*Study area*

This study was conducted in Beef Basin on the Monticello District of the Bureau of Land Management (BLM) in San Juan County, Utah (Map 1). It is on the Colorado Plateau south of Canyonlands National Park and north of the Abajo Mountains, also locally known as the Blue Mountains. Beef Basin is an area characterized by flat plains of deep sandy soil covered in grass, and interspersed and surrounded by shallow rocky outcrops with piñon pine (*Pinus edulis*) and juniper (*Juniperus osteosperma*). It is located at 37°58'14.4"N 109°55'46.2"W with an elevation range of 1845 meters to 2020 meters. Mean precipitation of the study area is approximately 20.5 mm during the winter and 28.4 mm during the summer. Mean winter temperatures range from 5.4˚C to -7.7˚C, and mean summer temperatures range from 30.2˚C to 13.2˚C (1981-2010 PRISM data, Daly et al. 2008).

This study focused primarily on North Plain and South Plain which are the two southernmost plains in the basin, but a larger view of the whole basin was also conducted using data collected by and in collaboration with the United States Geological Survey (USGS). Recreation and cattle grazing are the primary uses for the area.

*Sampling design*

The North Plain and South Plain plots were selected using ArcGIS to randomly sample across the two basins based on the three dominant soil types (Begay, the Ignacio/Leanto complex, and Mido) (Utah AGRC) and 4 vegetation classes which were assigned using a quartile break based on September 2011 NDVI values (2011 NAIP 1m 4-band imagery from Utah AGRC). They were buffered a minimum of 50-m from roads, the edge of the study basins, and other sample points. The USGS plots were selected from the whole of Beef Basin using conditioned Latin Hyper Cube (cLHC). These selected plots were then subject to elimination or minor adjustment based on certain on-the-ground criteria. Sites had to be completely within one vegetation type, safely accessible (ie. not on a cliff face), and buffer requirements set above using ArcGIS were confirmed on the ground. A total of 99 plots were sampled within North Plain and South Plain, with an additional 37 USGS plots added to the dataset for a total of 136 sampled sites. 6 of the USGS plots were located within North Plain or South Plain. Sites were sampled from May to August of 2013.

*Methods*

Upon reaching a sampling site photos were taken at the plot center in the four cardinal directions. Vegetation cover, soil surface characteristics, and shrub density were collected using line-point-intercept (LPI) and belt transects. Additional plot photos were taken at the beginning and end of each transect. Detailed methods used in the field are described below. These methods were used to collect both the North Plain and South Plain data as well as the USGS data, with the exception that the USGS plots removed transect lines two and four.

*Data Collection Methods*

Data on ground cover (litter, lichens and mosses, rocks, bare ground) and foliar cover of vascular plants (by species and functional group, live or standing dead) will be collected along five 30-m transects using the line-point intercept method (Herrick et al. 2005). **A pin flag will be dropped every 0.5 m along each transect starting at 0.5 m and ending at 30 m for 60 points per transect or 300 points per plot**.

Plot Layout

1. Transects will be separated by 7 m and will be oriented parallel to the hillslope contour.
2. The central transect will be centered on the soil pit (15 m each side) but offset 2 m upslope of the soil pit leaving 3 m downslope of the pit to use for the tarp and soil descriptions as well as a 2 m buffer before the next transect.
3. If there is no perceptible slope orient the transects on an E-W axis and offset the central transect to the north
4. Transects will be numbered starting with the most downslope transect. If there is no perceptible slope, transect 1 will be the southernmost transect.
5. If the plot will cross a clearly changing vegetation boundary (e.g. 4 transects in grassland but transect 5 in sagebrush) shift the plot, **including the soil sampling point**, the minimum distance needed to fit the entire plot into vegetation that is visually similar to what is found at the original soils sampling point.
6. If there is not room to fit a plot into relatively homogeneous vegetation, drop the sampling point and move to the next for that category.

7 m

7 m

7 m

7 m

2 m

5 m

15 m

Transect 1

Transect 5

Transect 4

Transect 3

Transect 2

0 m

30 m

**Line-point intercept**

1. Begin at the “0” end of the transect.
2. Working from left to right, move to the first point on the line (0.5 m). Always stand on the same side of the line (downslope side of line for sites with slope, south side without slopes).
3. Drop a pin flag to the ground from a standard height of 5 cm above herbaceous canopy next to the tape on the side on which you are not standing.

***Rules***

3.1 The pin should be held vertical before dropping.

3.2 The pin should be dropped from the same height (~ 5cm) above the vegetation each time. A low drop height minimizes “bounces” off of vegetation but increases the possibility for bias.

3.3 Do not guide the pin all the way to the ground. It is more important for the pin to fall freely to the ground than to fall precisely on the mark.

3.3 If vegetation over the point is greater than arms-length, then the pin should never be dropped from higher than the height of the out-stretched arm.

1. If vegetation is above the height of the out-stretched arm, record the species as a “tree” or “shrub” foliar or canopy hit, appropriately. This will involve projecting upwards and attempting to clearly determine whether vegetation would be contacted if the pin were extended straight above.

***Rules***

* 1. If the pin hits a point where there is a shrub or tree canopy overhead without actually contacting the plant record the species code under the “shrub canopy” or “tree canopy” column. Record whether the branches of the tree above are dead or alive (Y=Dead, N= Alive). If the entire plant is dead put /D after the code.
  2. If a projection above the point would contact vegetation record it as a foliar hit.
  3. For a tree, if there is a hole of 50 cm or greater (i.e a very clear obvious gap in vegetation that extends all the way down to the pin) in the canopy with no vegetation, then no canopy hit will be recorded.
  4. For a shrub, if there is a gap of > 5 cm, then no canopy hit will be recorded.
  5. If the shrub or tree is unidentifiable record DS or DT in species code

1. Once the pin flag is flush with the ground, record every plant species it intercepts.

***Rules***

5.1 If the pin does not contact a shrub or tree, but the line at that point is surrounded (within the perimeter of the canopy) by shrub/tree vegetation from the same shrub/tree species with a gap in the vegetation < 5 cm (shrub) or 50 cm then record a canopy cover hit.

5.11 **If the pin contacts the shrub/tree species anywhere on that point do not record a “Shrub Canopy” hit (you will not have the same species recorded in the “Shrub Canopy” and the “Foliar Layer.”)**

5.12 Record the species code and whether the nearest branches in the canopy hit are live or dead using codes Y or N.

If the entire shrub is dead (has no leaves) identify to species if you can and note it is dead (e.g. ARTRW8/D). If it cannot be identified to species record it as dead shrub (DS) or dead tree (DT).

5.13 If there is a foliar hit of another species over a canopy hit, still record the canopy hit in the “Shrub Canopy” column.

5.2 Record the species of the first stem, leaf or plant base intercepted in the first “Foliar Layer” column using the PLANTS database species code (http://plants.usda.gov/).

5.21 If the pin intercepts standing dead material record the standing dead by growth form as follows:

DT Dead tree

DS Dead shrub

DF Dead forb

DG Dead grass

Record the species if you can.

5.22 If the point hits a dead branch of a shrub and the shrub is still alive record the species code and DP for the foliar hit (e.g. ARTRW8/DP). To clarify, for all shrubs, trees, and the large-padded *Opuntia*, but only for these, distinguish completely dead (D) and dead part of a live shrub (DP). We put the *Opuntia* in this category because in places large spreading clones are a patchwork of live and dead parts. If no suffix is added it is a foliar hit on live tissue. For herbaceous species when a foliar hit is on attached dead material (e.g last year’s growth of a perennial grass) consider it a live hit as long as any portion of the contacted plant is alive See appendix for list of species considered shrubs for the purposes of this study.

5.3 Record all additional species intercepted by the pin in the subsequent “Foliar Layer” columns.

5.4 Record each canopy or foliar species (including DT, DS, DF, DG) only once in the foliar *or* canopy columns, even if it is intercepted several times.

5.5 If you can identify the genus, but not the species either use the PLANTS database genus code (http://plants.usda.gov) or record a number for each new species of that genus. ALWAYS define the functional group for the unknown genus at the bottom of the data form.

5.6 Record herbaceous litter as “L,” if present. Litter is defined as detached dead stems and leaves that are part of a layer that comes in contact with the ground. Record “W” for detached woody litter that is greater than 5 mm (or ~1/4 in) in diameter and in direct contact with soil. **Litter and Woody Litter are the lowest foliar layer recorded**.

6. Record whether the pin intercepts a plant base or one of the following in the “Soil surface” column.

**R** = Rock

**R/FG** = fine gravel (>2-5mm diameter)

**R/G** = gravel (>5-76mm diameter)

**R/C** = cobbles (>76-250mm diameter)

**R/CH** = channers (>2-150mm diameter)

**R/F** = flagstones (>150-380mm long)

**R/S** = stones (>250-600mm diameter or >380-600mm long)

**R/B** = boulders (>600mm diameter or >600mm long)

**BR** = Bedrock

**EL** = Embedded litter

**D** = Duff

**M** = Moss

**LC** = Lichen crust on soil (lichen on rock is recorded as “R”)

**S** = Soil that is visibly unprotected by any of the above

If an ant mound or disc is present, record soil surface code followed by /AM or /AD (i.e. S/ AM)

**AD =** Ant Disk

**AM =** Ant Mound

***Rules***

6.1 If pin intercepts a live plant base record the plant code for soil surface. This is the only time one species may be recorded twice for one point (ARTR in ‘canopy’ or in ‘foliar’ layer and in ‘soil surface’.

6.3 If the pin hits the base of a dead plant enter “DS, DT, DF, DG” appropriately for the soil surface code.

6.4 Record embedded litter as “EL” where removal of the litter would leave an indentation in the soil surface or would disturb the soil surface. Record duff as “D” where there is no clear boundary between litter and soil and litter is not removed during typical storms (occurring annually).

6.4 Describe the size class of each rock hit recoding first that it is a rock hit (R), then the size class of the rock (e.g. R/G).

6.4.1. Fine gravel, gravel, and cobbles are roughly spherical

6.4.2. Channers and flagstones are flattish, stones.

6.4.3. Boulders can be either spherical or flat but have separate size requirements depending on the shape.

These rock classes can be found in the *Field Book for Describing and Sampling Soils* Version 3.0 page 2-47.

**Shrub Density: Belt Transect**

**This should be done after all other transect measurements are complete because it requires the data collector to walk along the side of the tape where all other measurements are taken from.**

1. Shrub Density will be sampled on the three central transects (transect 2, 3 and 4).
2. Using a meter pole, walk along each side of the transect and count the number of shrubs within 1 meter of the tape. For purposes of density only count *Yucca baccata* as shrubs

***Rules***

* 1. Shrub density counts are recorded by species in five different size classes (<15 cm juvenile, <15 cm mature, >15-50 cm, >50-100 cm, and >100 cm).
     1. Mature shrubs in the <15 cm category can be distinguished from juveniles in the same size class based on the growth form. For example, a sagebrush juvenile will generally have much thinner branches and be less sprawling than an adult in the same height class.
  2. Record by species and for *Artemisia tridentata* by subspecies.
  3. Also record by categories of dead versus alive.

**Soil Pit Methods**

1. The soil pit will be sampled two meters downslope of transect three, and five meters upslope of transect two. A tarp for soil descriptions will be placed downslope of the soil pit not exceeding three meters downslope. This will allow for a two meter buffer before the next transect. Soil data collected is to follow the standards in *Field Book for Describing and Sampling Soils* Version 3.0
2. Auger soil pit to two meters. Use sharpshooter (shovel) where soil is too rocky to reasonably permit auger use.
   1. Place auger on soil pit point and begin turning. Fill auger then empty onto tarp in as close an approximation of the soil pedon as possible.
   2. Measure and record depth of pit between each use of the auger. This will allow for the estimation of horizon depths.
   3. Continue auguring until a depth of two meters is reached or bedrock is reached.
      1. In the case that the auger can go no further but bedrock depth is suspect consider moving the soil pit one meter to the right. The narrow diameter of the auger can sometimes prevent it from continuing past a large rock.
   4. Use color, texture, structure (often destroyed by sharpshooter), pH, and any other means described in *Field Book for Describing and Sampling Soils* Version 3.0 to determine horizon breaks.
   5. Place markers at each horizon break and photograph the resulting pedon.
   6. Estimate the depths of each horizon based on the depth measurements collected for each auger pile and the location of the horizon break within the pile.
   7. Collect dry and moist matrix color (hue, value, chroma from the Munsell soil color charts), texture, rock fragment kind, percent, and size, sand percent and size, clay percent, pH, and effervescence. Collect structure (grade, size, type) and roots (quantity, size, location) from whichever horizons are within reach from the soil pit.
      1. Structure and roots are only collected from the top horizon(s) because they are inaccessible further down the soil pit (narrow hole) and are usually destroyed by removal with the auger.
   8. Record any other relevant data in the notes section of each horizon (carbonate coats, etc…)
3. Collect geomorphology, soil surface, and rough vegetation type data.
   1. Geomorphology data to be collected include landform, aspect (°), slope (%), slope shape landform, parent material, bedrock geology, soil depth class, and carbonate stage. *Field Book for Describing and Sampling Soils* Version 3.0 pages 1-(4-9), 2-(31-32)
   2. Soil surface data include rock fragment size classes (same as listed in LPI methods), percent cover of each noted class, and biotic crust classes (Brungard and Boettinger, 2012), as well as a photo of the undisturbed soil surface near the soil pit from two meters up with a soil knife for scale.
   3. A rough estimate of dominant vegetation types is to be collected using species code and an estimate of percent cover for each species.

Sagebrush leaf samples collected were the interior winter persistent leaves, and not the exterior early ephemeral leaves. They were collected twice, once in 2013, and once in 2014. In 2013 leaves were collected and weighed at night between midnight and 5:30 a.m. Because of the limited timeframe and poor visibility only 16 viable sites were sampled. Where possible, a total of four sagebrush individuals were sampled at each plot, with ten leaves collected from each plant. Otherwise, all sagebrush present were sampled. Samples were kept on ice while transferred to the lab, and leaf area was measured within 12 hours of collection. They were then dried and measured again. From this the percent dry weight (PDW) in grams, and the specific leaf area (SLA) in centimeters was obtained. The 2014 leaves were collected during the day, dried, and weighed. They were then wrapped in a square of tin foil and ran through a Laboratory Equipment Corporation (LECO) mass spectrometry machine which provided nitrogen and protein percentages for 67 sites.

