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Spatial Analysis of Livestock Grazing and Forest Service Management in the High Uintas Wilderness, Utah - A Case Study

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Abstract

This case study addresses the Forest Service reauthorization for grazing of 12,850 ewe/lamb pairs of domestic sheep in ten grazing allotments covering 160,410 acres in Utah's High Uintas Wilderness. It provides an approach to evaluate livestock grazing here as well as in other areas. The evidence of widespread damage from grazing sheep in areas that are susceptible to degradation of soil and plant communities make change necessary as wilderness and ecosystem values are compromised. We address the Forest Service's criteria for determining lands capable of supporting livestock grazing by field determination of forage production and GIS analysis incorporating aerial imagery. As defined by the Forest Service, capable lands for grazing domestic sheep include slopes ≤45%, forage production ≥200 lbs/acre, lacking dense timber, soils that are not unstable or highly erodible, ground cover >60%, and areas within one mile of water. While the Forest Service determination of capable lands shows 35.7% of the lands are capable, our analysis led to a determination that only 6% of the lands are capable for domestic sheep if current forage production is used (Case 1). If the Forest Service determination of forage production generated in the 1960's is used, which is their most current evaluation, then only 1.8% of the lands are capable (Case 2). When we apply current forage production to the capable acres, Case 1 provides only 10.6% of the current forage demand, while Case 2 provides only 3.2% of the demand. This indicates stocking rates should be reduced by 90% (Case 1) and 97% (Case 2). The failure of the agency to align stocking rates with capacity has led to ecosystem damage, degradation of wilderness values and wildlife habitat.

Key Words

- Livestock, capacity, wilderness, spatial analysis, normalized difference vegetation index, remote sensing

1. Introduction

In 2014, the Ashley National Forest (ANF) and the Uinta-Wasatch-Cache National Forest (UWCNF) in Utah initiated a scoping process for the High Uintas Wilderness Domestic Sheep Analysis, followed by a Draft Environmental Impact Statement in 2019 (USDA 2014a; 2019a). The purpose of the project is to reauthorize grazing of 12,850 ewe/lamb pairs of domestic sheep on ten grazing allotments totaling 160,410 acres within the High Uintas Wilderness which lies in NE Utah's Uinta Mountain Range. As part of this process, the public is asked to provide comments on the proposed plans.

Due to the importance of these watersheds, their associated water supplies for the public, wilderness qualities, and concerns for the effects of this proposal on native fish and wildlife, the authors and volunteers engaged in a study and Geographic Information System (GIS) analysis to inform the Forest Service environmental analysis. The goal of the study was to evaluate the capacity of the allotments to support domestic sheep grazing using Forest Service criteria, field data collection and image analysis combined in a GIS analysis. Using such a technique offers a means of reducing or eliminating many of the negative impacts of livestock grazing by balancing livestock use with available capacity by avoiding placing livestock in sensitive areas such as steep slopes, unstable or highly erodible soils. This can lead to healthier watersheds, reduction of soil erosion, restoration of fish and wildlife habitat and their associated populations across not only wilderness areas, but all livestock-grazed public and private lands.

1.1 Livestock Grazing Extent and Effects

There are approximately 3.4 billion ha worldwide that are grazed by livestock, with 73% estimated to be suffering soil degradation (Gabathuler et al., 2009). In the western USA, livestock are permitted to graze on over 103 million acres within the National Forest System and 168 million acres of public lands managed by the Bureau of Land Management (Fleischner, 1994). These BLM and Forest Service managed lands suffer degradation with over 50% in poor or fair condition (GAO, 1988).

In the Lower 48 States, there are 52 million acres of wilderness, 13 million acres of which are grazed by domestic livestock (WW, 2019). Thirty active livestock grazing allotments cover 272,768 acres of the High Uintas Wilderness (USDA, 2016a). It was designated wilderness in 1984 and includes 456,705 acres. This wilderness area is managed by the Ashley and Uinta-Wasatch-Cache National Forests in Region 4 (USDA, 2019b). Regionally important rivers such as the Bear, Green and Colorado are supplied water from its watersheds and provide water to regional populations for agriculture, municipal and industrial use, power and recreation (USU, 2019).

These rivers and their watersheds are also important to native fish such as Colorado River cutthroat trout (*Oncorhynchus clarkii pleuriticus*) and Bonneville Cutthroat trout (*Oncorhynchus clarki utah*). Wildlife, including bighorn sheep (*Ovis canadensis*), Rocky Mountain elk (*Cervus canadensis nelsoni*) and many other mammals and birds also depend on these watersheds (USDA, 2019a). The High Uintas Wilderness is a core area for Canada lynx (*Lynx canadensis*) (Bates and Jones, 2007) and historically significant numbers occurred here (Lewis and Wenger, 1998). It is part of a Regionally Significant Wildlife Corridor (Corridor) connecting the Greater Yellowstone Ecosystem and Northern Rockies to the Uinta Mountains and Southern Rockies. This Corridor is recognized by the Forest Service as well as regional conservation organizations (Jones et al., 2004; Noss et al., 2001; USDA, 2003a).

Peer-reviewed studies illustrate there are many adverse impacts of livestock grazing. A meta-analysis of the effects of cattle grazing on arid ecosystems in western North America found reductions in rodent species diversity and richness; vegetation diversity; shrub, forb and grass cover; total vegetation cover and biomass; seedling survival; biological crust cover; and litter cover and biomass while soil bulk density increased, soil erosion increased, and infiltration rates decreased in grazed areas when compared to ungrazed areas (Jones, 2000). A comprehensive review of ecosystem effects of livestock grazing in western North America found that livestock grazing reduces levels of biodiversity, leads to decreased population densities for a wide variety of taxa, disrupts ecosystem functions, including nutrient cycling and succession, changes community organization, and changes the physical characteristics of both terrestrial and aquatic habitats (Fleischner, 1994). A similar review of livestock effects to streams and riparian ecosystems determined that livestock grazing negatively affects water quality and seasonal quantity, stream channel morphology, hydrology, riparian zone soils, instream and streambank vegetation, and aquatic and riparian wildlife. No positive environmental effects of grazing were found in this comprehensive survey of the literature (Belsky et al., 1999).

Field surveys by the Forest Service in the 1960's in the High Uintas Wilderness documented erosion damage on highly erodible soils and steep slopes which had developed gullies, and which was exacerbated by sheep grazing and trampling (USDA, 2019c). Mont Lewis, a Forest Service range conservationist working in the Uinta Mountains in the 1960's, documented accelerated erosion, alpine turf in poor condition, and lakes being filled with sediment from grazing sheep in areas that were sensitive to erosion damage (Lewis, 1970).

A recent study using sediment cores from Lake EJOD in a grazing allotment in the High Uintas Wilderness found increased nutrient and sediment loading in the past century, coincident with the period livestock have grazed here. This is a departure from rates of deposition going back 5,300 years (Munroe et al., 2013; Figure 1). Lewis (1970) noted that these non-suitable areas (today these are called non-capable) should not be grazed. Many of the soils were determined to have a very high erosion hazard. Surveys in the late 1990's and early 2000's showed grazed uplands had suffered loss of plant cover with upland grazed areas having bare soil averaging over 50% while areas that had not been grazed for decades had almost no bare soil. Streams were damaged from high runoff events creating bank scouring (Carter, 2007; Figures 2, 3). Surveys by soil scientists working for the Ashley National Forest in the 1980's described severe erosion and loss of soil cover and biological crusts (Oprandy and Voerner, 2019). In recent decades Forest Service monitoring has been sporadic and focused in areas of low erosion hazard in more level terrain such as valleys, wet or mesic meadows, and riparian areas, finding conditions to be satisfactory (USDA, 2019a; 2019c).

Figure 1. Lake EJOD, High Uintas Wilderness, deposits of sediment entering the lake from its grazed watershed. (Carter, 2007)

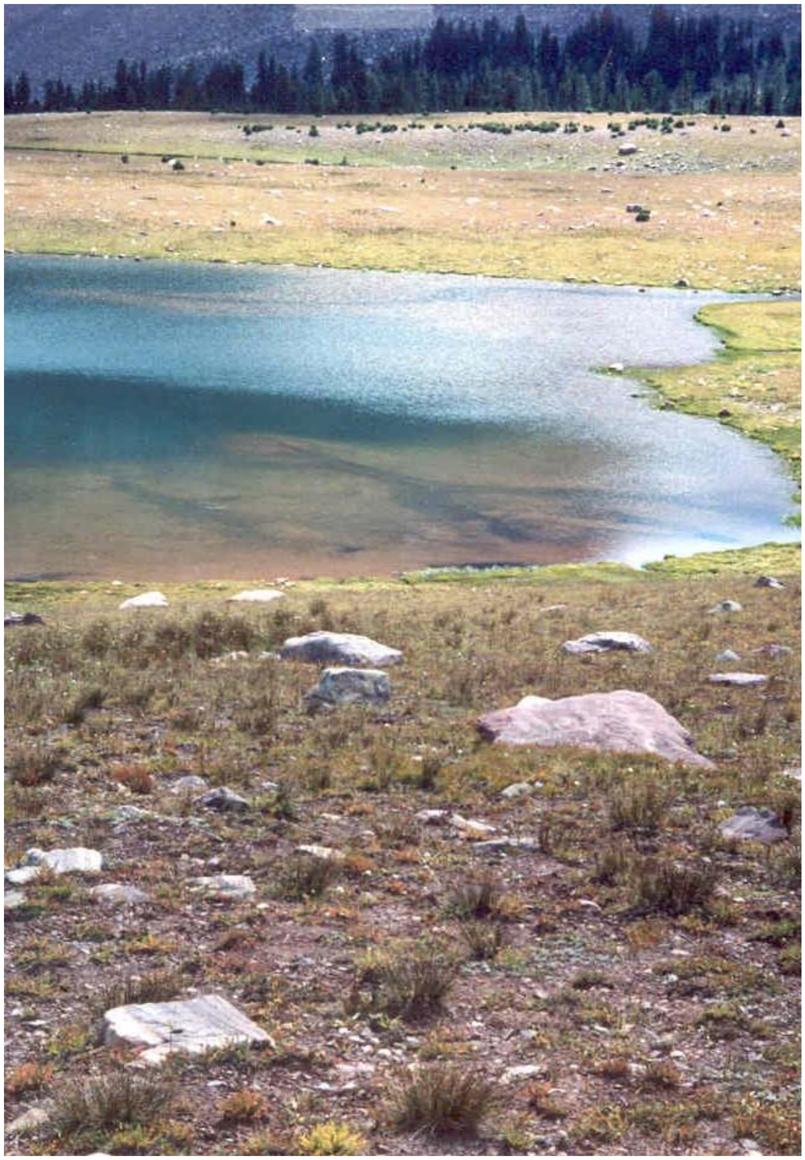
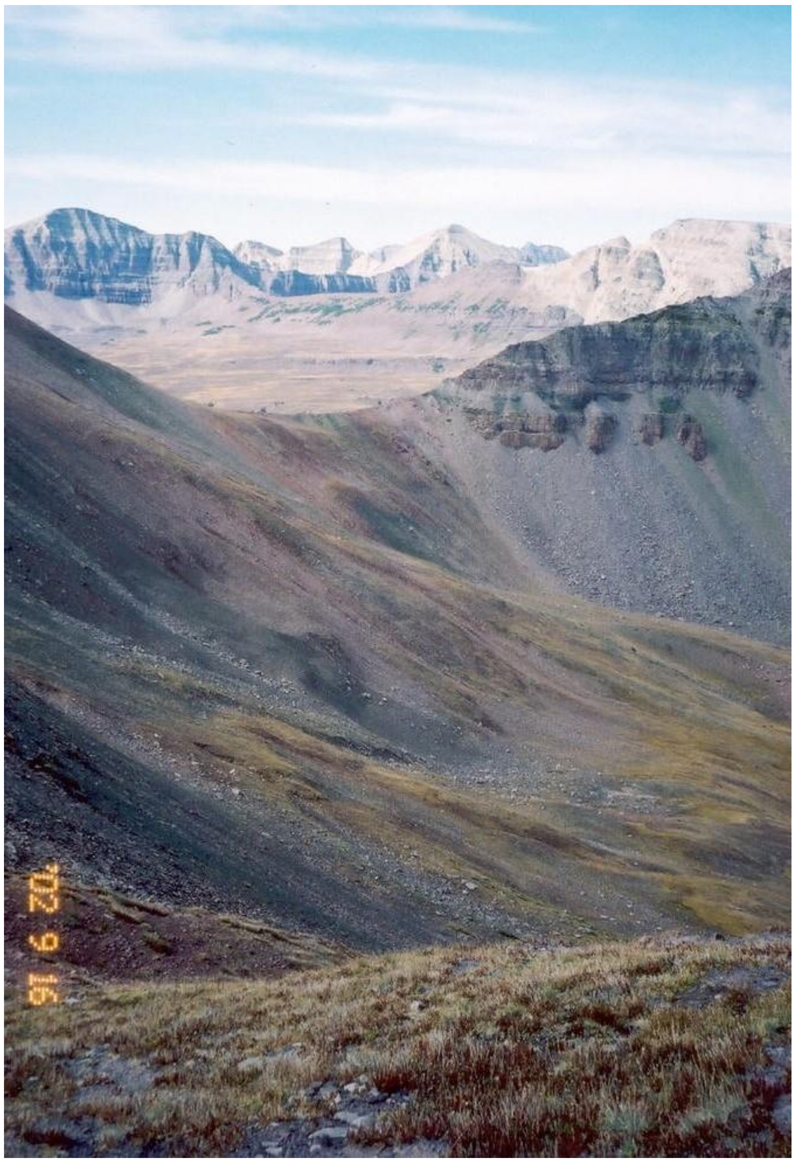


Figure 2. Stream bank scouring, High Uintas Wilderness (Carter, 2007).

Figure 3. High Uintas Wilderness steep slopes grazed by domestic sheep (Carter, 2007).



1.2 Grazing in Wilderness

In 1964, Congress passed the Wilderness Act and defined wilderness: "A wilderness, in contrast with those areas where man and his works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain." Wilderness is "land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions...." In addition, wilderness should be "affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable" (16 U.S.C. § 1131(c)). The law provided statutory protections for wilderness areas and established the National Wilderness Preservation System. The Act, among other things, mandated that wilderness areas be administered in a manner that will leave them "unimpaired for future use and enjoyment as wilderness" and provide for "the protection of these areas" and "the preservation of their wilderness character" (16 U.S.C. § 1131(a)).

The provision allowing livestock grazing in the Wilderness Act is an exception to the general premise of the Act, which directs agencies to manage wilderness areas to preserve their wilderness character and natural conditions. "Within wilderness areas in the national forests designated by this Act...the grazing of livestock, where established prior to September 3, 1964, shall be permitted to continue subject to such reasonable regulations as are deemed necessary by the Secretary of Agriculture" (16 U.S.C. § 1133(d)). Thus, livestock grazing which existed in wilderness areas when the Wilderness Act was enacted, has continued. Livestock grazing is an exception to normal wilderness protections.

2. Methods

2.1 Study Area

The study area is the ten grazing allotments at issue that occur in the ANF and UWCNF within the High Uintas Wilderness (Figure 4). Elevations range from about 8,000 feet to 13,528 feet above sea level at the summit of Kings Peak. The land consists of steep canyons, U-shaped glaciated basins and river valleys, alpine tundra, lakes, streams and wetlands, mountain peaks, and large open meadows. (Figure 5). Forested areas consist of sagebrush (Artemesia spp.), quaking aspen (*Populus tremuloides*), lodgepole pine (*Pinus contorta*), Douglas fir (*Pseudotsuga menziesii*), subalpine fir (*Abies lasiocarpa*), and Engelmann spruce (*Picea engelmannii*) (USDA, 1986; 2003a).

The ten grazing allotments cover a total of 160,410 acres and have a near summer long grazing season (USDA, 2019a). At this high elevation the grazing season occupies most of the snow-free period with some areas retaining snow into August (USDA, 2019c; Table 1).

Table 1. Numbers of permitted sheep and length of grazing season.

Allotment	Permitted ewe/lamb pairs	Season	Allotment Acres
East Fork Blacks Fork	1350	7/6 - 9/10	25440
Fall Creek	1100	7/1 - 9/30	16612
Gilbert Peak	1400	7/11 - 9/10	11896
Hessie Lake Henry's Fork	1400	7/11 - 9/10	14539
Middle Fork Black's Fork	1200	7/11 - 9/10	16855
Ottoson Basin	1300	7/15 - 9/10	12620
Oweep	1400	7/15 - 9/10	16686
Painter	1200	7/12 - 9/6	14756
Red Castle	1300	7/6 - 9/10	14857
Tungsten	1200	7/12 - 9/6	16149
Totals	12,850		160,410

Figure 4. Study location and map of allotments

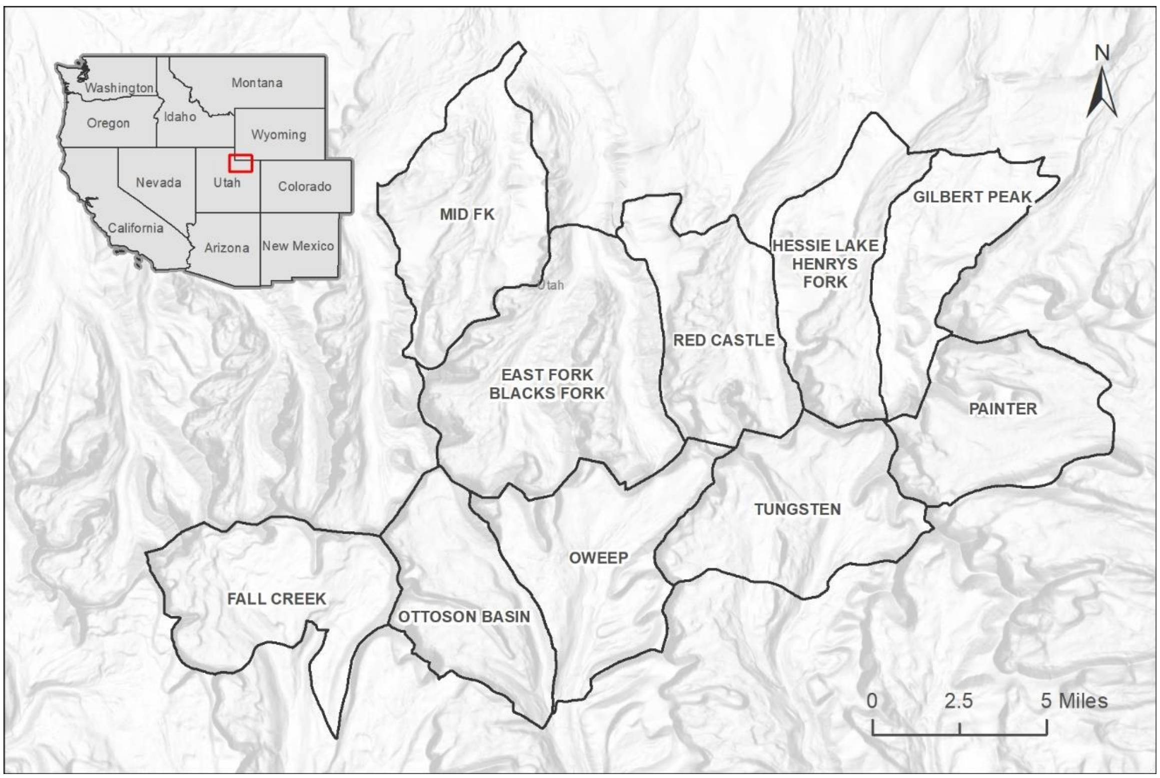


Figure 5. Forest Service photo showing topography, dense forested areas, mixed wetland and upland areas and adjacent steep slopes (USDA, 2019c).

2.2 Forest Service Capability Criteria

The concept of "capability" for livestock grazing is a core concept directed at limiting soil erosion and degradation of grazing allotment watersheds and plant communities by factoring out areas of steeper slopes, highly erodible soils, and barren areas in order to reduce risk of erosion and degradation of plant communities. It also determines stocking rates based on forage consumption rates of livestock and allocates an appropriate proportion of the available, preferred or desirable forage species on the capable acres to livestock so that stocking rates are sustainable and reduce the risk of degradation (USDA, 1964). The capable lands and stocking rates on the High Uintas Wilderness allotments have not been updated to reflect more recent guidance from the Region 4 Forest Service that oversees the ANF and UWCNF that manage these ten grazing allotments.

The current USFS regional criteria (Criteria) for range capability were described in a 1998 memorandum by the Forest Service (USDA, 1998). These were:

1. Areas with less than 45 percent slope for domestic sheep, 30% for cattle.
2. Areas producing or having the potential to produce an average of 200 lbs. or more of forage/acre on an air-dry basis over the planning period.
3. Areas without dense timber, rock, or other physical barriers.
4. Areas with naturally resilient soils (not unstable or highly erodible soils).
5. Ground cover greater than 60%.
6. Areas within one mile of water or where the ability to provide water exists.

In its 2003 Forest Plan Revision, the WCNF used only Criteria 1, 2 and 6 (USDA, 2003b). It evaluated the slope of the land using a digital elevation model to determine where the lands of less than or equal to 45 percent slope were located. Lacking current forage production data, the WCNF used a vegetation layer as a surrogate for forage production. While forage production had been determined in the 1960's and was their most recent data, it was not used. The Final Environmental Impact Statement for the Wasatch-Cache Revised Forest Plan (USDA, 2003b) described it thusly: “The vegetation layer was used as a surrogate for minimum forage production. In general, coniferous-forested vegetation types (spruce, fir, pine, Douglas-fir), oak, and barren areas were said to not produce the minimum 200 lbs/acre of forage. All other types were included as potential forage-producing types.” The Forest Plan for the ANF was produced in 1986 prior to the publication of these recent Regional criteria. According to the ANF, the capability analysis done in the 1960's was used in the Forest Plan (USDA, 2016a). It does not incorporate the current Criteria. Neither Plan relied on current forage production data.

2.3 Grazing Capability Model

Due to the lack of a dataset for ground cover and sufficiently detailed soil surveys, our model did not exclude highly erodible soils and areas with ground cover less than 60% (criteria 4 and 5). It is of note, however, that excluding slopes greater than 45 percent by the very nature of soil erosion/slope relationships defined in the Universal Soil Loss Equation (USDA, 1978) would inherently exclude many areas of unstable soils or soils with high erosion hazard. Criterion 6, distance to water, was evaluated and was not a limiting factor as all areas meeting slope, forage production and lack of dense timber criteria 1, 2 and 3 were within one mile of water. Small, isolated capable areas were removed from the final map as these are inaccessible (within dense forest) or surrounded by non-capable areas that are impractical to graze without placing the non-capable areas at risk. In sum, the model determined capable acres based on land less than one mile from water, less than or equal to 45 percent slope, producing 200 lb/acre or more of forage (based on actual forage surveys, described below), and lacking dense timber.

The model used ESRI's ArcGIS 10.5.1 (ESRI, 2015) and ModelBuilder (ESRI, 2004) as the modeling environment. As the main output, we obtained a dataset in polygon format that described the landscape according to the areas capable of supporting domestic sheep grazing. Water bodies were excluded. Wetlands are not grazed by sheep, so were excluded in the model (Lewis, 1970). Figure 6 illustrates the steps implemented for the sheep grazing capability model. Datasets used or generated in model development are listed in Table 2. We requested and received GIS data from the Forest Service (USDA, 2014b) and their historic monitoring data (USDA, 2019c) in order to perform the analysis.

Figure 6. Flowchart of the Domestic Sheep Grazing Capability Model.

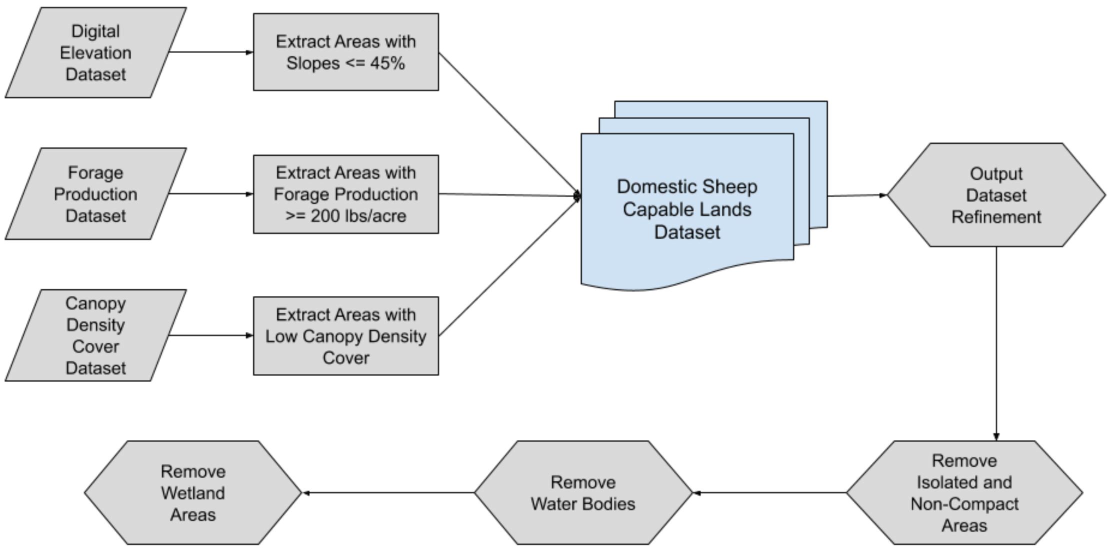


Table 2. GIS Datasets

Dataset Name	Format Type	Version	Resolution	Source
NED Digital Elevation Model	Raster	2013	10 meters	US Geological Survey (USGS, 2013)
Slope	Raster	2018	10 meters	Derived from NED Digital Elevation Model
NAIP Digital Ortho Photo Images	Raster	2016	1 meter	USDA National Agriculture Imagery Program (USDA, 2016b)
Canopy Density Cover	Raster	2018	1 meter	Wild Utah Project
National Wetlands Inventory	Polygon		Version 2.0 - 2016	US Fish and Wildlife Service (USFWS, 2016)
Predicted Forage Production	Raster	2018	10 meters	Wild Utah Project
Forage Production Maps	Digitized PDFs	1960 - 1967	1:17,000	US Forest Service (USDA, 2014c)
Digitized Forage Production	Polygon	1960	1:17000	Digitized by Wild Utah Project
Grazing Allotments and Pastures Boundaries	Polygon	2016	1:24,000	US Forest Service (USDA, 2016c)
NHD Water bodies	Polygon	Version 1.07	1:24,000	US Geological Survey (USGS, 2016)
Grazing Capability (Forest Plan Revision)	Polygon	2001	1:24,000	US Forest Service (USDA, 2001a; 2001b)
Forage Production Survey Sites	Point	2016	N/A	Wild Utah Project
Soils	Polygon	2011, 2016	1:24,000	US Forest Service (USDA, 2011; 2016d)

2.3 Development of Model Parameter Inputs

Slope: Criterion 1 as interpreted in the WCNF Revised Forest Plan (USDA, 2003b) defines areas with slope ≤45% as capable for domestic sheep grazing. Determination of such areas was made using the Slope Analysis tool within the ESRI ArcGIS software (ESRI, 2015). As the chief input dataset, the NED Digital Elevation Model (USGS, 2013; Table 2) was used to derive the slope raster file. In a follow-up process, the output slope raster was filtered in order to generate a raster dataset containing areas with slopes ≤45%.

Forage Production: To refine the vegetation production estimate used by the Forest Service, we obtained field data for actual forage production. In order to get a representative sample of available forage in the project area, our team relied on areas that were not grazed by livestock prior to field sampling which occurred in August, 2016. Using soil map files (USDA, 2011) and soil descriptions (USDA, 2014d) obtained from the Forest Service, we determined that seven soil types were most common in the UWCNF portion of the project area. These occurred in the ungrazed areas and could be sampled to determine forage production. Of these soil map units, the Rubble and Rock Outcrop type covers 17,219 acres or almost 22% of the UWCNF study area, and is largely barren high county, so would not be expected to contain enough forage to factor into a grazing capacity analysis. Therefore, this soil type was not sampled and was assigned a value of zero for forage. The six remaining soil types were then visited by field teams in August, 2016 to collect forage production samples. Sites were inspected for signs of current sheep use such as droppings, tracks, bedding areas, and visible grazing use, in order to exclude these from the forage capacity samples if they were determined to have been grazed that season.

Sample site locations for collecting forage data were determined from locations of Forest Service monitoring sites and complemented with random locations generated with GIS to ensure coverage of all soil types. The number of locations were distributed equally among the soil types. Thirty-six locations were sampled across the 6 common soil types. At each pre-determined location within each soil type, plot clippings were collected along a transect heading due north (BLM, 1996). To collect plot clippings, 24 x 24-inch sample frames were placed at 25′, 50′ 75′ and 100′ along each 100′ transect. All herbaceous species in each sample plot were clipped to one inch above the ground, placed in Ziploc bags and brought back to camp, where they were kept open to air out until transported to the lab where they were air dried and weighed on an electronic balance. The amount of air-dry forage per acre was then calculated.

The forage production samples were then correlated with the aerial ortho-photos of the study area. Figure 7 illustrates the process of correlation and NAIP image classification that was applied to derive a predicted forage production raster layer, using the Image Analysis tools within ESRI ArcGIS (ESRI, 2015). In the first step, we utilized NAIP imagery from August 2016 to estimate Normalized Difference Vegetation Index (NDVI) values across the study area. (USDA, 2016b; Figure 8). NDVI is estimated based on a ratio between the red and near-infrared (NIR) optical bands embedded in the NAIP imagery. The equation for NDVI is presented as NDVI = (NIR – RED) / (NIR + RED). This mathematical operation was completed by using the Raster Calculator in ArcGIS which generated a raster file. In the next step, the forage production survey points were used to correlate those values to the NDVI values from the previous step. (Figure 9). These two datasets were correlated to each other by using the pixel values in the NDVI raster dataset and the forage production values determined at each survey location. By using the data correlation, we were able to re-calibrate the NDVI values to forage production values and confidently conduct a raster classification into different forage production classes based on the differential raster values of those vegetation classes. (Figure 10).

<u>Dense Timber</u>: Areas of dense timber are considered not capable in the Criteria because livestock generally avoid grazing in areas of thick conifer cover. In the model, areas with high and medium canopy density were excluded from capable areas since those canopy density categories are associated with areas with dense timber, high number of fallen trees, and areas with restricted access to livestock. In order to achieve a reliable dataset that would describe areas of dense timber throughout the study area, we revisited the NDVI raster dataset from the previous process and adjusted the raster classification process by targeting the different levels of forest canopy density. The resulting dataset describes the study area in terms of canopy density levels (i.e. high to low). Figure 11 illustrates the data transformation process to obtain the canopy density cover dataset. Figure 12 shows the resulting forest canopy density raster dataset.

Figure 7. Image Analysis Process for the Estimation of NDVI Values, Correlation of NDVI with Forage Production Survey Points, and Image Classification to Derive a Predicted Forage Production Raster Dataset.

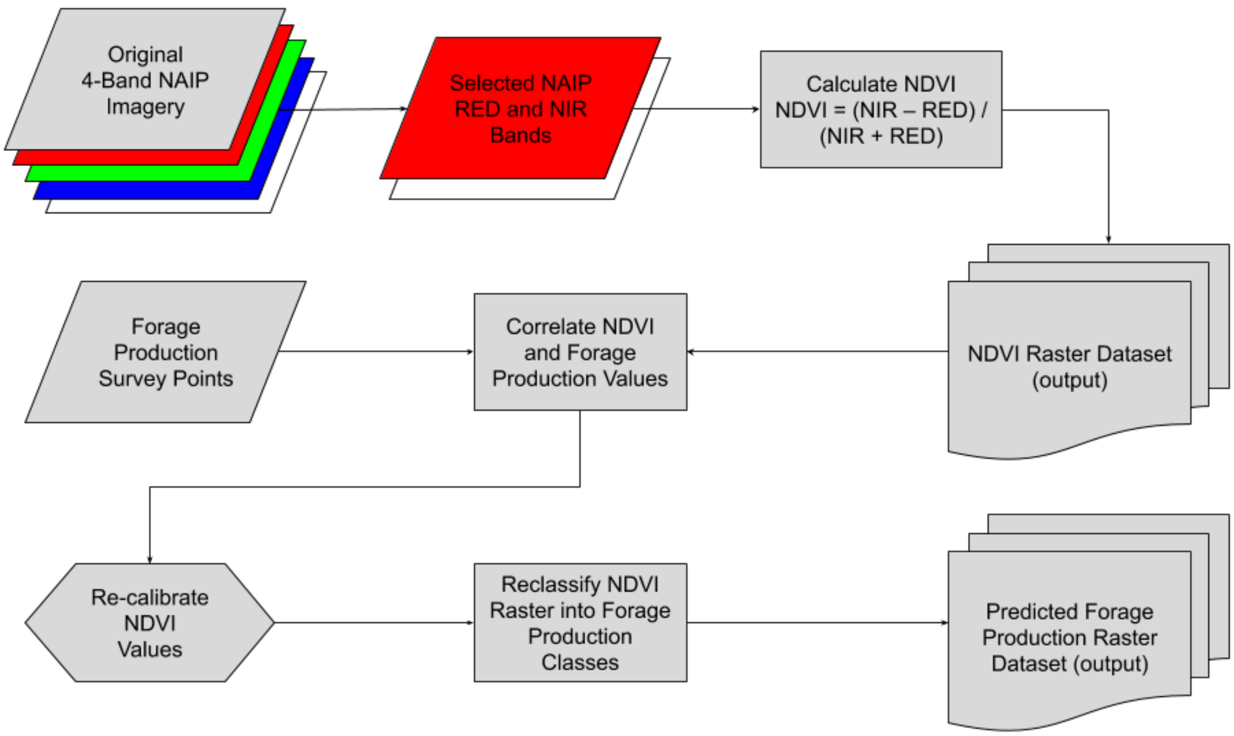


Figure 8. NDVI raster obtained from image analysis operation by estimation of a ratio between the green and near-infrared bands in NAIP ortho photo images. (USDA, 2016b). (Areas shown in blue represent water bodies and areas shown in various shades of green represent vegetation in various NDVI values)

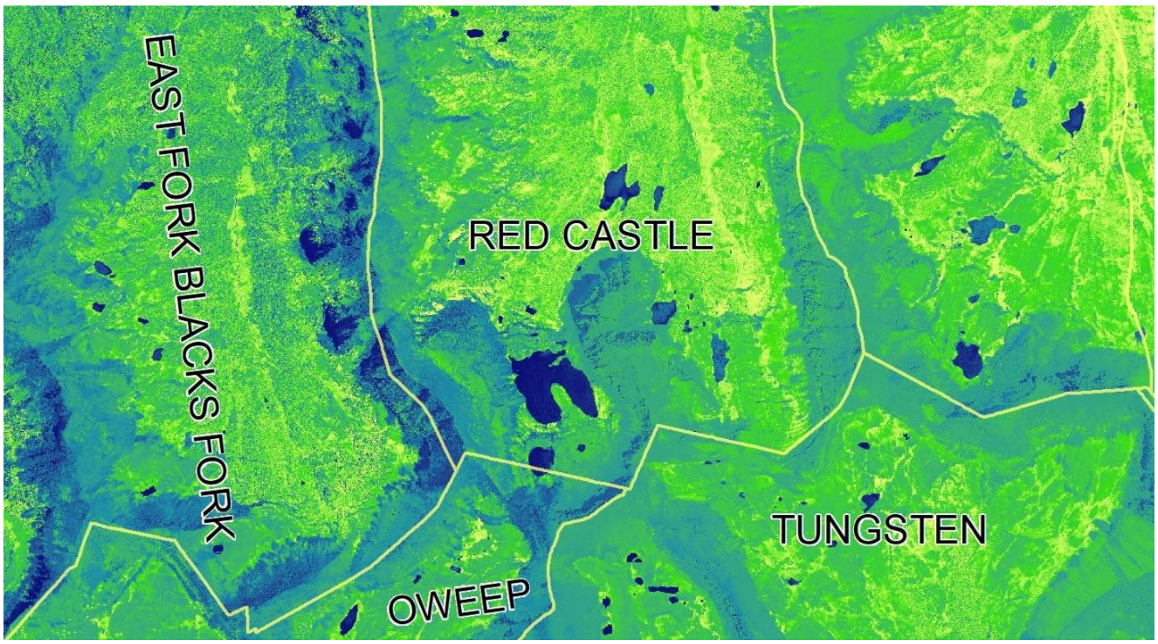


Figure 9. NDVI raster and forage production values estimated from the survey conducted in 2016

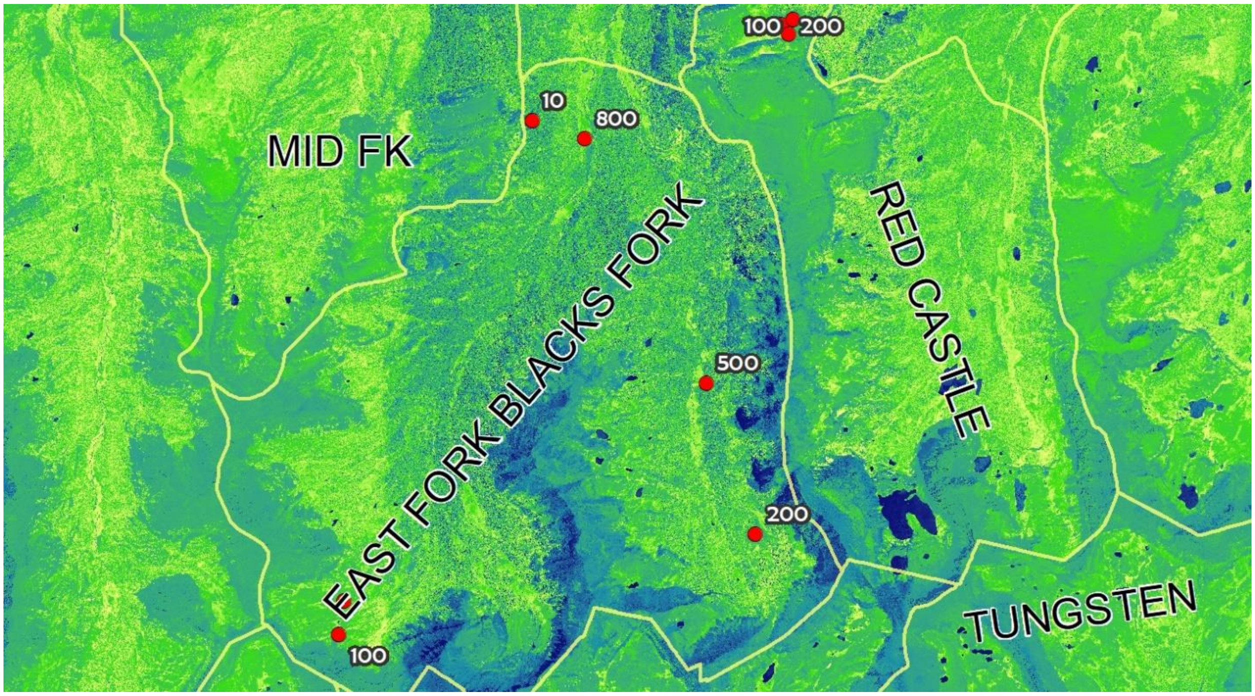


Figure 10. Predicted forage production raster from image classification of forage production data.

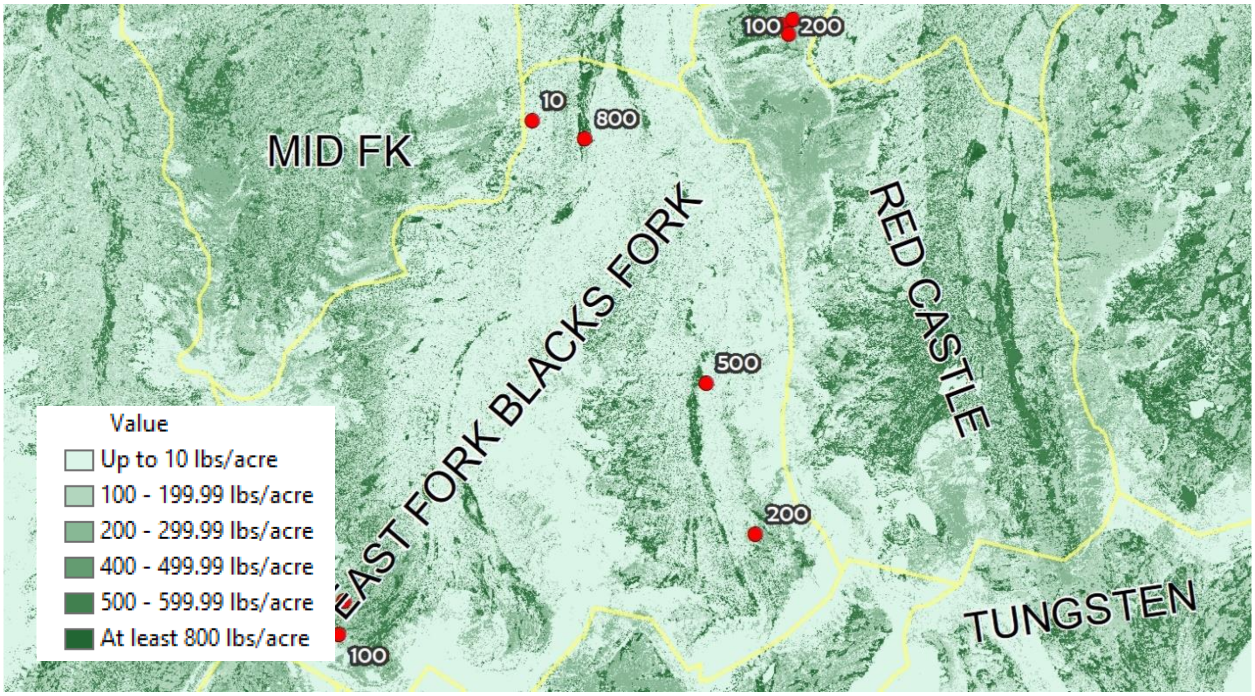


Figure 11. The data transformation process to obtain the canopy density cover dataset.

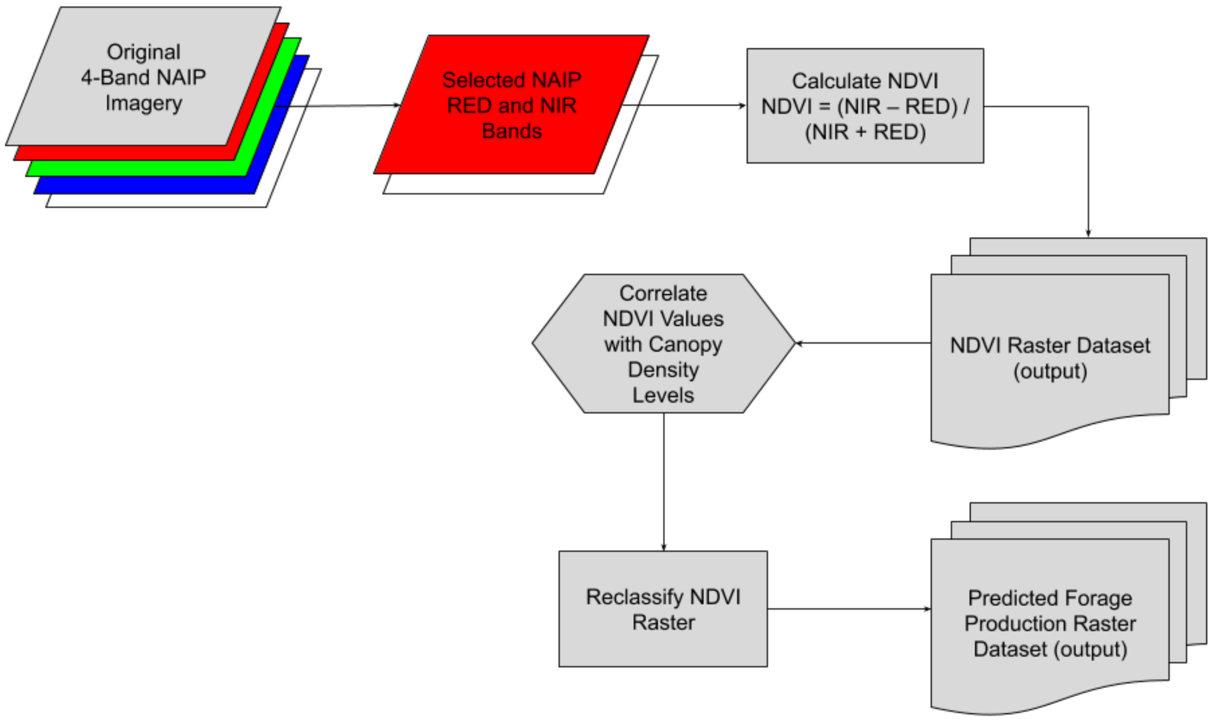
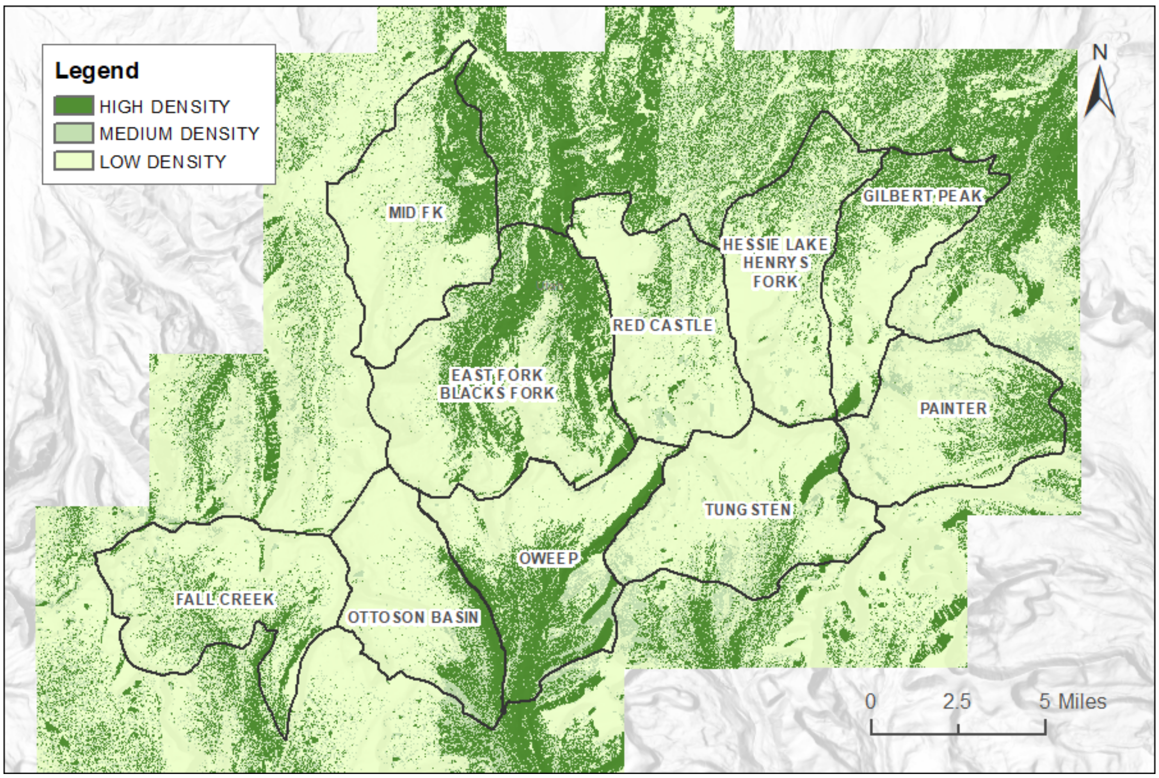


Figure 12. Canopy Density raster dataset using NDVI values from NAIP imagery and the resulting classification into density categories.



Comparisons Using Model Outputs: Once these model outputs were derived, we made two comparisons to the Forest Service determination of capable lands. In Case 1, we calculated the acreage of lands meeting current Criteria of ≤45% slope, 2016 forage production ≥200 lb/acre, and excluded areas of dense timber, water bodies and wetlands. In Case 2, since the most recent Forest Service forage production data was that collected in the 1960's, we digitized the 1960's forage production data (USDA, 2014c; Table 2) which was then used to determine acres with forage production ≥200 lbs/acre. This, along with slope ≤45% and excluding areas of dense timber were used to determine capable acres.

2.4 Stocking Rate Determination

Forage consumption: A forage consumption rate for sheep was provided in the USFS Region 4 Range Analysis Handbook showing forage consumption for a 125 lb ewe to be 4.1 lb/day air dry weight while an 80 – 90 lb lamb would consume 2.9 lb/day (USDA, 1964). Since permits allow two lambs per ewe, we used 9.9 lb/day (301 lb/month) as a forage consumption rate for each ewe/lamb pair applied to the permitted numbers for each allotment. According to government statistics, in 2017, the average live weight of sheep and lambs for slaughter was 132 pounds (USDA, 2017). This indicates our estimated forage consumption rate for a ewe and two lambs could be an underestimate if full permitted numbers of ewes and lambs are being grazed.

Utilization: Recommended utilization rates are 20% for alpine ranges grazed during the growing season or in poor condition, while for ranges in good condition and grazed during the dormant season 30% is recommended (Holechek et al., 2004). Lewis (1970) recommended 30% utilization for all areas except wetlands. He recommended 40% in wetlands, while acknowledging these are not preferred by sheep, are not suitable for grazing and that the drier uplands nearby will be preferred. For this analysis we used a 30% utilization rate even though past work has shown these alpine and subalpine upland areas to be in poor condition with depleted ground cover, gully erosion, stream bank scouring and heavy grazing in non-capable areas such as uplands and steep slopes, indicating that they are most often in poor condition (Carter, 2007; Lewis, 1970; Oprandy and Voerner, 2019).

3.0 Results and Discussion

3.1 Current Forage Production and Comparison to 1960's Data

The 1960's forage production data excluded non-forage species in grazing capacity determinations (USDA, 1964; USDA, 2019c; Lewis, 1970). Table 3 summarizes key statistics from the 1960's determinations and our 2016 forage production data set.

Table 3. Key Statistics for Forage Production (lb/acre)

Time Period	Median	Mean	Maximum
1960's	206	240	615
2016	166	294	1431

The median sample weight was less in 2016 than in the 1960's while the mean was greater in 2016. This is logical since the 2016 data included all herbaceous species whether forage or non-forage, while the 1960's data did not include non-forage species. The 2016 maximum values were samples from wetlands. The highest non-wetland sample was near the 1960's maximum.

3.2 Comparison of Capable Acres

Table 4 summarizes the capable acres determined for the ten allotments applying the current Criteria. These are contrasted with those determined by the ANF and WCNF in their Forest Plans. The Forest Service determination of capable lands was represented in the GIS data they provided (USDA, 2001a; 2001b). Their determination was that 57,399 of the total allotment acres, or 35.7% were capable (Table 4 and Figure 13). They did not exclude areas of dense timber or wetlands and did not collect forage production data, while relying on assumed production from their vegetation layer. Case 1, using current forage production, areas of ≤45% slope and not within dense timber resulted in only 6% of the total allotment area being capable (Figure 14). Case 2, using 1960's forage production, areas of ≤45% slope and not within dense timber resulted in only 1.8% of the total allotment area being capable (Figure 15). The Forest Service determination of capable lands overestimates the actual amount by nearly 6 times based on applying their current Criteria and our 2016 forage production data (Case 1) and nearly 20 times when the 1960's forage production data were applied (Case 2). If sufficiently detailed soil survey information and ground cover data were available, more areas would likely be found not capable as indicated by past surveys (Carter, 2007; Lewis, 1970; Oprandy and Voerner, 2019).

Table 4. Summary of Capable Acres

Total Allotment Acres	Forest Service Capable Acres	Total Capable Acres Current Forage Case 1	Total Capable Acres 1960's Forage Case 2
160,410	57,399	9,685	2,887
Percent of Total	35.7%	6.0%	1.8%

Figure 13. Ashley and Wasatch Cache National Forest Service Determination of Capable Acres = 57,399 acres, or 35.7 percent of total acres.

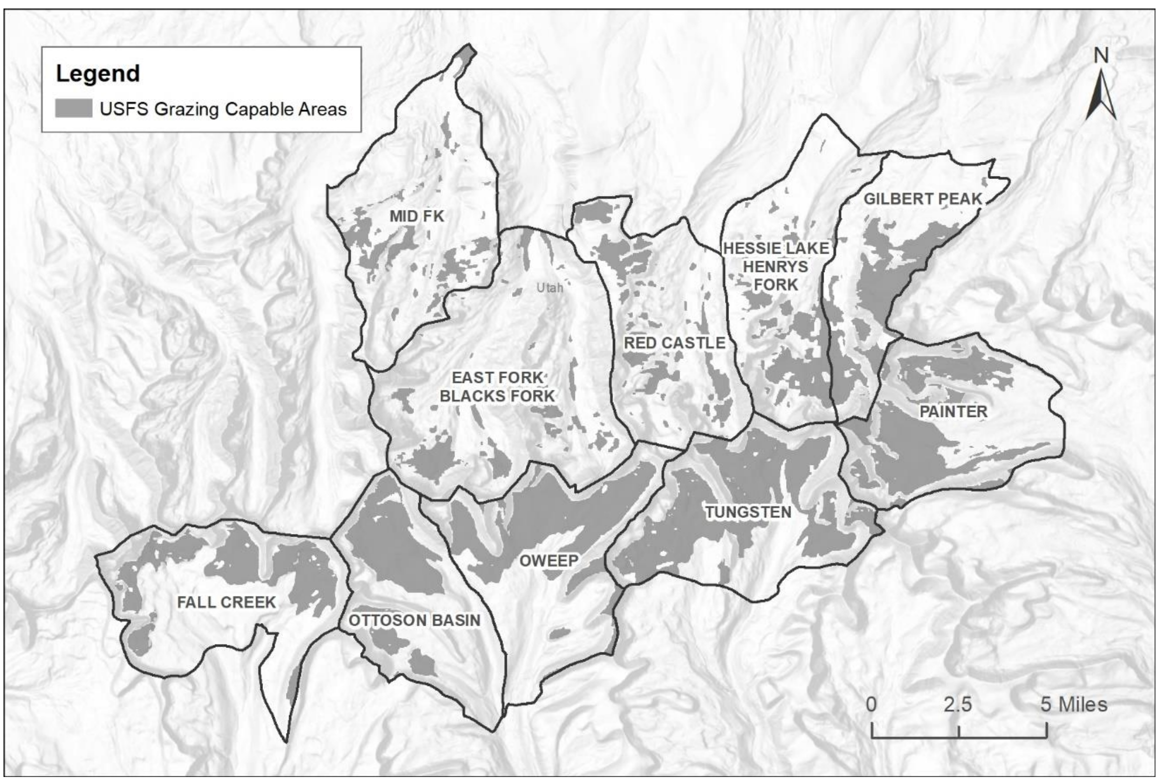


Figure 14. Capable Acres Determined from Regional Capability Criteria and Current Forage Production = 9,685 acres, or 6.0 percent of total acres

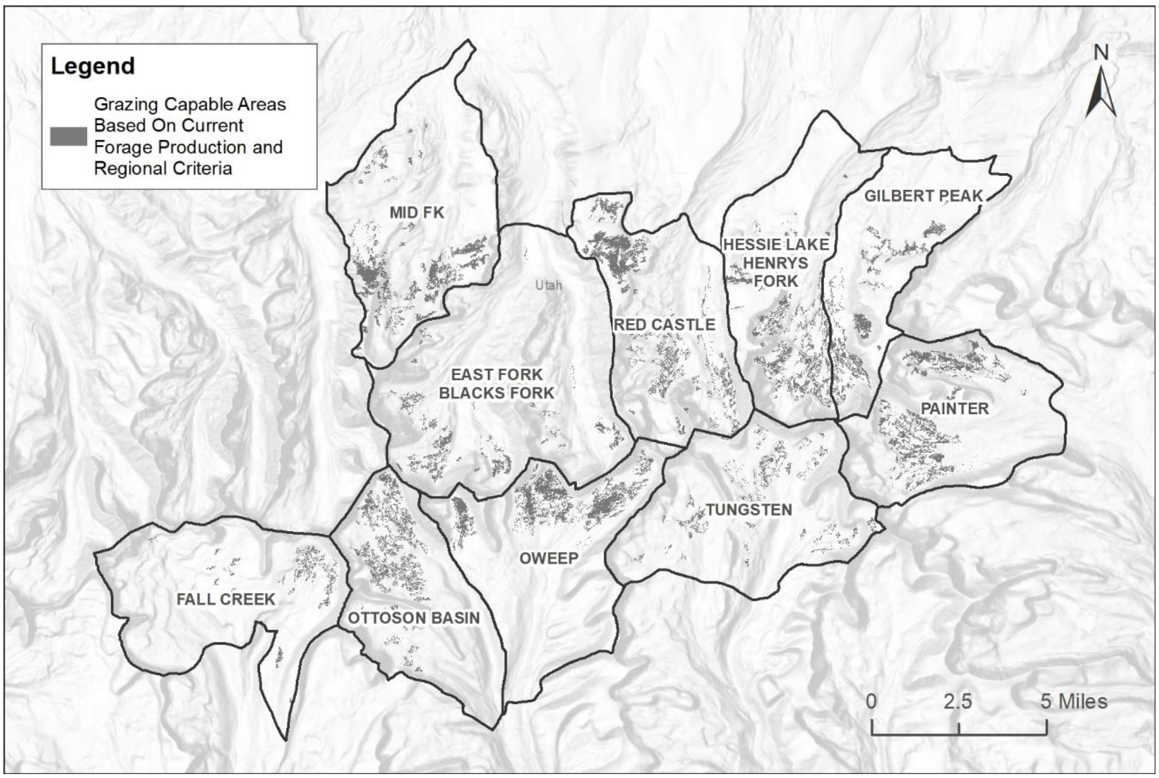
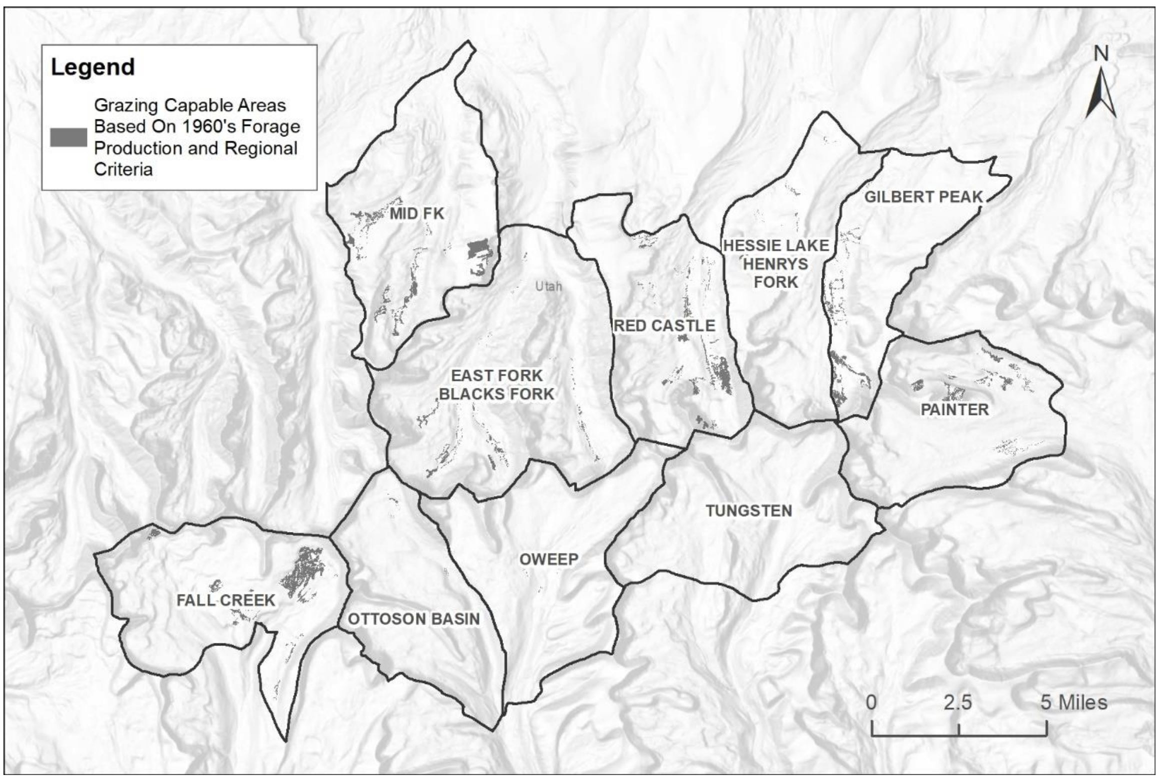


Figure 15. Capable Acres Determined from Regional Capability Criteria and 1960's Forage Production = 2.887 acres or 1.8 percent of total acres.



3.3 Evaluation of Forage Demand, Available Forage and Stocking Rates

The total forage demand for the currently permitted 12,850 ewe/lamb pairs grazing these ten allotments based on their time in the allotments and a forage demand of 301 pounds per month per pair is 8,062,641 pounds. In Case 1, using the 2016 mean forage production of 294 lb/acre and 9,685 capable acres gives total forage production of 2,847,390 pounds. Applying a 30% utilization rate to this amount gives 854,217 pounds available. This is 10.6% of the current demand. In Case 2, using the 2016 mean forage production values on the 2,887 capable acres is 848,778 pounds. Applying a 30% utilization rate to this amount gives 254,633 pounds available. This is 3.2% of the demand. The implication of this to current stocking rates is clear. In Case 1 a 90% reduction would be needed to balance domestic sheep use by the current permitted numbers to the available forage. In Case 2 a 97% reduction would be needed to balance domestic sheep use by the current permitted numbers to the available forage.

Where does the additional forage to support these 12,850 ewe/lamb pairs of permitted sheep come from? The domestic sheep are grazed and trailed throughout the non-capable areas on steep slopes and highly erodible soils and in the sensitive alpine meadows, where sheep consume whatever small amounts of edible plants they can find. This management has caused and continues to cause accelerated erosion, high flood forces during runoff events, changes in plant communities, and erosion of streambanks (Carter 2007; Lewis, 1970; Oprandy and Voerner, 2019).

Table 5. Forage Demand Compared to Available Forage

Total Forage Demand for 12,850 ewe/lamb pairs for the current grazing period	8,062,641 lbs.
Case 1: Available Forage on 9,685 capable acres	854,217 lbs. or 10.6% of Total Demand
Case 2: Available Forage on 2,887 capable acres	254,633 lbs. or 3.2% of Total Demand

3.4 Impact on Wilderness Values

Cole and Landres (1996) delineated the threats to wilderness ecosystems to include (1) recreation, (2) livestock grazing, (3) fire management, (4) invasive species, (5) diversion and impoundment of water, (6) atmospheric pollutants, and (7) management of adjacent lands. Here we are considering only the livestock grazing effects, which they delineate as trampling, grazing, defecation, death of plants, compaction and destabilization of soils, redistribution of nutrients, changes in geomorphology, gully formation, and lowering of water tables, water characteristics and wildlife populations. They considered the most significant effect at the species level is the indirect effects on wildlife. They point out that many of these wilderness areas are located at high elevations or in the desert, are naturally stressed and not resilient.

We have described the ecological degradation of plant and soil communities occurring in the High Uintas Wilderness due to grazing in non-capable areas. In addition, the current large-scale removal of vegetation by domestic sheep grazing in the High Uintas Wilderness reduces food and cover for native wildlife that depend on herbaceous plants. Snowshoe hares (*Lepus americanus*) are a principle food source for Canada lynx (*Lynx canadensis*), a Threatened species. Grazing by domestic sheep may be playing a role in the current absence of lynx from the High Uinta Wilderness (Ruediger et al., 2000). Bighorn sheep populations today are a small fraction of historical numbers, with a loss of over 98 percent of historic numbers (Toweill and Geist, 1999). Domestic sheep compete with native bighorn sheep for food, space and water. They are also asymptomatic carriers of diseases such as pneumonia that result in sick and dead bighorn sheep if the two come into contact with one another (Monello et al., 2001).

The ANF and UWCNF have monitored many locations in these ten grazing allotments and, in recent years, have not identified impacts of domestic sheep grazing. For example, the USDA (2019a) notes that "over 99% of the studies show ground cover is in satisfactory condition" and that plant communities are dominated by plants of high value for watershed protection. We reviewed the data files, photographs and data sheets provided by the Forest Service (USDA, 2019c) and analyzed the Forest Service monitoring locations (USDA 2014b) to determine why they failed to find the problems documented by earlier Forest Service range and soil scientists (Lewis, 1970; Oprandy and Voerner, 2019) and (Carter, 2007), which documented severe erosion, active gully progression, streambank scouring, and lack of ground cover in the drier uplands and on steeper slopes (Figures 16, 17). When long term ungrazed areas were compared to areas that continue to be grazed by domestic sheep, ground cover was high in the ungrazed areas, gully erosion was healing, streambanks were healthy and not eroding (Carter, 2007). Lewis (1970) showed definitive improvements in plant community composition with improved vigor in an area where sheep had been excluded for 11 years leading to a change in condition assessment from fair to good.

We compared the Forest Service monitoring locations to percent slope and found that 59% of monitoring locations were in areas <10% slope, and 83% in areas <20% slope. This indicated that monitoring was focused in areas that are less likely to be unstable and are less sensitive to sheep grazing impacts. Few sites were monitored in areas >40% slope which would be on the slopes more subject to erosion and instability.

Figure 16. Upland adjacent to riparian area showing bare soils and trailing damage. (Carter, 2007).

Figure 17. Result of sheep grazing on steep slopes leaving loose, erodible soil and sparse plant cover (Carter, 2007).

Eighty three percent of locations were in riparian areas, alpine wet and dry meadows and willow complexes which are the less sensitive areas and many that are least preferred by sheep and which also correspond to more level terrain. Forest Service ground cover data is rarely collected. If casual observations noted in their files as well as on data sheets are all counted, only 10.8% of the monitoring sites since 2000 noted a ground cover estimate. The satisfactory conditions the Forest Service noted in their Draft Environmental Impact Statement (USDA, 2019a) appear to logically follow, given these measures were taken in the areas less sensitive to domestic sheep impacts.

Cole and Landres (1996) note: "We can, however, attempt to identify those places where grazing is most inappropriate and develop grazing management objectives and guidelines that are more compatible with the goals of wilderness than the goal of maximizing sustainable animal production (the most common goal outside wilderness). We also must develop practical techniques for monitoring success at achieving and maintaining these objectives." They pointed out that, "we consider all modern human activities to cause deviations from 'natural conditions' to be threats and all such deviations to be detrimental impacts." "A wilderness, in contrast with those areas where man and his works dominate the landscape, is hereby recognized as an area where the earth and its community of life are *untrammeled by man*, where man himself is a visitor who does not remain." Wilderness is "land retaining its *primeval character and influence*, without permanent improvements or human habitation, which is protected and managed so as to *preserve its natural conditions*…." In addition, wilderness should be "*affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable*. By these definitions alone, domestic sheep grazing is incompatible with the Wilderness Act. The degradation documented in the Uinta Wilderness over the decades is clearly not compatible with the Wilderness Act's intent.

Forest Service management can address the problems in the High Uintas Wilderness by applying the analytical process we have provided and adjusting stocking rates and grazing periods based on the capable acres, current forage production and forage consumption rates, while applying a sustainable utilization rate. Sheep should be managed to remain within the capable areas and away from steep slopes. Monitoring should include trend in ground cover and utilization. It should be standardized, quantitative and performed annually. It should include capable and non-capable areas with a focus on those areas most preferred by domestic sheep such as the dry meadows and uplands in the valleys, uplands at the margins of wet areas and slopes at the valley margins. Only then will the Forest Service approach conditions where domestic sheep grazing in this wilderness may be sustainable and recovery of past degradation can begin.

Conclusions

The analysis we have conducted for the High Uintas Wilderness Domestic Sheep Analysis indicates that only a small fraction of these allotments are capable of supporting domestic sheep grazing. The capable acres identified in our forage capacity model for this mountain range are scattered, small areas disconnected from each other to a large extent and require sheep to be trailed between them. Historically, nearly every acre sheep can access has been grazed across the Uinta mountains, regardless of slope, ground cover, elevation, soil erosion hazard and vegetation condition. Previous monitoring has identified that large-scale erosion is occurring in the High Uintas Wilderness due to this practice of trailing and grazing domestic sheep in non-capable areas.

This analytical process using GIS provides a framework for evaluation of other grazed lands and an evaluation of the costs and benefits of livestock grazing versus other values such as wildlife, native plant communities and water supplies. It shows that current and proposed Forest Service management is based on lack of compliance with its own Regional Capability Criteria, inadequate monitoring and insufficient analysis.

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