# Supplemental Information

## Supplemental Field Methods

Field methods were based on those in the NRCS Range and Pasture Handbook (Natural Resources Conservation Service, 2003). We surveyed at least one transect per 1,000 acres of each soil map unit. We used the most up-to-date Natural Resources Conservation Service (NRCS) Soil Survey available to determine the extent and location of soil map units. Transect locations were randomly generated before field sampling, stratified by soil map unit and located within 2 miles from existing roads. In the field, we navigated to each generated transect location and ensured it occurred in a location typical of the soil map unit. If the transect occurred in an atypical area, we shifted the location to collect data in a representative area. Once an appropriate location was selected, we dug a small pit to ensure that the soil matched descriptions of the soil map unit we intended to sample. Ecological sites were determined based on soil type and vegetation.

At each transect we laid out a 30.5 meter (100-foot) transect tape in a random orientation and recorded site data including geographic coordinates, elevation, slope, aspect, landscape position, soil series, and ecological site. We then inventoried the plant species present by scanning the entire transect area over a ten-minute period and noting all species encountered. One photo was taken in each cardinal direction at the transect location.

The primary data necessary to calculate total available forage and stocking rates were obtained by sampling the aboveground biomass of plant species. After laying out the transect tape, aboveground biomass of grasses and forbs was sampled in ten locations by laying out a 0.89 meter2 hoop (9.6 feet2) every 3.05 meters (10 feet) along the transect. When vegetation in the hoop was sparse, all aboveground biomass of vegetation within each hoop was clipped and weighed (referred to as “total harvest”). When vegetation was abundant, a representative sample of each species was weighed and used to estimate the number of units of that species in each hoop. The total weight of each species biomass was calculated by multiplying the weight of the representative unit by the number of units estimated in the plot. If using this approach, we clipped all of the vegetation in two hoops to evaluate the accuracy of estimates and adjusted estimations as necessary (referred to as “double sampling”). For example, if 100 grams of biomass of a species was estimated among two hoops, but clipping and weighing the biomass in those hoops yielded only 50 grams of that species, it was assumed that all estimates of that species along that transect were twice as high as they should be, and all estimates were divided by two to correct this bias.

Shrub productivity was sampled through a similar but separate method, by tracing a circle with an outstretched 3.6 meter (11.8 foot) rope at two locations along the transect, each covering 40.72 square meters (438 square feet). Then, the amount of every shrub species occurring within the circles was estimated by collecting a reference weight unit of each shrub species (such as one large branch) and estimating how many of these reference units were found within each shrub circle. The shrub reference unit was then weighed, stripped of foliage, and weighed again to determine the foliage weight of the unit, and therefore an estimate of the total foliage weight within the shrub circles.

Lastly, we estimated the “growth curve completed” and “amount ungrazed” of all species present at each transect. These characteristics helped determine how much plant productivity we were unable to measure when sampling the transect. The “growth curve complete” accounts for plant development that had not yet occurred at the time of sampling, meaning additional biomass would be produced later in the year. If we measured 100 grams of a forb which was flowering at the time of sampling, for example, we assumed only 75% of the species’ total annual production had been achieved at the time of sampling, and estimated that the species’ total production for the growing season would be 133.33 grams (100 grams / 0.75).

 Similarly, the “amount ungrazed” allowed us to account for productivity lost to grazing by wildlife or livestock prior to sampling. When grazing of a species was evident, we found ungrazed individuals of the same species at a similar level of development and compared their weight to the grazed individual’s (Natural Resources Conservation Service 2003). If we found that grazed individuals had 10% less biomass than ungrazed individuals, we estimated that the grazed individuals would have been 10% heavier if they were not grazed. We estimated the average level of grazing across the transect for each species to make this correction for each species.

A small sample of every species was collected to be dried later, since stocking calculations are based on dried biomass amounts. We dried biomass samples in an oven, calculated the proportion of mass lost by drying samples, and used this ratio to calculate the amount of dry biomass of species at each transect.

**Table S-1.** Species codes and palatability factors of vegetation (for cattle) in the study area, previously established. Palatability factors range from 0, meaning completely unpalatable and unavailable for cattle grazing, to 1, meaning completely palatable and fully available for cattle grazing. Species codes correspond to USDA plant symbols (USDA - NRCS 2020).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Species Code** | **Palatability Factor** | **Species Code** | **Palatability Factor** | **Species Code** | **Palatability Factor** |
| AAFF | 0.2 | CYOF | 0.2 | MIAL5 | 0.2 |
| AAGG | 0.6 | CYPU2 | 0 | MUAS | 0.4 |
| ABFR2 | 0.2 | DAFR6 | 0.2 | MUPU2 | 1 |
| ACGL | 0.2 | DAGL | 1 | MURI | 1 |
| ACHY | 1 | DALEA | 0.2 | NABR | 0 |
| ACLE9 | 1 | DECA18 | 0.6 | OECA10 | 0.1 |
| ACMI2 | 0.5 | DELPH PF | 0 | OENOT PF | 0 |
| ACNE9 | 1 | DENU2 | 0.2 | OEPA | 0.1 |
| ACRE3 | 0.2 | DEOC | 0.2 | OPFR | 0 |
| AGAU2 | 0.5 | DEPI | 0 | OPPO | 0 |
| AGCR | 1 | DESCU | 0.2 | ORFA | 0 |
| AGGI2 | 1 | DESO2 | 0 | ORLU | 0.2 |
| AGGL | 0.4 | DISP | 0.5 | OROBA AF | 0 |
| AGST2 | 0.5 | ECCO5 | 0 | ORPA3 | 0.3 |
| AGUR | 0.4 | ECHIN3 | 0 | ORSE | 0 |
| ALBR | 0.2 | ECTR | 0 | ORTO | 0.1 |
| ALDE | 0 | ELEL5 | 1 | OSDE | 0 |
| ALLIU PF | 0.2 | ELLA3 | 1 | PACA6 | 0.4 |
| ALYSS AF | 0 | ELTR7 | 1 | PAMU11 | 0 |
| AMAL2 | 0.8 | ELYMU AG | 1 | PAMY | 0.2 |
| AMBRO | 0.2 | ELYMU PG | 1 | PASM | 1 |
| AMSIN | 0.2 | ENNU | 0 | PECE | 0 |
| AMTE3 | 0.2 | EPBR3 | 0 | PEDIC | 0 |
| AMUT | 0.8 | EPCA3 | 0 | PEHU | 0.2 |
| ANDI2 | 0 | EPHED SH | 0.2 | PENST PF | 0.2 |
| ANMI3 | 0 | EPTO | 0.2 | PEPA6 | 0.2 |
| ANPA4 | 0 | EPVI | 0.2 | PEPU7 | 0.1 |
| ANPR4 | 0 | EQAR | 0 | PERA4 | 0.4 |
| ANTEN PF | 0 | EQHY | 0 | PESI | 0 |
| APIAC PF | 0 | EQUIS | 0 | PEWA | 0.2 |
| AQCA2 | 0 | ERAL4 | 0.2 | PHACE PF | 0.2 |
| ARABI2 PF | 0.1 | ERAR3 | 0.2 | PHAR3 | 0.7 |
| ARAC2 | 0.2 | ERBA5 | 0.2 | PHCO16 | 0.2 |
| ARBI3 | 0.2 | ERCA8 | 0.2 | PHCRC | 0 |
| ARCAV2 | 0.4 | ERCE2 | 0.2 | PHGR16 | 0.2 |
| ARCO5 | 0.2 | ERCI6 | 0 | PHHA | 0.2 |
| ARCO9 | 0.2 | ERCO14 | 0.2 | PHHO | 0 |
| ARCOC4 | 0.2 | ERCO3 | 0.2 | PHLO2 | 0.2 |
| ARENA PF | 0 | ERCO4 | 0.1 | PHLOX PF | 0.2 |
| ARFE3 | 0.2 | ERCO6 | 0.1 | PHMI4 | 0.4 |
| ARFI2 | 0.2 | EREP | 0.2 | PHYSA PF | 0 |
| ARFR4 | 0.4 | ERGO | 0.2 | PHYSA2 PF | 0.2 |
| ARHO2 | 0.2 | ERHE2 | 0.2 | PIDE4 | 0.2 |
| ARHO4 | 0.2 | ERIGE2 PF | 0.1 | PLIN7 | 0 |
| ARHOR | 0.1 | ERIN4 | 0.2 | PLJA | 1 |
| ARLUI2 | 0.2 | ERIOG PF | 0.2 | PLMA2 | 0 |
| ARMI2 | 0 | ERMI4 | 0.2 | PLPA2 | 0 |
| ARNIC PF | 0.2 | ERNA10 | 0 | POA PG | 1 |
| ARNICA PF | 0.3 | EROC | 0.2 | POBU | 1 |
| ARNO4 | 0.6 | EROV | 0.2 | POCO | 1 |
| ARNU | 0 | ERPU2 | 0.1 | PODI2 | 0.6 |
| ARPA6 | 0.2 | ERPU9 | 0 | POFE | 1 |
| ARPE | 0.1 | ERRA3 | 0.2 | POGR9 | 0.2 |
| ARPU2 | 0.2 | ERSH | 0.2 | POPR | 1 |
| ARPU9 | 0.2 | ERSP4 | 0.1 | POSE | 1 |
| ARTEM PF | 0.2 | ERUM | 0.2 | POTEN | 0.2 |
| ARTRB3 | 0.3 | EUBR | 0 | POTR5 | 0.5 |
| ARTRT | 0.2 | EUEN | 0.3 | PPFF | 0.2 |
| ARTRV | 0.4 | EUES | 0 | PPGG | 1 |
| ARTRW8 | 0.2 | EUPHO | 0 | PRUNU SH | 0.2 |
| ASCH7 | 0.2 | FABAC PF | 0.6 | PRVI | 0.2 |
| ASCO12 | 0.2 | FEOV | 1 | PSJU3 | 1 |
| ASFL | 0 | FESTU | 0.2 | PSSP6 | 1 |
| ASPU9 | 0 | FETH | 1 | PTAN2 | 0 |
| ASRA2 | 0 | FRITI PF | 0 | PUTR2 | 1 |
| ASTE5 | 0.2 | FRSP | 0.4 | QUGA | 0.4 |
| ASTER AF | 0.1 | FRVI | 0.2 | RAJO | 0 |
| ASTER PF | 0.2 | GABO2 | 0.1 | RHAR4 | 0.2 |
| ASTER SH | 0.2 | GALIU PF | 0.1 | RHTR | 0.2 |
| ASTRA PF | 0 | GERAN PF | 0.3 | RIAU | 0.2 |
| ATCA2 | 0.6 | GERI | 0.3 | RIBES SH | 0 |
| ATCO | 0.6 | GEVI2 | 0.3 | RICE | 0.2 |
| ATCO4 | 0.6 | GLLE3 | 0.1 | RIIN2 | 0.2 |
| ATCUC | 0.6 | GLSPM | 0.2 | RIMO2 | 0 |
| ATRIP | 0.6 | GRSP | 0.6 | ROWO | 0.2 |
| BAAM4 | 1 | GRSQ | 0 | RUHY | 0.1 |
| BAHO | 0.4 | GUSA2 | 0 | RUID | 0.2 |
| BAPR5 | 1 | HACKE PF | 0 | RUPA | 0.1 |
| BASA3 | 0.4 | HAFL2 | 0 | SACO6 | 0.6 |
| BASC5 | 0 | HAGL | 0 | SADR | 0.1 |
| BOGR2 | 1 | HEAN3 | 0.2 | SAEX | 0.1 |
| BORAG AF | 0 | HEBO | 1 | SALIX SH | 0.1 |
| BORAG PF | 0.1 | HECO26 | 1 | SALSO | 0 |
| BRAN | 1 | HECY2 | 0 | SALU2 | 0.4 |
| BRASS2 AF | 0 | HEMU3 | 0 | SANIC5 | 0.4 |
| BRASS2 PF | 0 | HENU | 0.2 | SARA2 | 0.4 |
| BRCA5 | 1 | HETER8 | 0.2 | SATR12 | 0 |
| BRCI2 | 1 | HEVIV | 0 | SAVE4 | 0.4 |
| BRIN2 | 1 | HOJU | 1 | SAXIF PF | 0 |
| BRMA4 | 1 | HOUM | 0 | SCLER10 | 0 |
| BROB | 0.2 | HYFI | 0.2 | SCLI | 0 |
| BROMU AG | 0 | HYLA7 | 0 | SEIN2 | 0 |
| BROMU PG | 1 | IPAG | 0.1 | SELA | 0 |
| BRTE | 0 | IPPO2 | 0.1 | SENEC PF | 0 |
| CAAN7 | 0.2 | IPPU4 | 0 | SESE2 | 0.2 |
| CACR11 | 0.2 | IRIS PF | 0.2 | SHCA | 0.1 |
| CAFL | 0 | IRMI | 0.1 | SIAL2 | 0 |
| CAFL7 | 0.2 | IVAX | 0.1 | SILI5 | 0 |
| CAGE2 | 0.2 | JUBAM | 0.4 | SIOF | 0 |
| CALI4 | 0.2 | JUCO6 | 0.1 | SOLID | 0 |
| CALOC PF | 0.2 | JUNCU PG | 0.4 | SOMI2 | 0.2 |
| CANE2 | 0.2 | KOMA | 0.8 | SONA | 0 |
| CANU3 | 0.2 | KOPR80 | 1 | SOVE6 | 0 |
| CAPR5 | 0.2 | KOSC | 1 | SPAI | 0.6 |
| CAREX | 0.2 | KRLA2 | 1 | SPCO | 0.6 |
| CAREX PG | 0.2 | LACTU PF | 0.1 | SPCR | 0.6 |
| CARH4 | 0.2 | LALA3 | 0.4 | SPHAE PF | 0.6 |
| CARO5 | 0.2 | LAOC3 | 0 | SPPA2 | 0.6 |
| CASTI2 | 0 | LASE | 0.1 | STAC | 0 |
| CASTI2 PF | 0.2 | LECI4 | 1 | STARA | 0 |
| CEANO SH | 0.2 | LEFR2 | 0.2 | STELL PF | 0 |
| CELE3 | 0.4 | LELA2 | 0 | STEX | 0 |
| CEMO2 | 0.4 | LEMO2 | 0.2 | STMIM | 0.2 |
| CETE5 | 0 | LEPE2 | 0.2 | STPI6 | 0 |
| CEVE | 0.4 | LEPID | 0.2 | SUCA2 | 0.2 |
| CHAEN PF | 0 | LEPU | 0.2 | SUMO | 0 |
| CHAL7 | 0.3 | LESA4 | 1 | SYOR2 | 0.2 |
| CHAME2 | 0 | LESAS | 1 | TAOF | 0.6 |
| CHDE2 | 0 | LIGL2 | 0 | TARA | 0 |
| CHDO | 0 | LILE3 | 0 | TARAX | 0 |
| CHENO AF | 0 | LILY AF | 0.2 | TEAX | 0.2 |
| CHER2 | 0.1 | LILY PF | 0 | TECA2 | 0 |
| CHFE3 | 0.1 | LINAN2 PF | 0 | TEGL | 0.2 |
| CHGR6 | 0 | LIPE2 | 0.6 | TENU2 | 0 |
| CHMA15 | 0 | LIPU11 | 0 | TESP2 | 0 |
| CHRYS SH | 0 | LIRU4 | 0.1 | THAR5 | 0 |
| CHST | 0 | LITHO3 | 0.2 | THCA11 | 0 |
| CHTE2 | 0 | LOCA4 | 0.6 | THCL | 0 |
| CHVI8 | 0 | LOCO6 | 0.4 | THFE | 0.1 |
| CHVIL4 | 0 | LOMAT PF | 0.2 | THLAS AF | 0 |
| CIAR4 | 0.1 | LOTR2 | 0.2 | THMO6 | 0 |
| CINE | 0.2 | LUAR3 | 0 | THSA2 | 0.2 |
| CIRSI PF | 0.1 | LUPIN PF | 0 | TOIN | 0 |
| CIUN | 0.1 | LUPU | 0 | TORY | 0 |
| CIVU | 0.1 | LYJU | 0 | TOWNS PF | 0.2 |
| CLCO2 | 0 | MAAF | 0 | TRCA13 | 0 |
| CLLI2 | 0.2 | MACA2 | 0.1 | TRDU | 0.2 |
| CLLU2 | 0 | MAGR2 | 0.1 | TRIFO PF | 1 |
| COKI | 0.2 | MALE3 | 0.6 | TRRE3 | 1 |
| COLLO PF | 0 | MARA7 | 0.2 | UKSH | 0.2 |
| COOR | 0.2 | MARE11 | 0 | URDI | 0 |
| COPA3 | 0 | MASO | 0 | VAED | 0 |
| CORET | 0.2 | MAST4 | 0.2 | VETH | 0.1 |
| COUM | 0.1 | MATO2 | 0.2 | VIAM | 0.8 |
| CRAC2 | 0.4 | MEAL6 | 0 | VUOC | 0 |
| CRBA6 | 0.2 | MEAR4 | 0.4 | YUCCA | 0 |
| CREPI PF | 0.4 | MEDI6 | 1 | YUHA | 0 |
| CRFL6 | 0 | MEDIC | 0.6 | YUHAS | 0 |
| CRYPT AF | 0 | MENTZ | 0.2 | ZIGAD | 0 |
| CRYPT PF | 0 | MEOF | 0.6 | ZUBRP | 0.4 |

**Table S-2.** Pearson’s correlations and p-values of observed forage at transects to covariates included in modeling.

|  |  |  |  |
| --- | --- | --- | --- |
| **Covariate** | ***R*** | ***r*2** | ***p-*value** |
| Annual Maximum NDVI | 0.372 | 0.138 | 4.99\*10-30 |
| NRCS Estimated Rangeland Production | 0.340 | 0.116 | 5.14\*10-25 |
| May-June VPD | -0.323 | 0.104 | 1.22\*10-22 |
| January-June Precipitation | 0.288 | 0.083 | 4.21\*10-18 |
| May-June Maximum Temperature | -0.262 | 0.069 | 3.64\*10-15 |
| May-June Minimum Temperature | -0.260 | 0.068 | 5.72\*10-15 |
| Depth to Restrictive Layer | 0.243 | 0.059 | 3.58\*10-13 |
| Available Water Capacity | 0.227 | 0.052 | 1.17\*10-11 |
| pH | -0.224 | 0.050 | 2.39\*10-11 |
| Elevation | 0.218 | 0.048 | 8.41\*10-11 |
| Tree Cover | -0.150 | 0.023 | 8.75\*10-6 |
| Silt | -0.137 | 0.019 | 5.21\*10-5 |
| Sand | 0.113 | 0.013 | 0.0009 |
| Sodium Adsorption Ratio | -0.110 | 0.012 | 0.0011 |
| Northness | -0.081 | 0.007 | 0.0170 |
| Organic Matter | 0.077 | 0.006 | 0.0222 |
| Cation Exchange Capacity | 0.063 | 0.004 | 0.0641 |
| Clay | -0.043 | 0.002 | 0.2084 |
| Compound Topographic Index | 0.013 | 0.000 | 0.6907 |
| Slope | 0.013 | 0.000 | 0.7070 |

## References

Natural Resources Conservation Service, 2003. National Range and Pasture Handbook [WWW Document]. URL <https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1043084> (accessed 6.26.20).

USDA - NRCS. 2020. The PLANTS Database, National Plant Data Team, Greensboro, NC 27401-4901 USA. [WWW Document]. URL <https://plants.usda.gov> (accessed 26.05.20).