the multispectral (at the Spring site) as input bands into the Maximum Likelihood Classification tool. At the Plateau site, the multispectral data was not used due to excessive banding.

We then removed all but the vegetation pixels and performed another image classification to classify by plant species. The ground cover classified layer was used to create a mask using the Set Null tool that could be used in the Extract by Mask tool to extract only the pixels classified as vegetation from the RGB and multispectral composites and the nDSM. Then the classification steps were repeated, this time training using the remaining vegetation pixels in each raster layer into one of a few key plant species, with a few bin categories for grass and unidentified shrubs. This time the nDSM was added when using bands to create the signature file and perform the classification. Again, at the Plateau site, the multispectral data was not used.

In order to get a species count at each site, we had to determine the average number of pixels representing each plant in our classified vegetation species layer. To accomplish this, we used training sample polygons to count the number of pixels for about ~20-25 correctly identified specimens (using the RGB imagery to verify) and took the average of these counts. We then divided the number of pixels in each species category and divided this by the calculated pixels per species specimen.

c. Spatial variation

We originally examined the vegetation community types using synthmap08 before taking measurements on the sites (Fig. 5; Peterson, 2008). Synthmap08 ecological communities are defined with a 30m/pixel granularity. Thus, our higher resolution drone imagery and ground sampling data provided an opportunity to build more granular borders for our study sites. While the Plateau site clearly only contained a single vegetation community, the Spring site had three vegetation communities in successive bands moving away perpendicular from the spring stream corridor. We drew new vegetation community borders at the Spring site that were consistent with the Synthmap08 border, but followed clear delineations visible in the ground sampling, the RGB imagery, and the vegetation classification map (Fig. 6). We then used these new borders to divide the ground sampling and UAV data into the three ecological regions to analyze the different ecological conditions of these plant communities. This will also help determine whether the regions moving outwards from a riparian zone are affected differently by grazing.

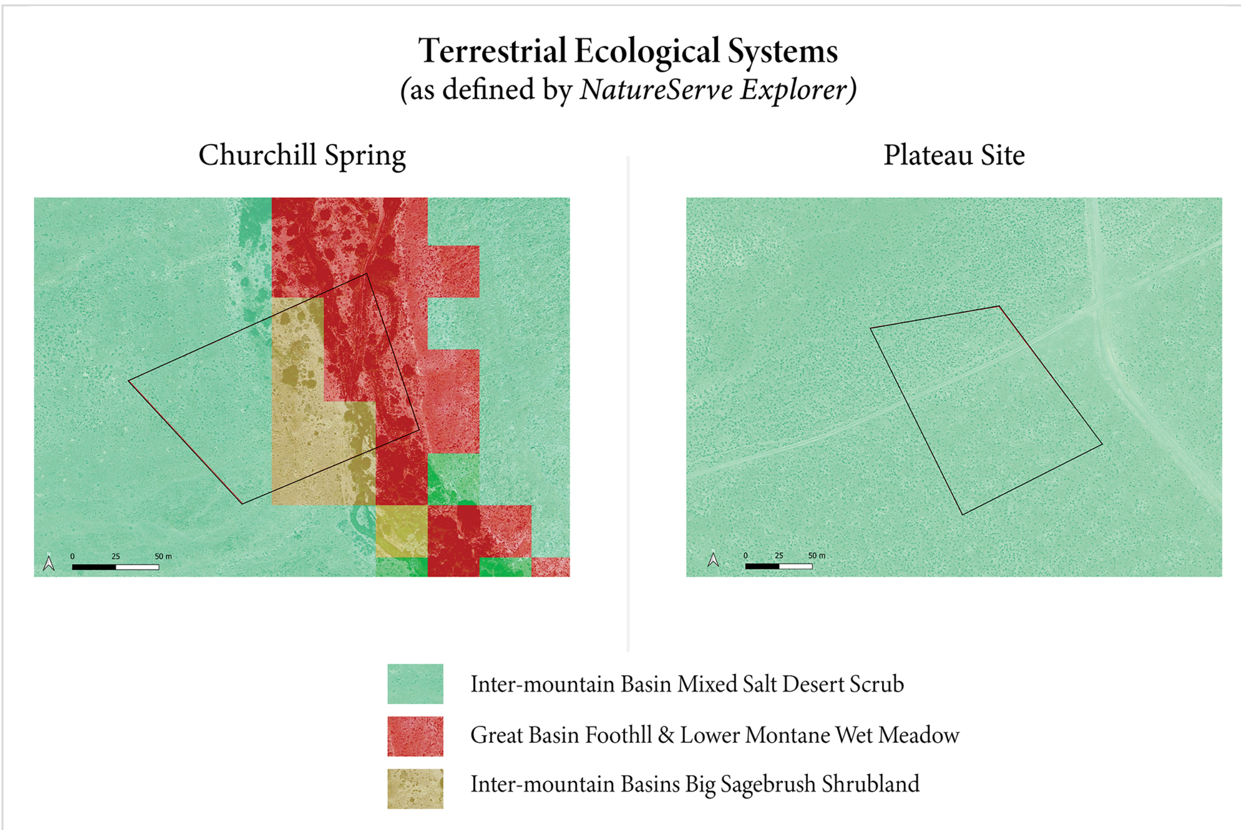



**Figure 5**. ***The ecological vegetation communities defined Synthmap08*** - The Spring site exhibits three systems while the Plateau is entirely composed of only one ecological system (*Inter-mountain Basin Mixed Salt Desert Scrub*).

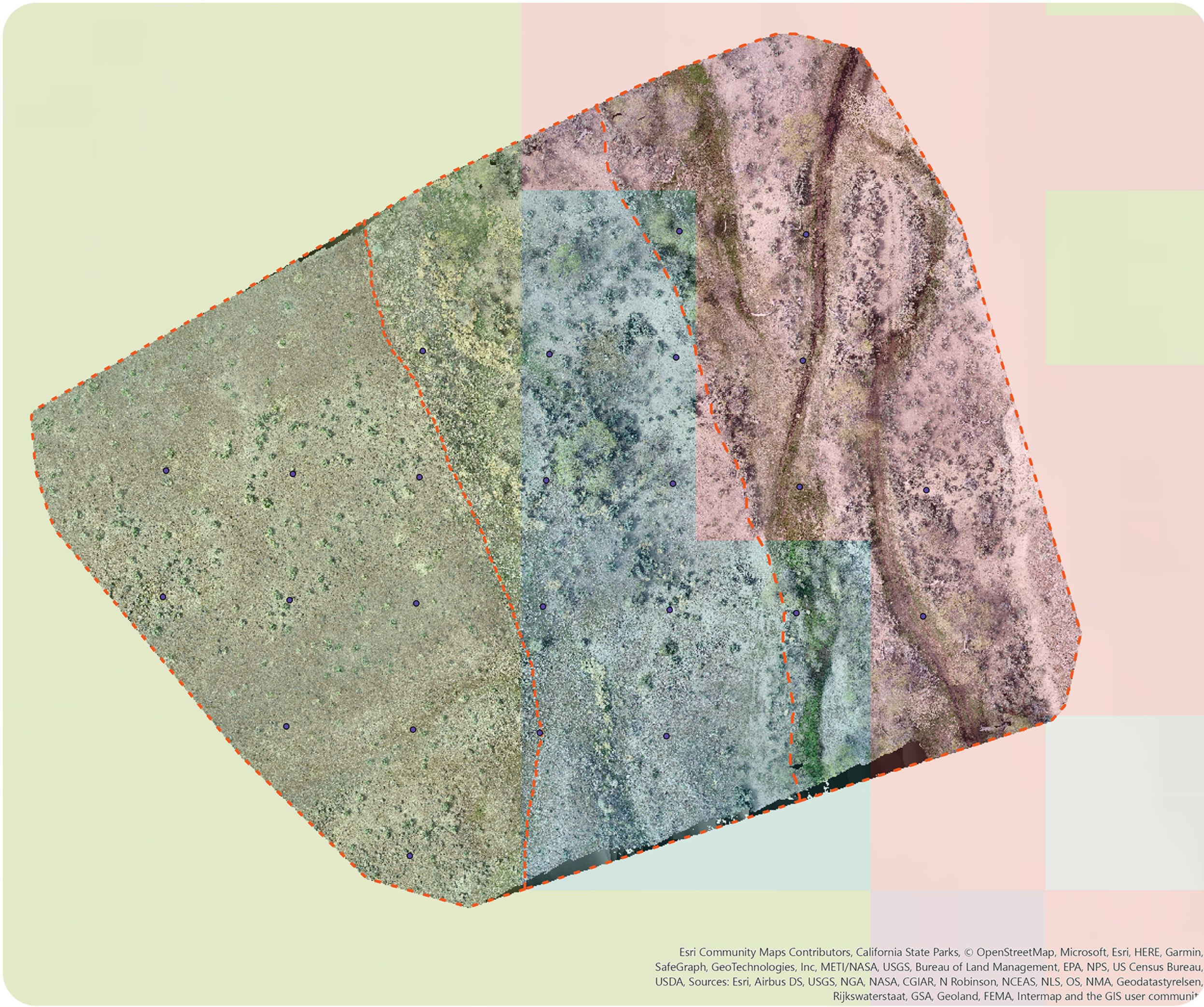



**Figure 6**. ***Redefined borders for three ecological systems at the Spring site*** - Showing the synthmap08 ecological systems as an overlay, a redefined border was established to better capture the transitions between *Inter-Mountain Basins Mixed Salt Desert Scrub* (left), *Inter-Mountain Basins Big Sagebrush Shrubland* (middle), and *Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland* (right).

### 4. *Criteria Calculation Methods*

#### a. *Species Diversity*

Ground Sampling:

Simpson's Diversity Index was calculated for each of the Transect plots, which counted vegetation type and abundance within a 12' radius. The score was also calculated for each of the plant communities at the spring site, as well as the for the entire Spring and Plateau sites.

UAS:

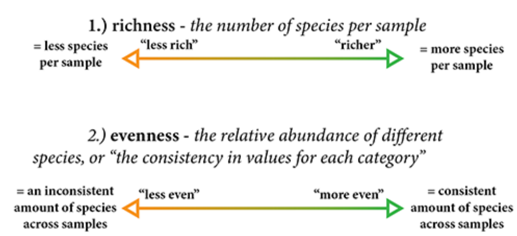
The Simpson's Diversity Index was also calculated using the species counts from the UAS measurements. This was done for each of the plant communities at the Spring site, and for the entire Spring and Plateau sites.

The formula is the following:

*Calculating Diversity Score:*

$$D \text{ (diversity)} = 1 - \left( \frac{\sum n(n-1)}{\sum N(N-1)} \right)$$

where: n = the total # of a particular species
N = the total number of organisms of all species
* scores range from 0.01 (low diversity) to 0.99 (high).
* final scores are standardized on scale of (0.1 to 1.0).




#### b. *Plant Density:*

Plant density was calculated using the total number of plants of a given species divided by the sample area. In the case of the UAS data, the total number of plants were the number of pixels in each area classified as that species divided by the average number of pixels per plant. The resulting number of plants is divided by the total hectares in the area. The ground sampling classification was the observed number of plants of a species in all the plots in the area divided by the combined area of all those plots.

**UAS density formula:** total number of plants / # of hectares in each community type

**Ground sampling density formula:** total number of plants / (# of plots * area of each plot)

#### c. *Ground Cover:*

Ground cover was only calculated for UAS data since we were not able to complete the ground point sampling.

**Cover percentage:** number of pixels in each category / total # of pixels X 100

## IV. Results

1. Diversity

Figs. 7, 8,9, & 10 show the diversity score and species count for the ground sampling plots. This data was also used to calculate the species density as described in the methods in 4a.

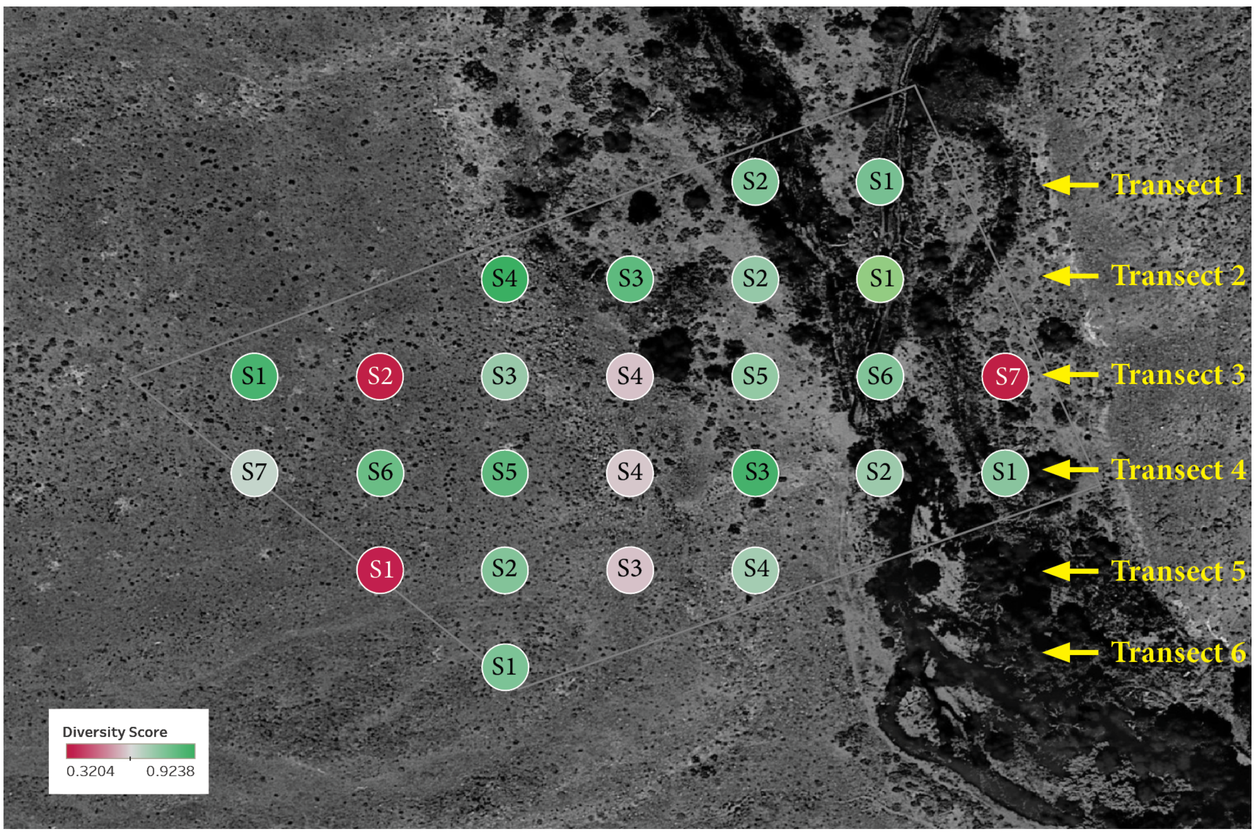



**Figure 7**. ***Measuring Diversity Index at Spring site*** - A total of 25 ground plots were measured for diversity. Lack of evenness in species distribution was the biggest factor for the low index scores.

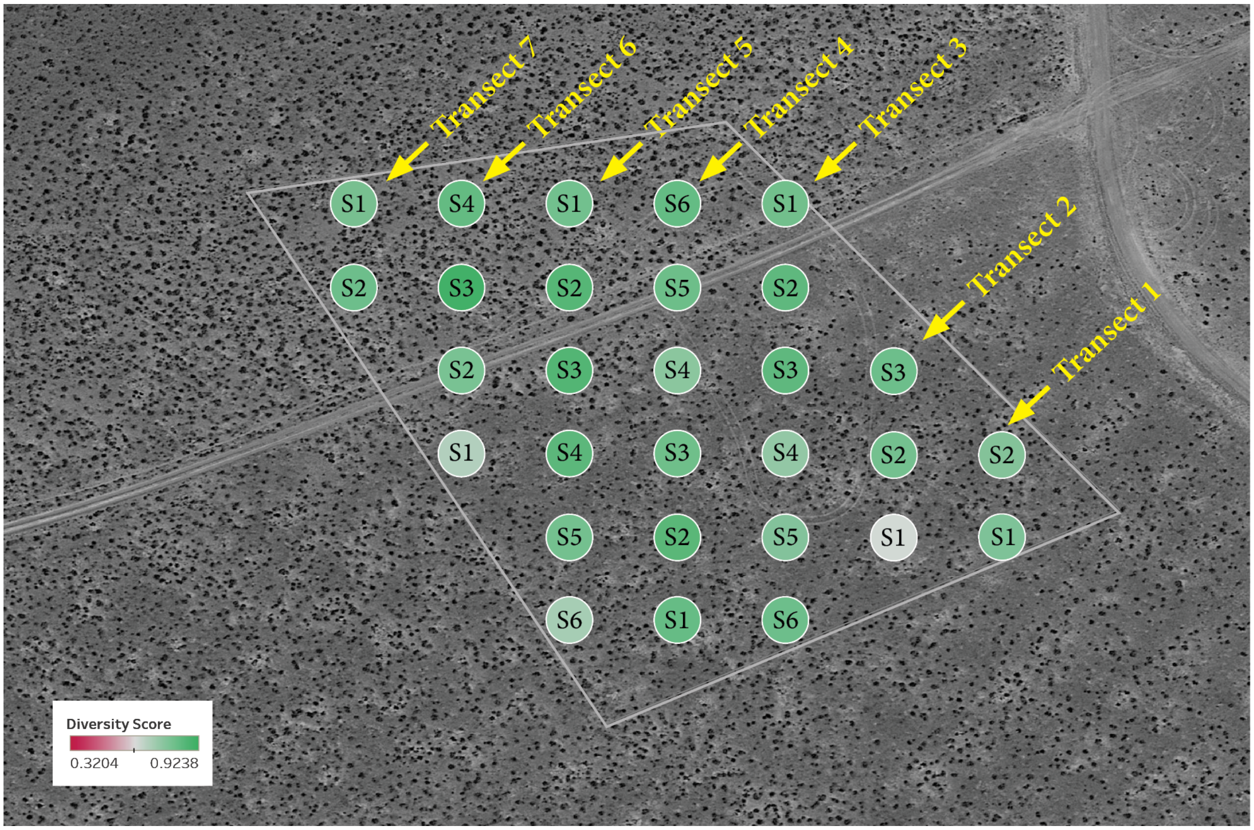



**Figure 8**. ***Measuring Diversity Index at Plateau site*** - A total of 29 ground plots were measured for diversity. Surprisingly high diversity scores (compared to Spring site) were attributed to better evenness in species count at each plot.

| | Common Sage (*Artemisia tridentata*) | Rabbitbrush (*Ericameria nauseosa*) | Bitterbrush (*Purshia tridentata*) | *Willow* (*Salix spp.*) | Milk Thistle (*Silybum marianum*) | Spiny Hopsage (*Grayia spinosa*) | Fourwing Saltbush (*Atriplex canescens*) | Shadscale (*Atriplex confertifolia*) | Desert Globemallow (*Sphaeralcea ambigua*) | Mormon Tea (*Ephedra viridis*) | Bud Sagebrush (*Artemisia spinescens*) | Greasewood (*Sarcobatus vermiculatus*) | Fremonts Pincushion (*Chaenactis fremontii*) | Desert Dandelion (*Malacothrix glarata*) | Bristly Fiddleneck (*Amsinckia tesselata*) | Grasses | Weeds | Cheatgrass | Diversity Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1S1 | | | | | | | | 1 | | | | 5 | 12 | | 10 | Sparse | Sparse | Medium | 0.778966132 |
| T1S2 | | | | | | | | 1 | | | | 7 | 11 | | 14 | Sparse | Sparse | Medium | 0.770580297 |
| T2S1 | | | | | | | | 2 | | | 6 | 1 | 21 | | | Sparse | Sparse | Medium | 0.636507937 |
| T2S2 | | | | | | | | 2 | | | 10 | 8 | | | 11 | Sparse | Sparse | Sparse | 0.801801802 |
| T2S3 | | | | | | | | 4 | | | 1 | 7 | | 1 | 10 | Sparse | Sparse | Sparse | 0.815270936 |
| T3S1 | | | | | | | | 1 | | | | 10 | 6 | | 7 | Sparse | Sparse | Medium | 0.806896552 |
| T3S2 | | | | | | | | | | | 3 | 8 | 5 | | 5 | Sparse | Sparse | Sparse | 0.846153846 |
| T3S3 | | | | | | | | 3 | | | 5 | 4 | 6 | | 11 | Sparse | Sparse | Medium | 0.845378151 |
| T3S4 | | | | | | | | 1 | | | | 6 | 14 | | 3 | Sparse | Sparse | Medium | 0.742528736 |
| T3S5 | | | | | | | | | | | 16 | 4 | 9 | | 4 | Sparse | Sparse | Sparse | 0.769230769 |
| T3S6 | | | | | | | | | | | 8 | 6 | 11 | | 3 | Sparse | Sparse | Medium | 0.814616756 |
| T4S1 | | | | | | | | 1 | | | 9 | 7 | 9 | | 2 | Sparse | Sparse | Medium | 0.827094474 |
| T4S2 | | | | | | | | | | | 1 | 5 | 5 | | 2 | Sparse | Sparse | Sparse | 0.859649123 |
| T4S3 | | | | | | | | 2 | | | 16 | 9 | 5 | | 10 | Sparse | Sparse | Medium | 0.809397163 |
| T4S4 | | | | | | | | | | | 4 | 7 | 15 | | 2 | Sparse | Sparse | Medium | 0.757575758 |
| T4S5 | | | | | | | | 1 | | | 1 | 8 | 9 | | 9 | Sparse | Sparse | Medium | 0.816399287 |
| T4S6 | | | | | | | | | | | 5 | 10 | 8 | | 6 | Sparse | Sparse | Medium | 0.830252101 |
| T5S1 | | | | | | | | | | | 2 | 8 | 5 | | 11 | Sparse | Sparse | Sparse | 0.804435484 |
| T5S2 | | | | | | | | 6 | | | 3 | 11 | 4 | 4 | 5 | Sparse | Sparse | Sparse | 0.867746289 |
| T5S3 | | | | | | | | 2 | | | 3 | 9 | 4 | 2 | 6 | Sparse | Sparse | Medium | 0.868951613 |
| T5S4 | | | | | | | | 5 | | | 11 | 8 | 8 | | 7 | Sparse | Sparse | Sparse | 0.853535354 |
| T5S5 | | | | | | | | | | | 2 | 11 | 4 | | 8 | Sparse | Sparse | Sparse | 0.8 |
| T5S6 | | | | | | | | 9 | | | 27 | 9 | 1 | | 3 | Sparse | Sparse | Sparse | 0.711111111 |
| T6S1 | | | | | | | | 2 | 1 | | 30 | 11 | 3 | | 4 | Sparse | Sparse | Sparse | 0.686090226 |
| T6S2 | | | | | | | | 1 | | | 18 | 9 | 6 | | 15 | Sparse | Sparse | Sparse | 0.791245791 |
| T6S3 | | | | | | | | 2 | | | | 4 | 1 | | 3 | Sparse | Sparse | Sparse | 0.908333333 |
| T6S4 | | | | | | | | 1 | | | 7 | 4 | 8 | | 11 | Sparse | Sparse | Medium | 0.833333333 |
| T7S1 | | | | | | | | 1 | | | 14 | 13 | 14 | 1 | 2 | Sparse | Sparse | Sparse | 0.794509804 |
| T7S2 | | | | | | | | 17 | 1 | | 14 | 11 | 5 | 1 | 2 | Sparse | Sparse | Sparse | 0.815789474 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 65 | 2 | 0 | 216 | 220 | 209 | 9 | 186 | | | | 0.810393075 |

**Figure. 9: *Species count for Plateau site*.** To allow 'grasses', 'weeds', and 'cheatgrass' to be quantified on a comparable scale to the other plant species, ground cover for these species was counted based on three category types: 'Solid' (most abundant, dense cover), 'Medium' (diffused cover throughout radius), and 'Sparse' (patchy or intermittent growth). Solid values are quantified with the value of "12", Medium values are counted as "6", and Sparse values are counted as "2". These numbers were chosen based on the median value for the entire dataset - coding them with low values allows them to have less weight (importance) in the overall score, as the quantification method for these is less precise.

| | Common Sage (*Artemisia tridentata*) | Rabbitbrush (*Ericameria nauseosa*) | Bitterbrush (*Purshia tridentata*) | *Willow* (*Salix spp.*) | Milk Thistle (*Silybum marianum*) | Spiny Hopsage (*Grayia spinosa*) | Fourwing Saltbush (*Atriplex canescens*) | Shadscale (*Atriplex confertifolia*) | Desert Globemallow (*Sphaeralcea ambigua*) | Mormon Tea (*Ephedra viridis*) | Bud Sagebrush (*Artemisia spinescens*) | Greasewood (*Sarcobatus vermiculatus*) | Fremonts Pincushion (*Chaenactis fremontii*) | Desert Dandelion (*Malacothrix glarata*) | Bristly Fiddleneck (*Amsinckia tesselata*) | Grasses | Weeds | Cheatgrass | Diversity Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1S1 | ` | | | 8 | | | | | | | | | | | | Solid | Medium | sparse | 0.794326 |
| T1S2 | 10 | | | | 1 | | | | | | | | | | | Medium | sparse | sparse | 0.778325 |
| T2S1 | 4 | 1 | | 1 | | | | | | | | | | | | Solid | Medium | sparse | 0.763066 |
| T2S2 | 13 | | | | | | | | | | | | | | | Medium | sparse | sparse | 0.735484 |
| T2S3 | 5 | | | | | | 2 | 5 | | | | | | | | Medium | Medium | sparse | 0.848276 |
| T2S4 | 3 | 3 | | | 1 | 2 | 4 | 1 | 1 | | | | | | | Sparse | sparse | sparse | 0.92381 |
| T3S1 | 1 | | | | | | | | 2 | | | | | | | Sparse | Sparse | Sparse | 0.888889 |
| T3S2 | 2 | | | | | | | | 65 | 1 | | | | | 5 | Sparse | Sparse | Sparse | 0.320351 |
| T3S3 | 1 | 2 | | | | 2 | 4 | | 15 | | | | | | | Sparse | Sparse | Sparse | 0.733333 |
| T3S4 | 14 | | | 1 | | | | 1 | | | | | | | | Sparse | Sparse | Sparse | 0.593074 |
| T3S5 | 5 | | | | | | | | 9 | | | | | | | Sparse | Sparse | Sparse | 0.742105 |
| T3S6 | 1 | | | 9 | | | | | | | | | | | | Solid | Sparse | Sparse | 0.773913 |
| T3S7 | 28 | | | | | | | | | | | | | | | Sparse | Sparse | Sparse | 0.320856 |
| T4S1 | 8 | | | | | | | | | | | | | | | Solid | Sparse | Sparse | 0.761099 |
| T4S2 | | | | 14 | | | | | | | | | | | | Medium | Sparse | Sparse | 0.725806 |
| T4S3 | | | 4 | | | | 2 | | 2 | | | | | | 3 | Sparse | Sparse | Sparse | 0.897059 |
| T4S4 | 1 | | | | | | 2 | | 17 | | | | | | 1 | Sparse | Medium | Dense | 0.60114 |
| T4S5 | 2 | | | | | | | | 5 | 1 | | | | | | Sparse | Sparse | Sparse | 0.846154 |
| T4S6 | 4 | | | | | 1 | | | 6 | | | | | | | Sparse | Sparse | Sparse | 0.823529 |
| T4S7 | 2 | | | | | | | | 11 | | | | | | | Sparse | Sparse | Sparse | 0.654971 |
| T5S1 | | | | | | 1 | | | 30 | | | | | | | Sparse | Sparse | Sparse | 0.342342 |
| T5S2 | 6 | | | | | | | | 7 | | | | | | | Sparse | Sparse | Medium | 0.77193 |
| T5S3 | 1 | | | | | | 1 | | 14 | | | | | | | Sparse | sparse | Medium | 0.593074 |
| T5S4 | | 1 | 2 | | | | | | 10 | | | | | | | Sparse | Solid | sparse | 0.71345 |
| T6S1 | | | | | | 1 | | | 9 | | | | | | | Medium | Sparse | Medium | 0.785714 |

**Figure. 10*: Species count for spring site*** - Mutual exclusivity plays a role here, as most of the Spring site species are not present (or were not discovered at sample plots) at the Plateau site.

2. Ground Cover

Fig. 11,12,15, & 16 show the ArcGIS raster classification input bands and results. Fig. 11 & 15 show the ground cover classification, and Fig. 12 & 16 show the vegetation classification. Fig. 13 & 17 show the vegetation classification confusion matrices. You can see the boundaries between the three plant communities as orange dotted lines that the classification maps were divided into in order to get the vegetation statistics and ecological criteria shown in Fig. 14 and the Analysis. The vegetation statistics for the single Plateau site vegetation community is shown in Fig. 18.

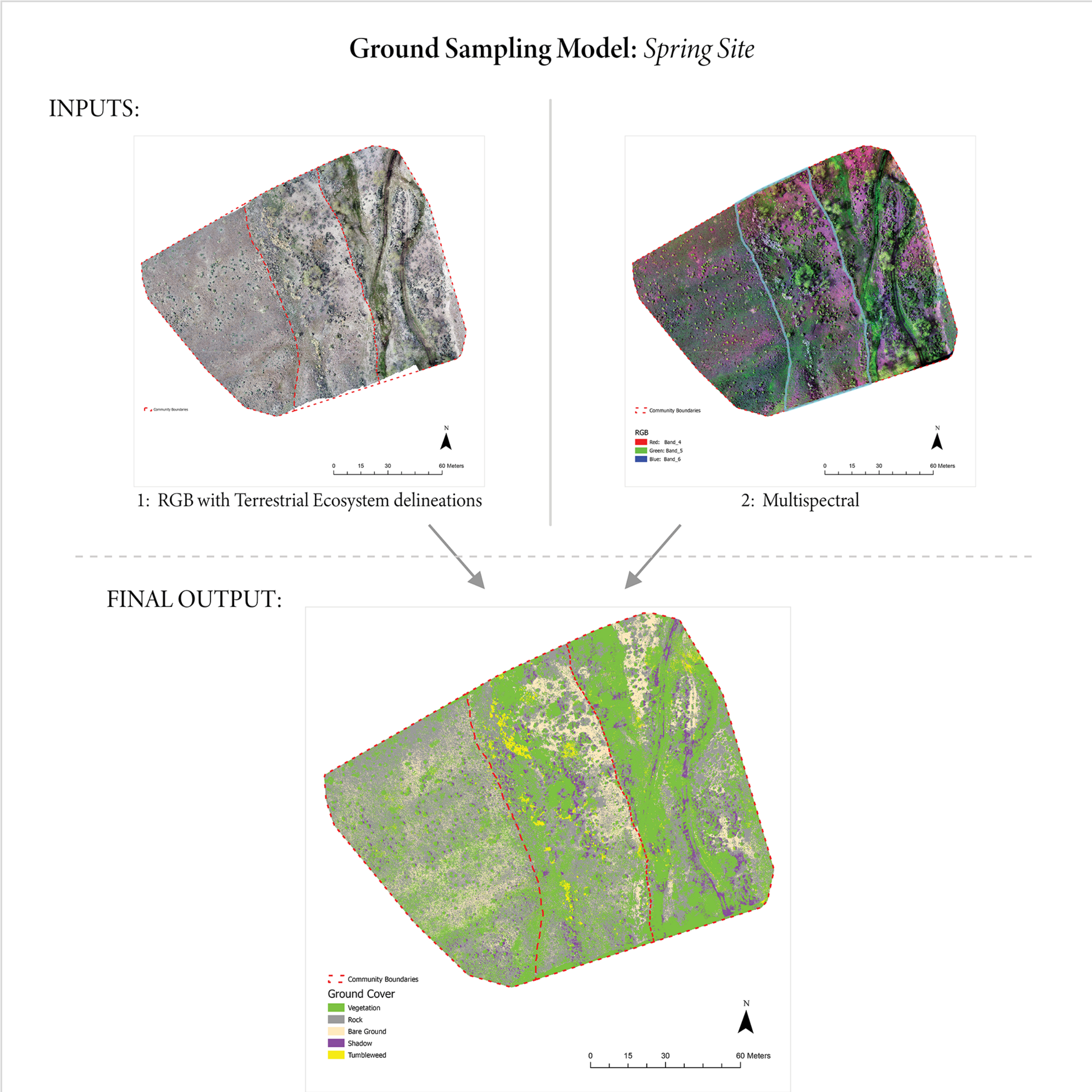



**Figure 11**. ***Ground sampling model for Spring site*** - Ground cover classification at the Spring site used 2 sets of bands as inputs.

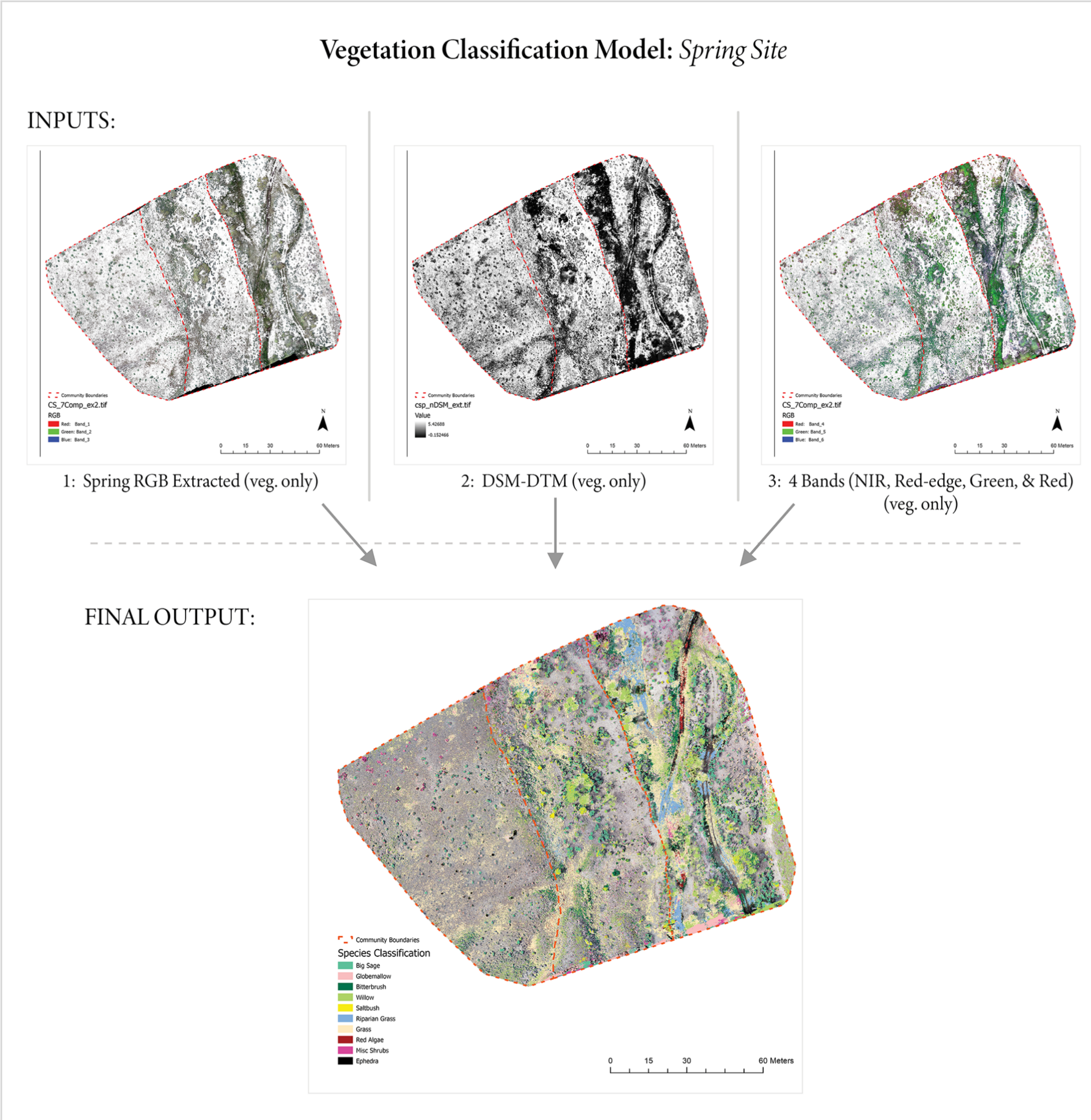



**Figure 12.** ***Vegetation classification model for Spring site -*** Vegetation classification at the Spring site used 3 sets of bands from vegetation only extracted rasters as inputs. The resulting classification statistics are shown in Fig. 14.

| ClassValue | Big Sage | Globemallow | Bitterbrush | Willow | Saltbush | Rip Grass | Grass Misc | Red Algae | Misc Bush | Ephedra | Total | U_Accuracy | Kappa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Big Sage* | 8 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 10 | 0.8 | 0 |
| *Globemallow* | 1 | 1 | 0 | 1 | 1 | 0 | 5 | 0 | 0 | 0 | 9 | 0.11111111 | 0 |
| *Bitterbrush* | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 0 | 1 | 0 | 10 | 0 | 0 |
| *Willow* | 0 | 0 | 0 | 4 | 0 | 0 | 7 | 0 | 0 | 0 | 11 | 0.36363636 | 0 |
| *Saltbush* | 4 | 0 | 0 | 3 | 2 | 0 | 1 | 0 | 0 | 0 | 10 | 0.2 | 0 |
| *Rip Grass* | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 1 | 0 |
| *Grass Misc* | 0 | 0 | 0 | 1 | 0 | 0 | 15 | 0 | 0 | 0 | 16 | 0.9375 | 0 |
| *Red Algae* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 9 | 1 | 0 |
| *Misc Bush* | 4 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 3 | 0 | 10 | 0.3 | 0 |
| *Ephedra* | 4 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 1 | 9 | 0.11111111 | 0 |
| **Total** | 21 | 1 | 0 | 12 | 4 | 11 | 41 | 9 | 4 | 1 | 104 | 0 | 0 |
| **P_Accuracy** | 0.380952 | 1 | 0 | 0.333333 | 0.5 | 0.909091 | 0.36585366 | 1 | 0.75 | 1 | 0 | 0.50961538 | 0 |
| **Kappa** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.443383 |

**Figure 13.** ***Vegetation classification Confusion Matrix for Spring Site -*** Vegetation classification confusion matrix shows that our Kappa value for this classification is 0.44.

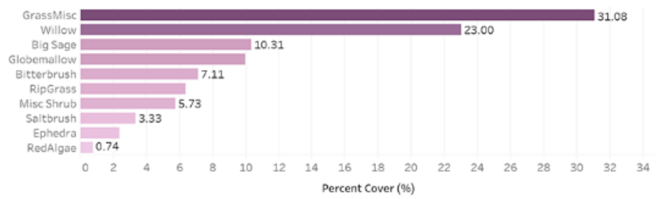
# Spring Site

## *Overall Vegetation:*

**Churchill Spring:** Overall Vegetation

| | Percent Cover | Area (ha) |
|---|---|---|
| Big Sage | 10.31 | 0.08 |
| Bitterbrush | 7.11 | 0.05 |
| Ephedra | 2.36 | 0.02 |
| Globemallow | 9.98 | 0.07 |
| GrassMisc | 31.08 | 0.23 |
| Misc Shrub | 5.73 | 0.04 |
| RedAlgae | 0.74 | 0.01 |
| RipGrass | 6.36 | 0.05 |
| Saltbrush | 3.33 | 0.02 |
| Willow | 23.00 | 0.17 |
| Total | 100.00 | |

**Churchill Spring:** Overall Vegetation
- Percent Cover

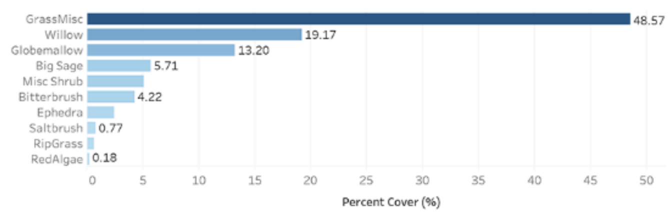



## *Mixed Salt Desert Scrub:*

**Churchill Spring:** Mixed Salt Desert Scrub

| | Percent Cover | Area (ha) |
|---|---|---|
| RedAlgae | 0.18 | 0.00 |
| RipGrass | 0.65 | 0.00 |
| Saltbrush | 0.77 | 0.00 |
| Ephedra | 2.45 | 0.00 |
| Bitterbrush | 4.22 | 0.01 |
| Misc Shrub | 5.07 | 0.01 |
| Big Sage | 5.71 | 0.01 |
| Globemallow | 13.20 | 0.02 |
| Willow | 23.00 | 0.17 |
| GrassMisc | 48.57 | 0.09 |
| Total | 100.00 | |

**Churchill Spring:** Mixed Salt Desert Scrub
- Percent Cover

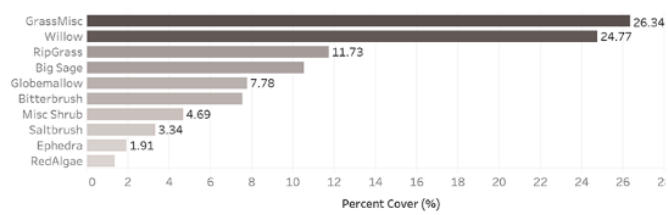



## *Riparian Woodland and Shrubland:*

**Churchill Spring:** Riparian Woodland and Shrubland

| | Percent Cover | Area (ha) |
|---|---|---|
| GrassMisc | 26.18 | 0.06 |
| Willow | 22.97 | 0.05 |
| Big Sage | 13.19 | 0.03 |
| Globemallow | 11.08 | 0.02 |
| Bitterbrush | 8.49 | 0.02 |
| Misc Shrub | 7.79 | 0.02 |
| Saltbrush | 5.12 | 0.01 |
| Ephedra | 3.00 | 0.01 |
| RipGrass | 2.01 | 0.00 |
| RedAlgae | 0.16 | 0.00 |
| Total | | |

**Churchill Spring:** Riparian Woodland and Shrubland
- Percent Cover




## *Big Sagebrush Shrubland:*

**Churchill Spring:** Big Sagebrush Shrubland

| | Percent Cover | Area (ha) |
|---|---|---|
| GrassMisc | 26.18 | 0.06 |
| Willow | 22.97 | 0.05 |
| Big Sage | 13.19 | 0.03 |
| Globemallow | 11.08 | 0.02 |
| Bitterbrush | 8.49 | 0.02 |
| Misc Shrub | 7.79 | 0.02 |
| Saltbrush | 5.12 | 0.01 |
| Ephedra | 3.00 | 0.01 |
| RipGrass | 2.01 | 0.00 |
| RedAlgae | 0.16 | 0.00 |
| Total | | |

**Churchill Spring:** Big Sagebrush Shrubland
- Percent Cover

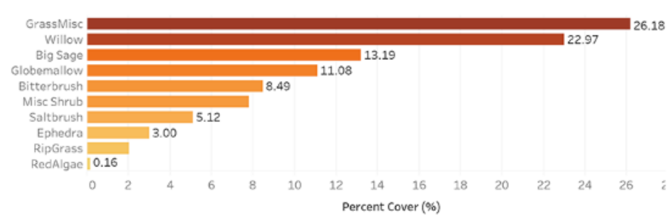


**Figure 14.** ***Spring site cover (above)-*** Summarizes the percent and area cover of each vegetation species or class from the Spring vegetation classification map. The overall Spring site stats are shown at the top is followed by the results for each of the three ecological systems.

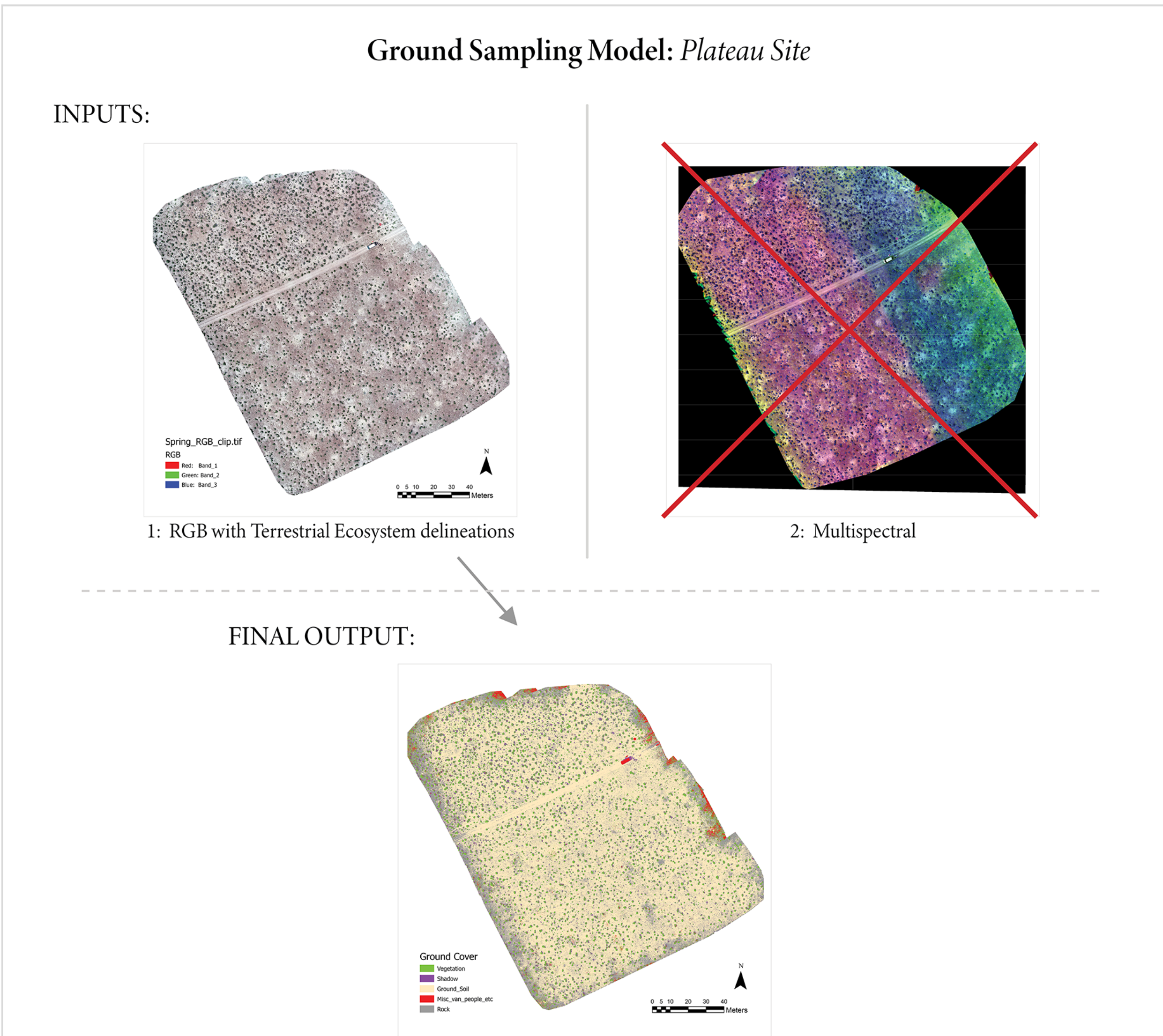



**Figure 15.** ***Ground sampling model for Plateau site -*** Ground cover classification at the Plateau site used 1 set of bands as inputs since the multispectral imagery was intensely banded.

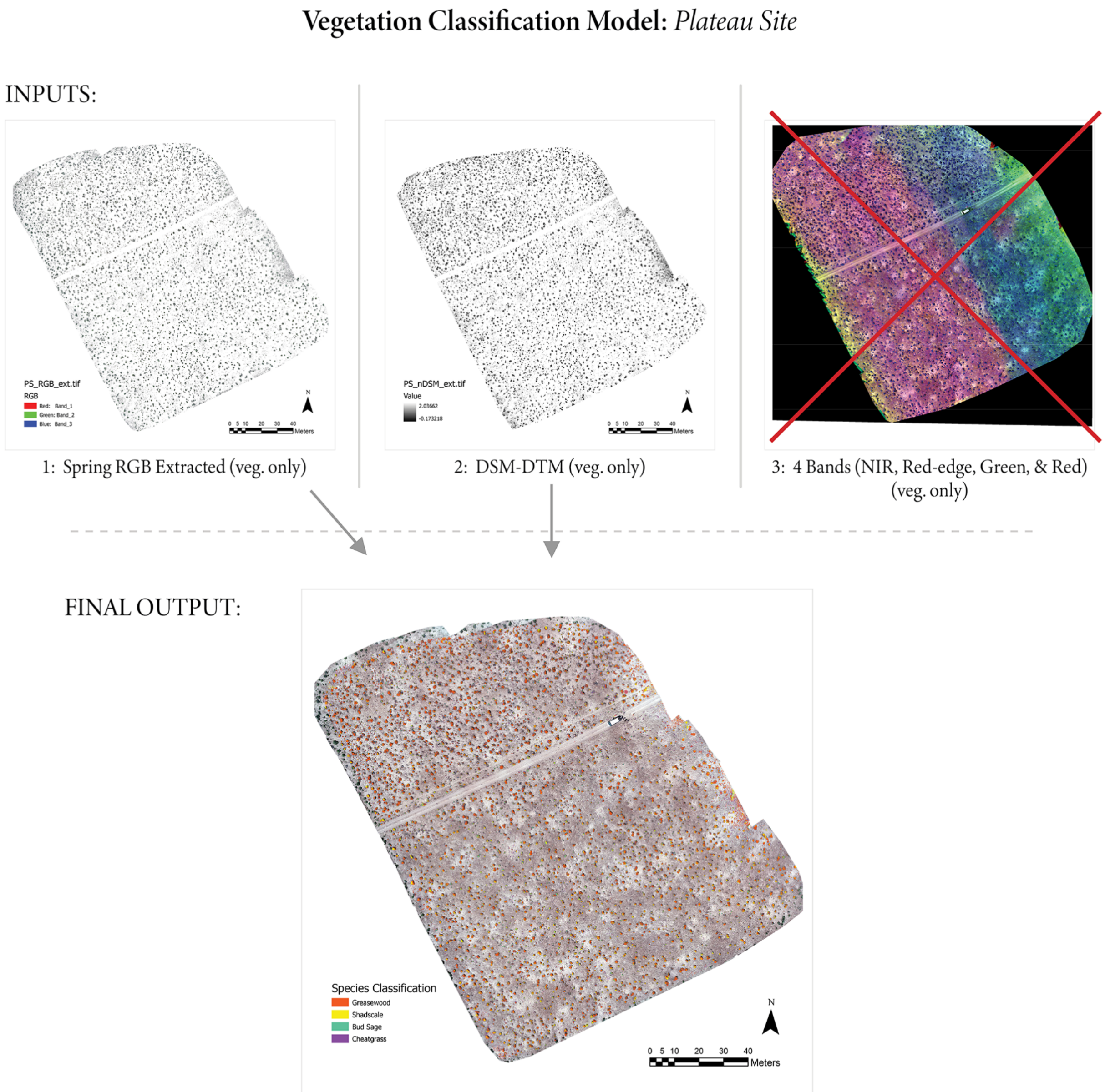



**Figure 16.** ***Vegetation classification model at Plateau site -*** Vegetation classification at the Plateau site used 2 sets of bands from vegetation only extracted rasters as inputs since the multispectral imagery was intensely banded. The resulting classification statistics are shown in Fig. 18.

| ClassValue | Greasewood | Shadscale | Bud Sagebrush | Cheatgrass | Total | U_Accuracy | Kappa |
|---|---|---|---|---|---|---|---|
| *Greasewood* | 20 | 1 | 1 | 2 | 24 | 0.83333333 | 0 |
| *Shadscale* | 6 | 4 | 0 | 0 | 10 | 0.4 | 0 |
| *Bud Sagebrush* | 6 | 1 | 3 | 0 | 10 | 0.3 | 0 |
| *Cheatgrass* | 0 | 0 | 1 | 12 | 13 | 0.92307692 | 0 |
| **Total** | 32 | 6 | 5 | 14 | 57 | 0 | 0 |
| **P_Accuracy** | 0.625 | 0.6666667 | 0.6 | 0.8571429 | 0 | 0.68421053 | 0 |
| **Kappa** | 0 | 0 | 0 | 0 | 0 | 0 | 0.531293 |

**Figure 17.** ***Vegetation classification Confusion Matrix for Plateau Site -*** Vegetation classification confusion matrix shows that our Kappa value for this classification is 0.53.

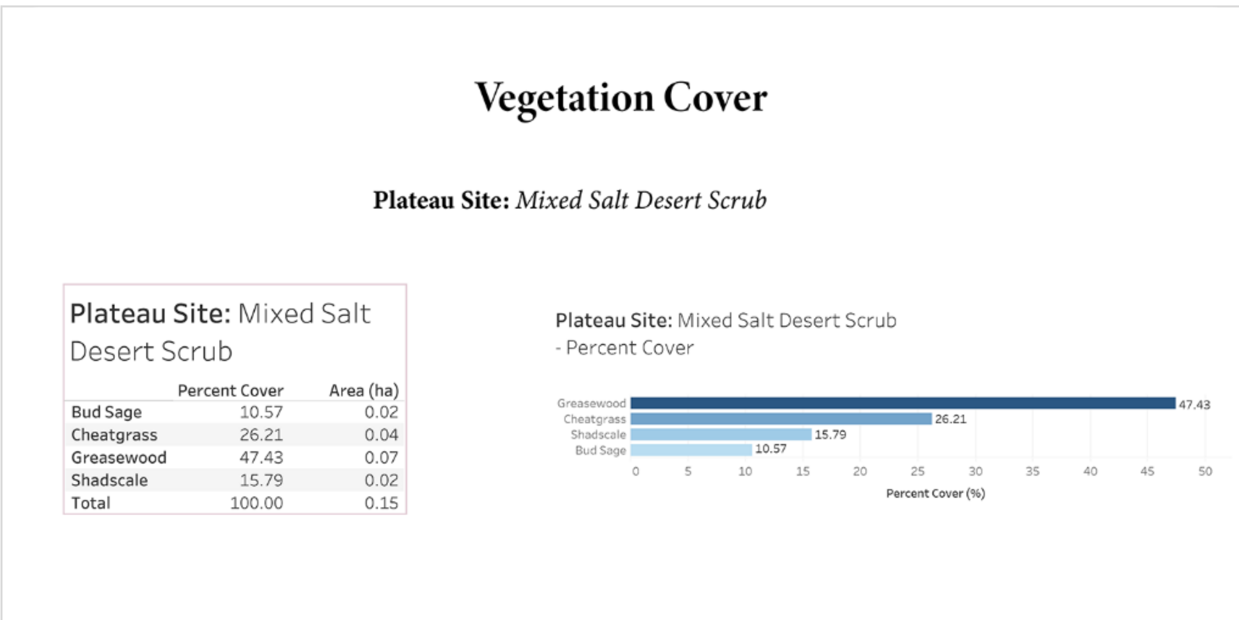



**Figure 18.** ***Vegetation cover at Plateau site -*** This summarizes the percent and area cover of each vegetation species or class from the Plateau vegetation classification map.

## V. Analysis

1. Plateau to Spring Site Diversity Comparison

Aggregation of Diversity scores at each site provided overall Global indices. While the Spring site had a wider range of Diversity scores and the highest single-plot Diversity score (Transect 2, sample 4 = 0.9238), it had a lower overall Global score (0.738 vs 0.810). The Plateau site scored higher for Global Diversity even with less overall species (i.e. species “richness”), largely due to the fact that each site had a much more uniform and equivalent distribution of the three heavy-hitters for *Inter-mountain Basin Mixed Salt Desert Scrub:* Greasewood, Shadscale, and Bud sagebrush.

Most plants found at each site were mutually exclusive; however, our sample plots only covered a small portion of the total polygon area. With a deeper scouring of the environment, it's possible to find more shared species between the sites. The non-mutually exclusive plants include Shadscale, Bristly Fiddleneck, Cheatgrass, and Desert globemallow.

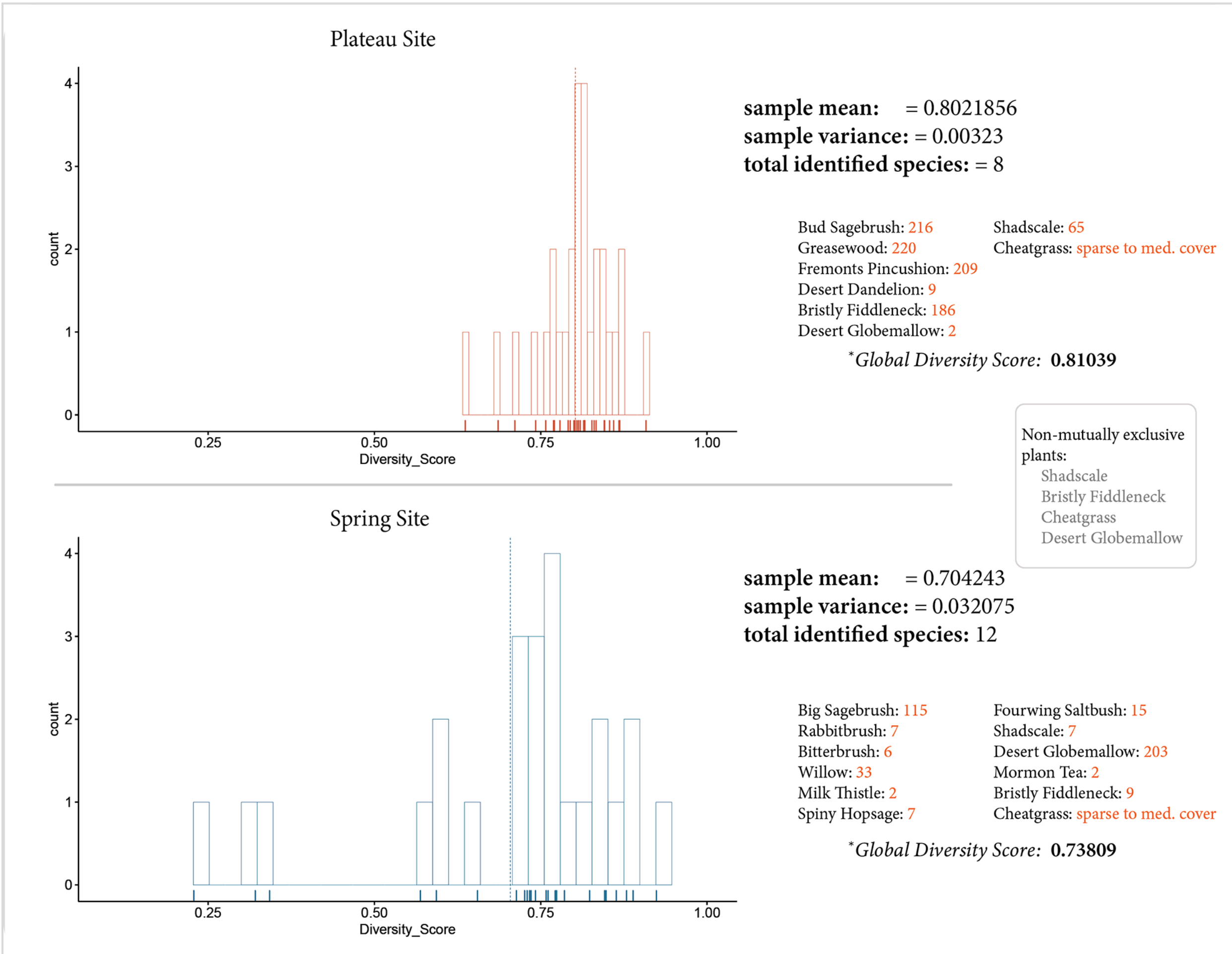



**Figure 19.** ***Comparison of Diversity indices* -** Overall, the Plateau site had a higher Diversity score than the Spring site (0.81039 vs 0.73809). Less variation in scores between sample plots can be easily seen by the compact nature of the Plateau site's histogram, while the Spring site's histogram illustrates much less uniformity between samples.

2. UAS to Ground Sampling Comparison

The next step in our analysis involves comparing the UAS plant density and diversity to the ground sampling density and diversity in order to test the accuracy of the UAV data. Fig. 20, which shows this analysis, suggests that the UAS measurements are often hundreds to thousands of specimens off in density and ~50% off the diversity score. In general, the density was calculated to be a lot higher with the ground sampling data. However, the relative proportions of species seen in the Ground Sampling data are often captured by the UAS measurements. The same largely holds for the Diversity score with relative changes between the ecological sites being mirrored in the UAS values. For example, looking at the Spring site, the diversity for the Mixed Salt Desert Scrub is almost half the diversity for the Big Sagebrush Shrubland for both Ground and UAS measurements. Again, the diversity for Big Sagebrush Shrubland is close to the diversity score of the Riparian Woodland and Shrubland.

There are a number of readily apparent explanations for the discrepancies between the ground sampling and UAS metrics. The most obvious is that the classification of the UAS orthomosaic data is clearly wrong in many places. This can be seen by the detection of species in vegetation communities that they are not found in such as the presence of 20 willow trees in the Spring site Mixed Salt Desert Scrub that we noticed were clearly not present even outside of our ground sampling plots when sampling that vegetation community. Another, likely source of the discrepancy was an inability to identify smaller samples of species either alone or in clumps from the orthomosaic when counting the average number of pixels per species specimen that were counted during the ground sampling. This is likely the explanation for why the ground sampling data produced much higher densities in most cases where a species was counted in both UAS and ground sampling since the ground sampling would have accounted for smaller specimens where the UAS data didn't. This likely applies to many of the species including Big Sagebrush and Desert globemallow. Desert globemallow in particular was extremely abundant as a very small plant as well as an occasional larger shrub. It was impossible to make out the smaller specimens with the UAV RGB orthomosaic. The reason the UAV data gave estimates as close to the ground sampling estimates as it did was likely due to abundant partial misclassification of sagebrush and other species as Desert globemallow.

This analysis assumes that the ground sampling methods are accurate and establish a benchmark for the UAS data reach. However, the UAS data, although plagued with potential issues and misclassifications, represents a measurement of the whole population of the flight areas, whereas the ground plots are a sample of the population. Thus assuming classifications errors can be kept to a minimum, the UAS data should represent a truer measure of the vegetation.

**Plateau Site:** *Mixed Salt Desert Scrub*

| | plant/ha UAV | plant/ha Ground |
|---|---|---|
| Greasewood | 810 | 2493 |
| Shadscale | 949 | 736 |
| Bud sagebrush | 1020 | 2447 |

Overall Diversity Score

| | UAV | Ground |
|---|---|---|
| Diversity | 0.664 | 0.810 |

**Spring Site:** *Mixed Salt Desert Scrub*

| | plant/ha UAV | plant/ha Ground |
|---|---|---|
| Big sagebrush | 166 | 452 |
| Desert globemallow | 2741 | 3902 |
| Bitterbrush | 26 | 0 |
| Willow | 20 | 0 |
| Saltbrush | 14 | 119 |
| Ephedra | 45 | 48 |

Overall Spring Diversity Score

| | UAV | Ground |
|---|---|---|
| Diversity | 0.320 | 0.738 |

Mixed Salt Desert Scrub Diversity Score

| | UAV | Ground |
|---|---|---|
| Diversity | 0.168 | 0.497 |

**Spring Site:** *Big Sagebrush Shrubland*

| | plant/ha UAV | plant/ha Ground |
|---|---|---|
| Big sagebrush | 574 | 1279 |
| Desert globemallow | 3458 | 1160 |
| Bitterbrush | 79 | 178 |
| Willow | 35 | 30 |
| Saltbrush | 140 | 506 |
| Ephedra | 82 | 0 |

Big Sagebrush Shrubland Diversity Score

| | UAV | Ground |
|---|---|---|
| Diversity | 0.354 | 0.822 |

**Spring Site:** *Riparian Woodland and Shrubland*

| | plant/ha UAV | plant/ha Ground |
|---|---|---|
| Big sagebrush | 643 | 1734 |
| Desert globemallow | 3404 | 0 |
| Bitterbrush | 99 | 0 |
| Willow | 53 | 1088 |
| Saltbrush | 128 | 0 |
| Ephedra | 73 | 0 |

Riparian Woodland and Shrubland Diversity Score

| | UAV | Ground |
|---|---|---|
| Diversity | 0.378 | 0.715 |

**Figure 20.** ***UAV vs Ground methods -*** This summarizes the percent and area cover of each vegetation species or class from the vegetation classification map. The overall Spring site stats are shown in the top row, while the stats for each of the three vegetation communities are shown in the three rows below.

3. Comparing UAS Vegetation Cover to Ecological Benchmark Cover

The final part of our analysis involves comparing the UAS vegetation community percent ground cover metrics to the vegetation community benchmarks found within the NatureServe Explorer database to determine the impact of grazing and other land-use at the site (Crawford et al., 2016; Nachlinger et al., 2014; Schulz, 2015). The results of this analysis are summarized in Fig. 21.

The Spring site mixed salt desert scrub vegetation community fits well within Benchmark 1, and thus appears to be in healthy ecological shape. The mixed salt desert scrub vegetation community has two potential benchmarks representing different ecological development phases. The first Benchmark is the Mid-Development 1 Open phase and 45% of the total area across the Western US of this vegetation community is found in this phase. Benchmark 2 is Early Development 1 which accounts for 25% of the area in this community.

The Spring site big sagebrush shrubland is within Benchmark 1 (Mid Development 1 Open) which accounts for the majority of total area across the Western US of this vegetation community (50%) with other developmental phases either lasting a short time or including extensive pinyon-juniper encroachment. Shrubs account for 19.7 percent of the cover fitting into the benchmark of 11-50% cover. Grasses are supposed to be codominant, and are somewhat close at 11.4% cover, but this might still be a bit low. Given that this site is located near a riparian zone, it should experience lower fire disturbance, and thus the cover percentages above which are on the low side of meeting the benchmarks might be taken as evidence of heavy grazing. However, although pinyon-juniper is absent, willow tree cover make up 9.3 percent ground cover, helping make up for the lower Shrub and Grass cover than might be expected.

The Spring Site riparian woodland and shrubland makes the lower end of the shrubs and grasses benchmark, perhaps again due to grazing. The tree cover is lower than the shrubs and grasses cover, which is opposite to the stated benchmark, however, this is likely due to a bias in site selection to a part of the spring with unusually little tree cover to aid UAS methods. On the whole, it is likely that the low cover indicates extensive grazing or land use impact, but the benchmarks shows that the vegetation community still is barely healthy.

The Plateau site mixed salt desert scrub is on the border of Benchmark 1 & 2 when looking at Shrub cover. In order to determine the correct benchmark, an accurate measurement of the grass cover is needed. The UAS data classification was not able to detect the majority of the cheatgrass, and thus the 1.8% cover is highly inaccurate. If the grass cover was only 10-25%, the site would be on the verge of failing the Benchmark 1, showing unhealthy community conditions. If however the grass cover was >50% the site would be comfortably within Benchmark 2 with abundant shrub cover and would thus be considered healthy in this analysis.

**Spring Site:** *Mixed Salt Desert Scrub*

| | Percent cover | Benchmark 1 | | Benchmark 2 |
|---|---|---|---|---|
| Shrubs | 9.8 | 5-20% | (or) | 0-5% |
| Grasses | 15.3 | ~10-25% | | >50% |
| Trees | 5.95 | - | | - |

*Interpretation:* Fits well inside Benchmark 1 (Mid Development 1 Open ~45% of community type) and thus seems healthy.

---

**Spring Site:** *Big Sagebrush Shrubland*

| | Percent cover | Benchmark 1 | | Fire Severity |
|---|---|---|---|---|
| Shrubs | 19.7 | 11-50% | (&) | lower fire severity? |
| Grasses | 11.4 | co-dominant | | |
| Trees | 9.3 | - | | |

*Interpretation:* For low fire serverity, cover seems a bit low for this vegetation community (within Mid Development 1 Open). The tree cover might help make up for it.

---

**Spring Site:** *Riparian Woodland and Shrubland*

| | Percent cover | Benchmark 1 | | Fire Severity |
|---|---|---|---|---|
| Shrubs | 19.4 | >15-50% | (&) | lower fire severity? |
| Grasses | 20.7 | >15-50% | | |
| Trees | 13.4 | > Shrub or Grass | | |

*picked a clear site for drone survey

*Interpretation:* Although trees are not dominant, this is likely due to bias in site selection for the drone survey. However, for the lack of tree cover, shrub/grass cover is a bit low considering the lower fire severity, thus showing the grazing influence.

**Plateau Site:** *Mixed Salt Desert Scrub*

| | Percent cover | Benchmark 1 | | Benchmark 2 |
|---|---|---|---|---|
| Shrubs | 5.0 | 5-20% | (or) | 0-5% |
| Grasses | 1.8 | ~10-25% | | >50% |

*Interpretation:* Classification of grasses was problematic, and thus it is unclear whether the site barely passes Benchmark 1 (Mid Development 1), or if it is comfortably within benchmark 2 ( Early Development 1).

**Figure 21.** ***Vegetation Community Ecological Health Assessment -*** This figure shows the vegetation community ecological health assessment using percent cover of Shrubs, Grasses and Trees compared to NatureServe Explorer Benchmarks (Crawford et al., 2016; Nachlinger et al., 2014; Schulz, 2015).

## VI. Conclusion & Final Discussion:

Overall, this study provides a test-of-concept and workflow for cattle grazers and land managers who are interested in monitoring their rangeland for ecological health using UAS. It also provides an assessment of the impacts of grazing across multiple plant community types in spring riparian areas.

Our analyses suggest that there is evidence of significant grazing impact on the Spring Big sagebrush shrubland and riparian woodland and shrubland areas, but that these areas are both still ecologically healthy. The Spring site mixed salt desert scrub is healthy while the Plateau site mixed salt desert scrub ecological condition is unknown. Our recommendation from this part of the analysis is that grazing does not have to be reduced but that these sites should be closely monitored to ensure the conditions do not degrade any further.

However, it is unclear how accurate this analysis is given the significant errors notable when comparing the UAV vegetation metrics to the ground sampling vegetation metrics. In order to make the workflow in this study robust for rangeland managers to assess the ecological conditions of their riparian and upland sites, steps would need to be taken to produce a more accurate classification. Possible steps to accomplish this include including an NDVI as a band in the image classification, and making the training polygons out in the field to reduce any possible human misclassification and to be sure to include small scrubs when counting the pixels/plant.

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