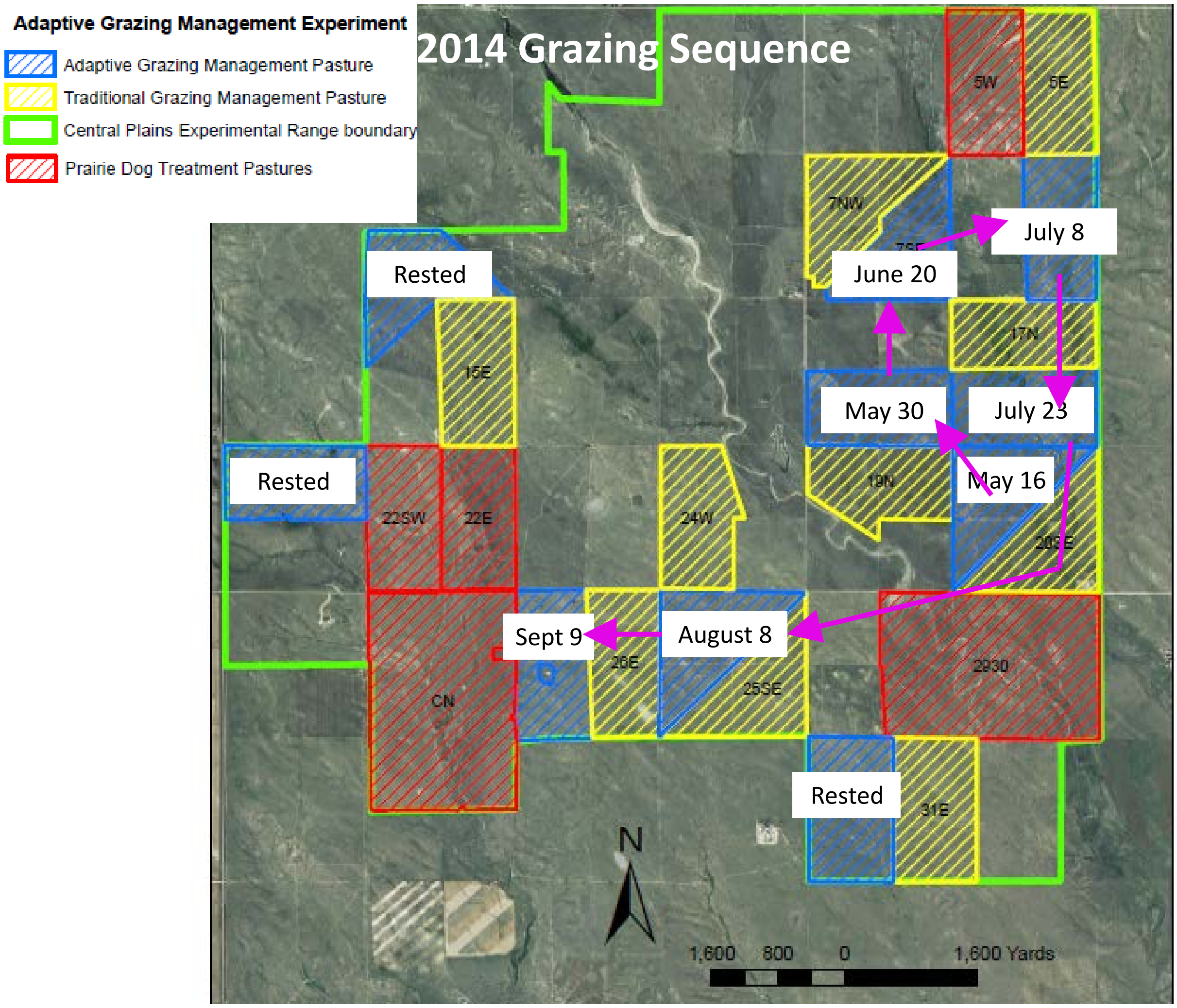
Adaptive Grazing Management Plan: December 1, 2014



Pastures of the Adaptive Grazing Management experiment at the Central Plains Experimental Range, near Nunn, CO.

Adaptive Grazing Management website:
http://www.ars.usda.gov/Main/Docs.htm?docid=24218

Summary

This document provides a current draft (December 2014) of the Adaptive Grazing Management Plan for the Adaptive Grazing Management (AGM) experiment at the Central Plains Experimental Range (CPER). The research team developed this current draft based on recommendations from the Stakeholder Group that previously met 1) September 18-19, 2012, 2) January 10, 2013, 3) September 10, 2013, 4) January 16, 2014, 5) April 23, 2014, and 6) September 29, 2014. The next meeting of the Stakeholder Group is set for Wednesday, January 13, 2015 at the Semiarid Grassland Research Center (SGRC). Meeting will be from 9 am to 3 pm.

The following list has been agreed upon by the Stakeholder Group in prior meetings and serves to guide further decision-making for this experiment:

1) desired goals and objectives (Figure 1),
2) consideration of management strategies (Figure 2)
3) understanding of the characteristics of the available ecological sites (Table 1),
4) the amount of area of ecological sites in each pasture (Table 2),
5) decision-making is by consensus; if consensus cannot be reached, then the decision-making will be by majority vote,
6) the ten 320-acre AGM pastures (total of 3,200 acres) will be managed as a single group of pastures, with the acknowledgement that there are some pastures dominated by Sandy Plains ecological sites (which have strong potential to restore desired cool-season species, such as needle-and-thread grass, western wheatgrass and saltbush – likely to emphasize grazing these pastures outside of critical growth periods for cool-season perennial grasses and shrub reproduction when possible), other pastures are dominated by Loamy Plains ecological sites (mostly dominated by blue grama, with less potential for restoration of desired cool-season species but are expected to be resistant to further losses of desired species), and there are some pastures with mixed (combination of Sandy and Loamy),
7) 2 of the 10 AGM pastures each year will be planned for entire rest (no grazing) for accumulating forage (i.e., grassbanking), promoting increased vegetation heterogeneity, and possibly restoring cool-season perennial grasses and saltbush. It is anticipated that rest would be rotated among pastures such that over a 5 year period, each pasture would experience 4 years of grazing with high stock density and 1 year of rest (Figure 3).
8) A decision-tree approach has been determined for triggers for entering and exiting an AGM pasture (Figure 4).
9) A decision-tree approach has been determined for assisting with within-season adaptations to the planned grazing sequence (Figure 5).

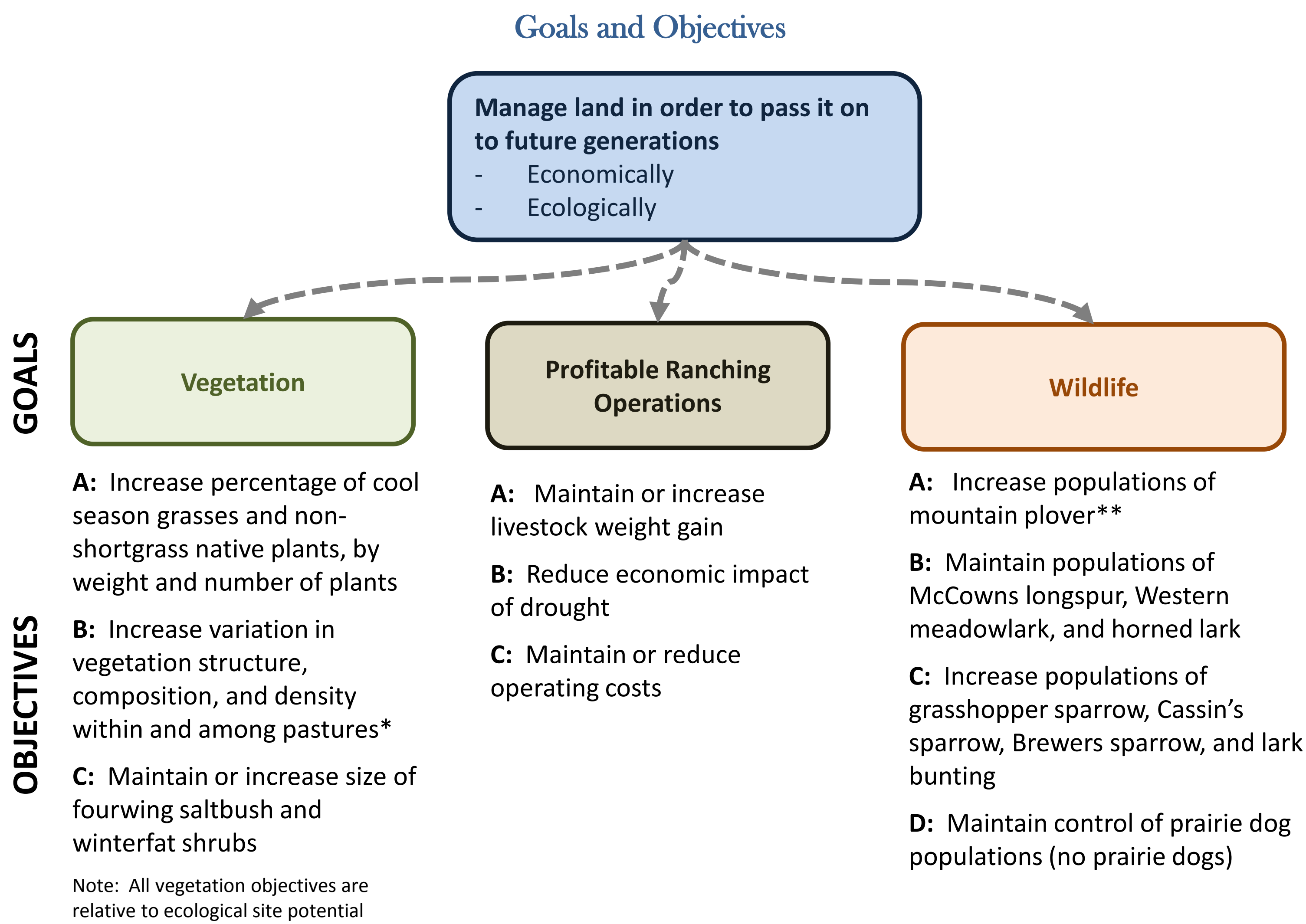


Figure 1. Goals and objectives identified by the Stakeholder Group in the Adaptive Grazing Management Workshops.

* "Composition" was added to this objective here because it was included in the discussion of this objective at the workshops.
** Wildlife objective A was combined with objective B in the workshops, but is split out here because strategies identified for mountain plover habitat were different from those identified for the other three species. Also, while a previous version of this objective read "maintain or increase", it reads "increase" here because many individuals and several of the proposed plans showed commitment to increasing mountain plover habitat in the experimental pastures.

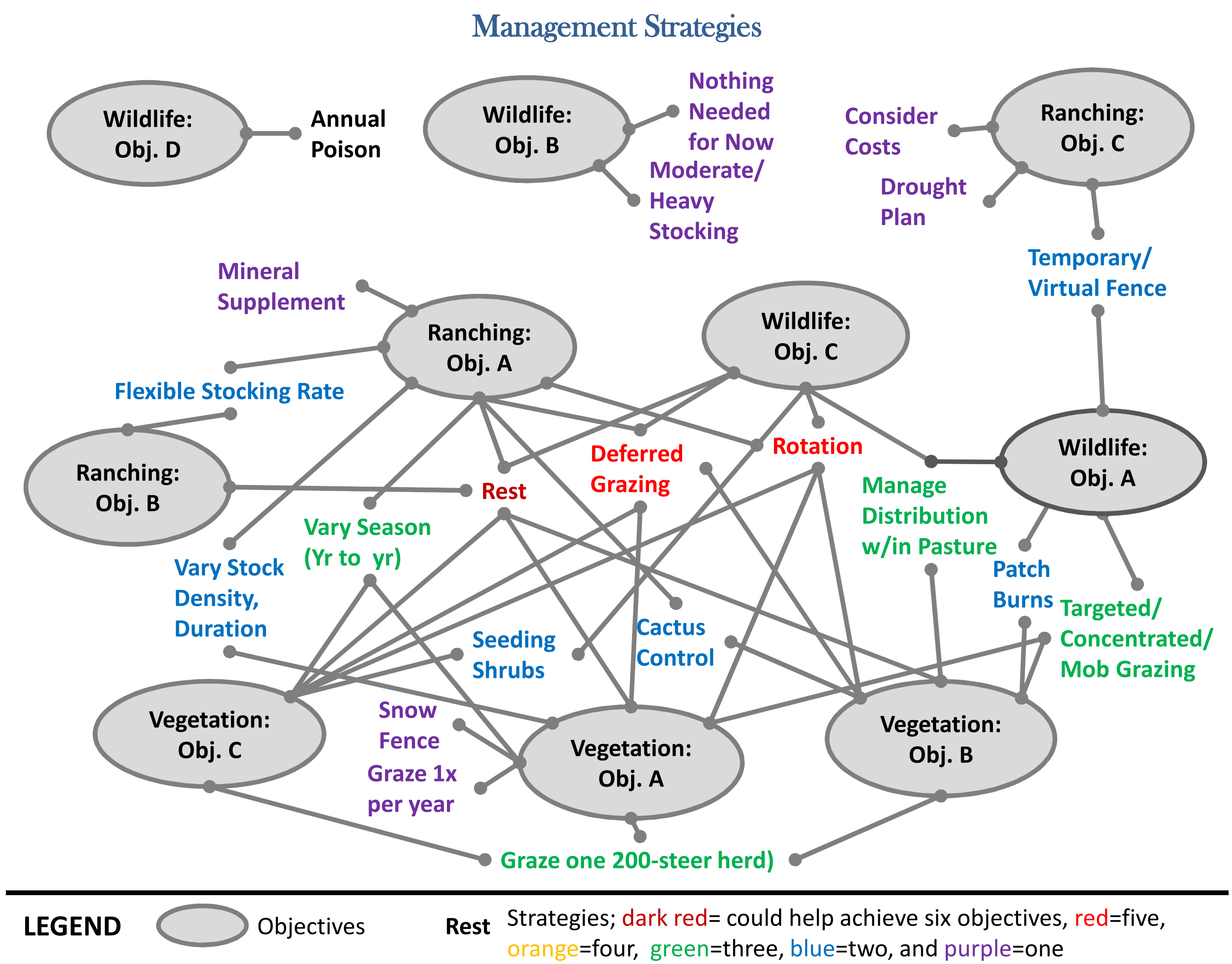


Figure 2. Management strategies suggested for each objective by the Stakeholder Group in the Adaptive Grazing Management Workshops. Strategies are color coded according to the number of different objectives they were suggested for.

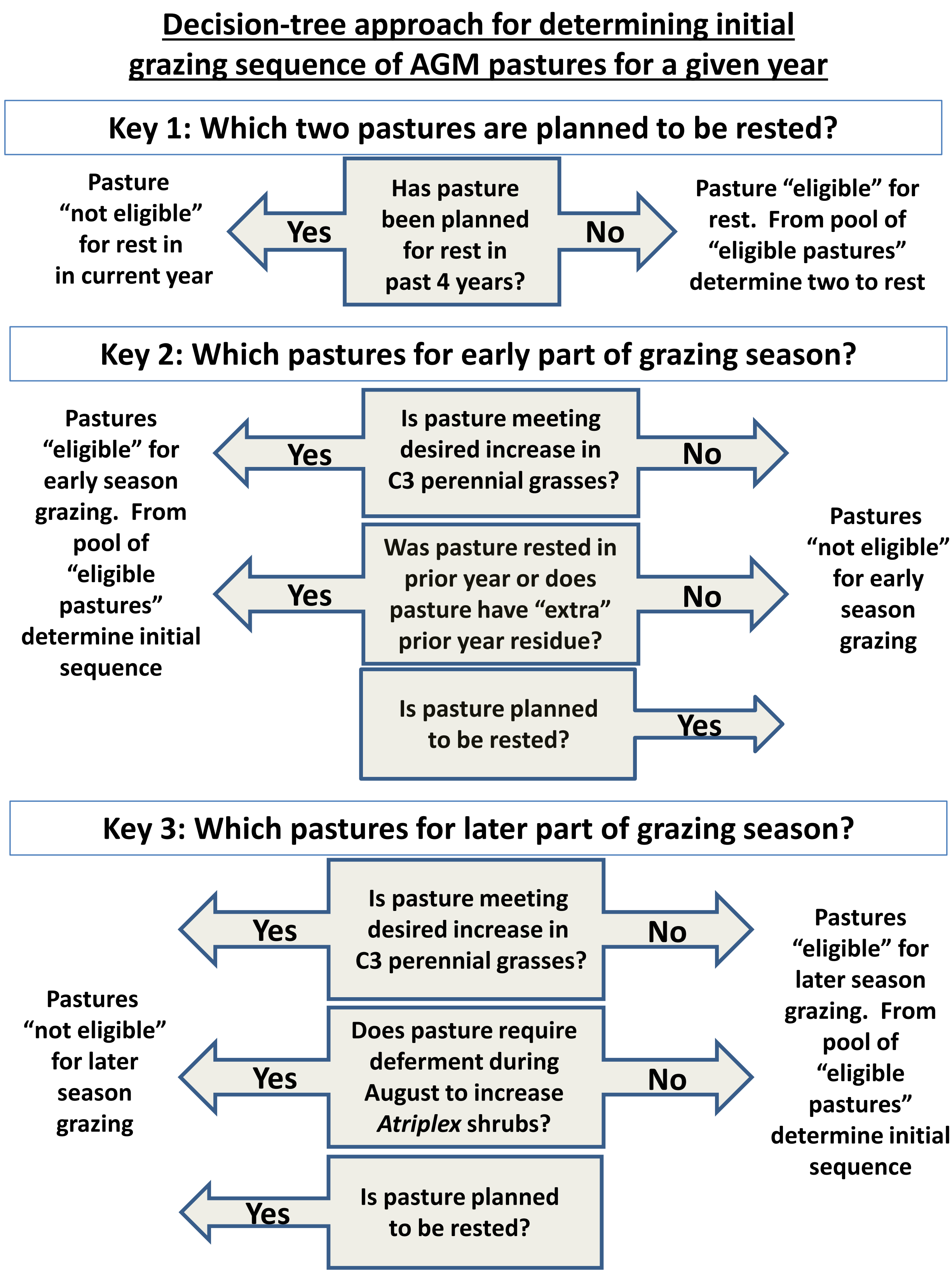


Figure 3. Decision tree for determining initial grazing sequence of AGM pastures.

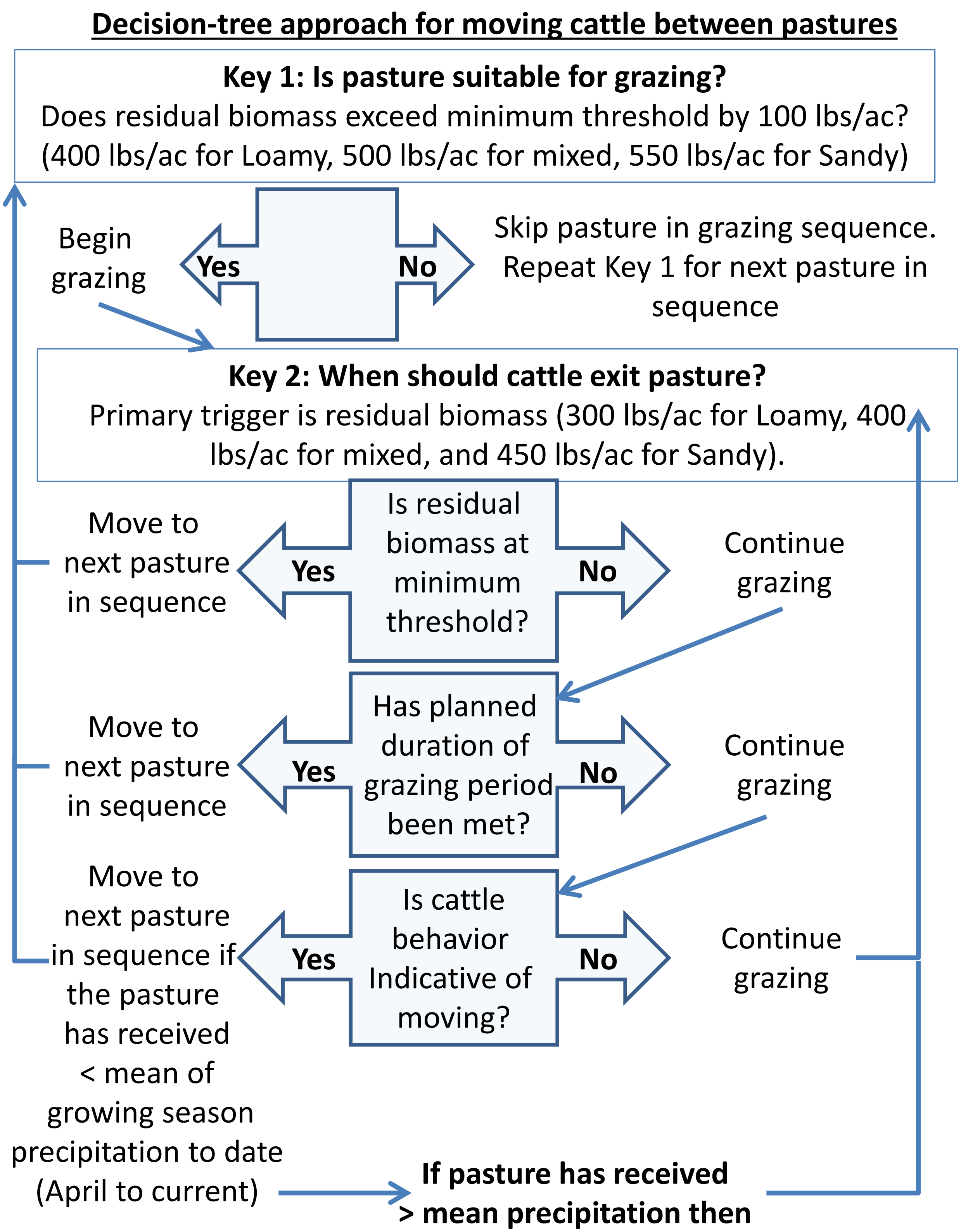


Figure 4. Within-grazing season decision tree for moving cattle between AGM pastures.

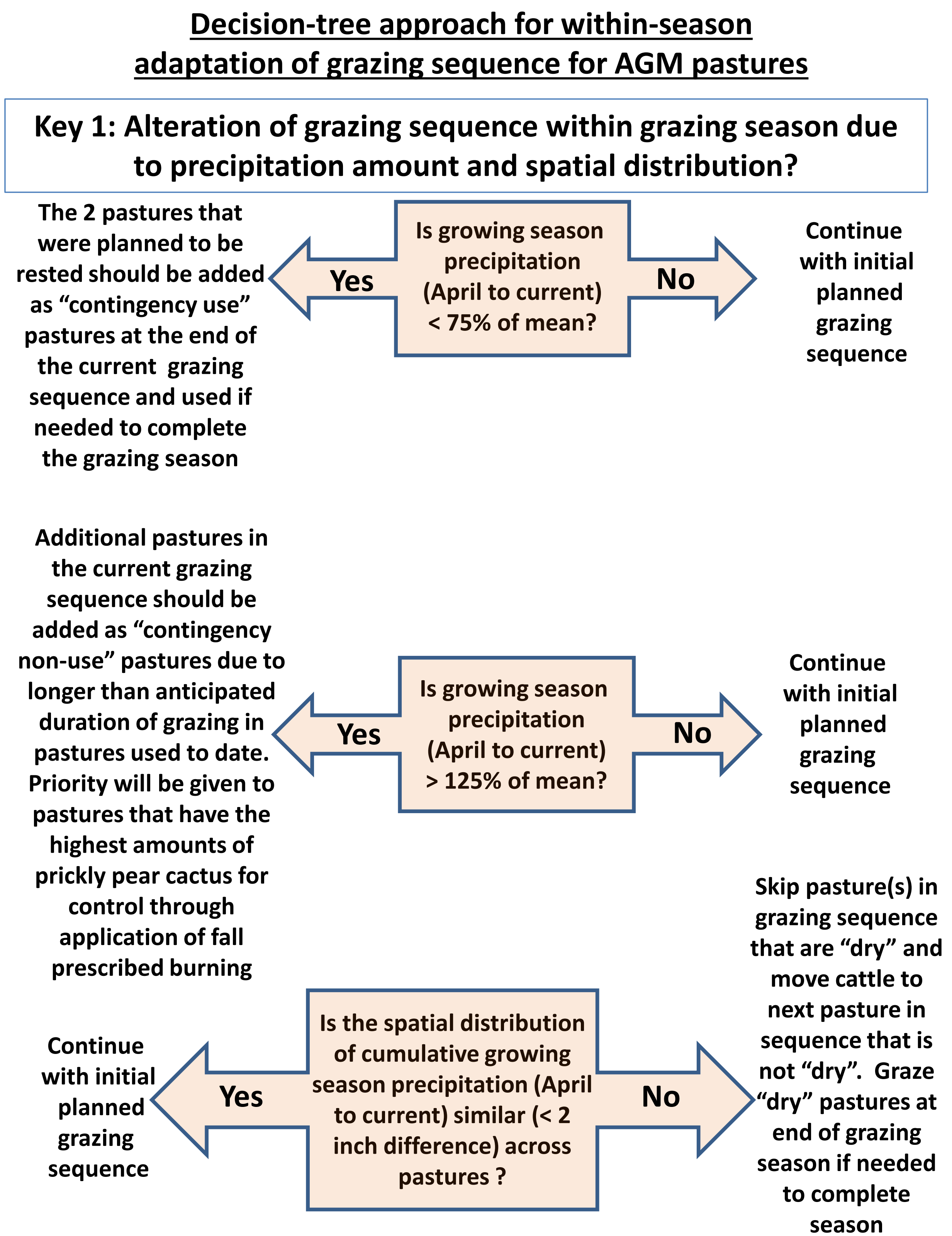


Figure 5. Within-grazing season decision tree for adapting grazing sequence of AGM pastures.

Site Characteristics

The 15,500 acre USDA Agricultural Research Service Central Plains Experimental Range (CPER) is the study site. Mean annual precipitation of 12.6 inches, greater than 80% of which occurs from April through September. Soils are primarily Aridic Argiustolls and Ustic Haplargids. Vegetation is dominated by the warm-season grasses blue grama (*Bouteloua gracilis*) and buffalograss (*Bouteloua dactyloides*). Other common species are the cool-season graminoid needleleaf sedge (*Carex duriuscula*), the perennial forb scarlet globemallow (*Sphaeralcea coccinea*) and prickly pear cactus (*Opuntia polycantha*). Desirable cool-season perennial grasses (needle and thread, *Hesperostipa comata*, and western wheatgrass, *Pascopyrum smithii*) and the shrub saltbush (*Atriplex canescens*) represent a minor component of the plant community, and are key species for restoration efforts (Table 1).

Background Information

This long-term (minimum of ten years) planned experiment will use 10 pairs of 320 acre pastures at the CPER (20 pastures total). Pastures were paired on the basis of similarity in the relative amount of different ecological sites (Loamy Plains, Sandy Plains, Salt Flat, see Table 1), mean pasture topographical wetness index (TWI), as well as prior management history of season-long grazing at moderate stocking rates (see Table 2 for summary of pasture pairs). One pasture in each pair was randomly assigned to a traditional grazing management treatment (TGM or control), while the other pasture in each pair was assigned to an adaptive grazing management treatment (AGM).

Objectives

Desired objectives of the AGM treatment, defined as grazing with high stock density (one large herd) grazing and periodic rest (1 in every 5 years), were determined by the Stakeholder Group, and are in three focal areas (see Figure 1):

1) Vegetation
    a. Increase percentage of cool-season grasses and non-shortgrass native plants, by weight and number of plants
    b. Increase variation in vegetation structure, composition and density within and among pastures
    c. Maintain or increase size of four-wing saltbush and winterfat shrubs
2) Profitable Ranching Operations
    a. Maintain or increase livestock weight gains
    b. Reduce economic impact of drought (by having full grazing seasons and not having to remove cattle early due to drought)
    c. Maintain or reduce operating costs
3) Wildlife
    a. Increase populations of mountain plover
    b. Maintain populations of McCown's larkspur, Western meadowlark, and horned lark
    c. Increase populations of grasshopper sparrow, Cassin's sparrow, Brewers sparrow, and lark bunting
    d. Maintain control of prairie dog populations (no prairie dogs)

Adaptive Grazing Management Plan Components

The Stakeholder Group identified common themes for moving livestock among pastures. These include:

1) Pastures (n=2) will be planned to be rested (no grazing) for at least one full growing season; this rest will be rotated among pastures across years. These pastures will serve as grassbanks for drought management, as well as where additional management practices (e.g., prescribed fire) can be implemented (note: same management practices will have to be implemented in the paired control pastures) (Figure 3)
2) rotation of 1 herd of cattle (214 head of yearlings for herd size) through the AGM pastures, with timing of grazing in a pasture altered across years (Figure 4)
3) using rested pastures as emergency feed in drought management plans and to achieve conservation goals in normal and wet years (i.e., grassbanks) (Figure 5)
4) incorporating fundamental understanding of the ecological sites (Loamy, Sandy, Saline Flats) for grazing management decisions as these sites have different productivity levels, plant composition and potential for achieving desired objectives (Tables 1 and 2)

Table 1. Ecological site, vegetation state, potential for restoration of dominant cool-season perennial grasses and shrubs (primarily saltbush), and total annual production (air-dry weight, pounds/acre) at the Central Plains Experimental Range. Ecological sites are arranged from most to least productive (from http://esis.sc.egov/usda.gov, Ecological Site Descriptions).

			Total Annual Production (pounds/acre)		
Ecological Site	Vegetation State	Restoration Potential	unfavorable	average	above-above
Salt Flat	Alkali sacaton, western wheatgrass, blue grama, green needlegrass, four wing saltbush	high	500	1100	1800
Sandy Plains	Increased blue grama	high	400	900	1200
Loamy Plains	Blue grama/buffalograss sod with cool-season remnants	low	200	700	900
Shaly Plains	Increased blue grama with remnant mid-warm/cool season grasses and shrubs	low	300	650	950

Table 2. Summary of percentage of ecological sites and topographical wetness index (TWI) in each pasture pair. For each pasture pair, the first pasture listed is the TGM (traditionally grazed management); the second pasture listed is the AGM (adaptive grazing management).

	TGM				AGM			
Pasture pair	Loamy /Shaly Plains	Sandy Plains	Salt Flat	TWI	Loamy /Shaly Plains	Sandy Plains	Salt Flat	TWI
1 (15E, Nighthawk)	100	0	0	6.84	95	5	0	6.81
2 (24W, Highway)	100	0	0	6.59	80	20	0	6.49
3 (26E, Hilltank)	77	22	0	7.36	53	47	0	7.64
4 (7NW, Headquarters)	53	35	11	7.79	58	25	17	7.78
5 (19N, Snowfence)	0	100	0	8.51	7	93	0	9.06
6 (25SE, Crossroads)	61	39	0	6.63	48	52	0	6.11
7 (31E, South)	53	47	0	6.00	41	59	0	6.47
8 (5E, Ridgeline)	27	73	0	7.68	39	61	0	6.31
9 (17N, Salt Flat)	31	46	23	6.78	21	53	26	7.10
10 (20SE, Elm)	25	54	21	8.08	2	74	24	8.08

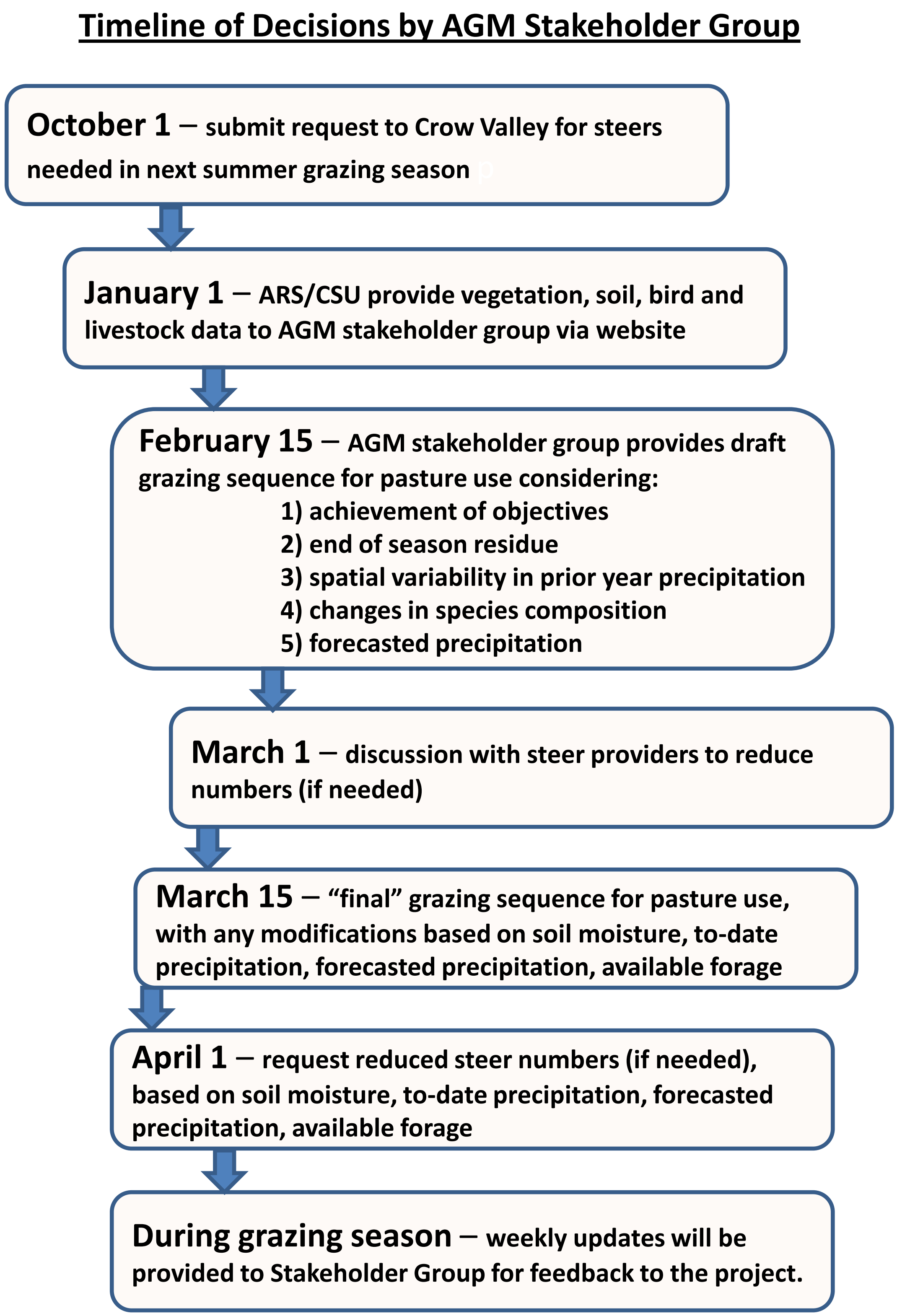


Figure 6. Flowchart of annual decision timelines for Stakeholder Group.

Adaptive Management Plan with Triggers

The Adaptive Grazing Management (AGM) and Traditional Grazing Management (TGM) treatments are planned to have the same annual moderate stocking rate (0.24 AUM $acre^{-1}$, recommended by NRCS for upland ecological sites) and the same targeted utilization rate (50% of "average" annual productivity left as standing crop residue), but will differ in terms of the timing of grazing and stock density. For the TGM treatment, grazing will occur in each pasture the entire grazing season (mid-May to early October) with no rest periods, and stocking density will be maintained at 20-24 yearling steers per 320 acres (0.0625 steers $acre^{-1}$). In contrast, the AGM treatment will rotate the single herd of 214 yearling steers among the 320 acre pastures resulting in a ten-fold higher stocking density (0.625 steers $acre^{-1}$) compared to the TGM treatment, and 2 pastures each year planned to be rested (no grazing, with rested pastures rotating each year, Figure 3).

For AGM pastures dominated by the Sandy Plains ecological site, grazing outside of the critical growth windows for desired cool-season perennial grasses (periods other than spring/early summer) and shrub reproduction (periods other than August) will likely increase desired cool-season perennial grass species, saltbush, increase vegetation structure, reduce bare soil exposure, and enhance habitat for bird species requiring taller structure such as Lark Bunting and Grasshopper Sparrow. Three underlying mechanisms contribute to these responses: 1) lack of grazing during critical cool-season growth windows, (2) longer periods of regrowth following a grazing pulse, and (3) altered cattle foraging behavior with the large, single herd compared to smaller herds in the control (TGM) pastures, which should result in a more even distribution of defoliation across all available plants with the pulse grazing events compared to the season-long grazed pastures.

For AGM pastures dominated by the Loamy Plains ecological site, grazing during the critical cool-season perennial grass growth windows and shrub reproduction will maintain cattle weight gains while preventing degradation of current grass species composition (dominated by blue grama with little cool-season perennial grass abundance), prevent any long-term increase in bare soil exposure, and sustain breeding habitat for disturbance-dependent bird species such as McCowns Longspur, Mountain Plover and Horned Lark.   Increases in desirable cool-season plant species in these pastures (relative to control pastures, TGM) could arise from only 2 of the 3 mechanisms discussed above: 1) changes in the length of recovery periods following grazing, and 2) shifts in cattle distribution within a pasture arising from differences in herd size.

Grazing Sequence

The grazing sequence of pastures for a given grazing season will initially be determined using a suite of criteria including 1) achievement of desired objectives (Figure 1), 2) consideration of management strategies (Figure 2), 3) end of prior growing season residue, 4) spatial variability in prior year precipitation, and 5) understanding of the characteristics of the available ecological sites (Table 1) and the amount of ecological sites in pastures (Table 2). Furthermore, forecasted weather conditions and precipitation (from the National Weather Service Climate Prediction Center (http://www.cpc.ncep.noaa.gov/) could be included.

At the January 10, 2013 meeting, seasonality of grazing was discussed with the following suggestions to consider:

For Days 1-45 (or until end of active cool-season growth) of the grazing season:

- Do not necessarily use previously rested pastures as start pastures
- Use pastures with salt flats early in grazing season
- Use different AGM pastures each year to enhance cool-season grasses

Could graze blue grama-dominated pastures to defer grazing on pastures where increasing cool-season grasses is a high priority

For Days 75-105 (saltbush growth) of the grazing season:

Avoid pastures where saltbush increase is desired (Headquarters, Snowfence, Ridgeline and South)

For Days 105-155 (late season) of the grazing season:

Consider late-grazing impact on next spring's bird habitat

If growing season is good, rest additional pastures? If so, priority for cactus control with prescribed burning, additional tall structure bird habitat, additional drought mitigation?

Figure 3 outlines a decision-tree approach to determining the initial grazing sequence of AGM pastures. First, a decision is made on the 2 planned pastures for rest. Second, pastures are separated into "eligible" and "not eligible" for both early and later parts of the grazing season.

At the January 16, 2014 meeting, the Stakeholder Group requested a summary table of key characteristics that would be of utility for developing the grazing sequence. That table (Table 3) is presented here:

Table 3. Summary Table for Grazing Sequence

Pasture	Ecological Site	Forage Prod	Cool season	Western Wheat	Needle thread	Cactus	Cool-season potential	Salt Flat	Four wing	VOR June
Nighthawk	Loamy	intermed	NO	low	low	high	low	No	low	low
Highway	Loamy	low	NO	low	intermed	high	low	No	low	low
Hilltank	Loamy	low	NO	low	low	low	low	No	low	low
Crossroads	mixed	low	remnant	intermed	low	low	high	No	low	low
South	mixed	low	remnant	low	low	high	high	No	intermed	intermed
Snowfence	Sandy	high	YES	high	high	high	low	No	high	High
Headquarters	mixed	intermed	remnant	low	intermed	intermed	high	Yes	intermed	intermed
Ridgeline	mixed	intermed	remnant	intermed	low	intermed	high	No	high	intermed
Salt Flat	Sandy	high	YES	intermed	high	intermed	low	Yes	low	High
Elm	Sandy	high	YES	low	high	low	low	Yes	low	High

Grazing Season: early May to October

214 head of cattle

rest 2 pastures each year (plan to)

Do not graze same pasture at same time in consecutive years

The Stakeholder Group collectively determined the initial sequencing of grazing through these pastures for implementation by the research team in 2014 and 2015. The resulting table (Table 4) also has the project objectives (L=livestock, W=wildlife, and V=vegetation identified for each pasture

Table 4. Draft grazing sequence developed by Stakeholder Group

Draft Grazing Sequence Table

Pasture	2014	Obj	2015	Obj	2016	Obj	2017	Obj	2018	Obj
Nighthawk	rest	V,W	3	L,V						
Highway	8	L,W	4	L,V,W						
Hilltank	7	L,W	5	L,W						
Crossroads	6	V	7	L,V						
South	rest	V,W	8	L,V,W						
Snowfence	2	L,V	rest	V,W						
Headquarters	3	neutral	6	L,W						
Ridgeline	4	V	rest	V,W						
Salt Flat	5	V,W	1	L,V						
Elm	1	L	2	L,V						

Obj = objectives for study; L=livestock, W=wildlife, V=vegetation

Triggers to Move Cattle Bewteen Pastures

Triggers to begin and end grazing in a given AGM pasture are outlined in Figure 4. These triggers serve as the decision criteria for movement from one pasture to the next, and encompass thresholds of 1) residual biomass (determined via regression equations developed from the Robel height-density value (see Table 5), 2) duration of planned use, determined from calculating forage demand (animal intake) and forage availability (standing crop residual, proportion of biomass growth to date, and biomass growth during planned duration of grazing), and 3) soil moisture (determined from Syntek probes, one each in all pastures) and cattle behavior (see animal and forage checklist developed – Table 6 below). The residual biomass threshold will be the primary trigger for both entry and exit determinations. Prior to entry into the next scheduled pasture in the grazing sequence, Robel pole readings (n=100, 4 transects of 25 readings each) will be conducted. If the residual biomass value does not meet the threshold identified (see Table 5), that pasture will be skipped in the grazing sequence (see Figure 4), and these data will be collected in the next pasture in the sequence to determine if cattle will be moved there. Following entry of cattle into a pasture, Robel pole readings (n=100) will be conducted weekly (every 7 days post-entry of cattle) to determine if the threshold is met for movement to the next pasture (see Figure 4). If the values obtained from the Robel pole are not at the threshold level for triggering a movement of cattle to the next pasture, then the second criteria will be meeting the planned duration of grazing (under “normal conditions”). Cattle behavior data (along with other cattle and forage observation data) will be taken each time cattle are checked (usually Monday, Wednesday and Friday) in the AGM pasture as well as the paired TGM pasture. Soil moisture data will be collected hourly each day via automated dataloggers.

Table 5. Threshold triggers for entry and exit of cattle on AGM pastures

Dominant Ecological Site	Entry threshold (pounds/acre)	Exit threshold (pounds/acre)
Loamy	400	300
Mixed	500	400
Sandy	550	450

Table 6. Cattle and forage observations checklist.

Cattle and forage Observations - CPER Summer 2014 - AGM study

Date	Time	Pasture

	1	2	3	4
Body Condition				

1=Skinny, ribs showing, unhealthy; 2=Thin, but not looking unhealthy

3=Normal looking, filled out and healthy; 4=Fleshy, fat

	1	2	3	4
Hair Coat				

1=Dull, patchy, hair falling out; 2=Rough, not shiny, dirty

3=Clean, shed out, healthy looking; 4=Shiny, silky

	1	2	3	4
Eyes				

1=Dull, cloudy, filmy; 2=Hazy, somewhat cloudy

3=Clear, dark; 4=Shiny, black, clean

	1	2	3	4
Activity				

1=Walking fence, pushing gate; 2=Grazing

3=Standing, licking salt, wandering; 4=Sleeping, loafing, chewing cud

	1	2	3	4
Forage Amount				

1=about 350 lbs/ac; 2= about 475 lbs/ac

3=about 650 lbs/ac; 4=No worries!

	1	2	3	4
Forage Color				

1=Brown; 2=Mostly brown, some green

3=Mostly green, some brown; 4=Green

	1	2	3	4
Forage Consumed				

1=Grazing evident on majority of non-palatable species (ARLO, sub-shrubs, prior year STCO)

2=Grazing evident on a mix of both desirable and non-palatable species

3=Grazing mostly on desirable species, minimal use on non-palatable species

4=Grazing only on desirable species, avoidance of use on non-palatable species

Notes/ Comments:

Achieving Desired Objectives

The profitable ranching operations objective of maintaing or increasing livestock weight gains is posited to occur due to a better matching of forage quality on offer and nutritional demands by the livestock across the grazing season. For the TGM (or control) pastures, livestock remain in the same pasture for the entire grazing season each year despite nutritional status of plants changing within the grazing season. In contrast, for the AGM treatment, the movement of the one large herd among pastures provides flexibility to match forage demand and plant nutritional status, as well as preventing (in theory at least) negative effects of multiple defoliations on key forage species. The vegetation objective of enhanced abundance and production of cool-season perennial grasses is posited to occur through the combination of rest (1 in 5 years) and pulsed grazing outside of the critical growth windows for these desired cool-season grasses (primarily for pastures dominated by Sandy Plains ecological sites). The vegetation objective of increased vegetation heterogeneity across the landscape, will be accomplished through rest (planned 2 of the 10 AGM pastures) to facilitate taller vegetation structure. Increased vegetation heterogeneity (within and among pastures) facilitates more variation in grassland bird habitat (from short-structure to taller-structure vegetation). The grassland bird community encompasses a broad gradient of habitat associations, from species associated with sparse, prostrate grassland (Mountain Plover, Horned Lark, McCown's Longspur), to species associated with tall, dense grassland (Lark Bunting, Grasshopper Sparrow). If AGM successfully increases heterogeneity in vegetation structure, it is hypothesized to provide the habitats necessary to increase the abundance of species associated with more dense grassland, and thereby increase species evenness of the bird communities

The intent of resting 2 pastures each year (i.e., grassbanking) in the AGM treatment is to increase drought management flexibility. Although it is likely that during an extremely dry year cattle would move more quickly among pastures not rested the year before (due to reaching the triggers faster), the strategy should be to maintain stocking rate at the moderate level with AGM and only reduce the length of the grazing season as a last option. TGM pastures would have to maintain the same moderate stocking rate and also have cattle removed at the same time as AGM, if that decision is made.

Management Monitoring Data

At the January 10, 2013 meeting, there was consensus agreement that photopoints were quite valuable and should be taken throughout the grazing season. These photos would provide an excellent archive throughout the length of this experiment. Photos should be taken at permantent locations in each pasture (likely at each transect) at the beginning (mid-May) and end (early October) of each grazing season as well as periodic times throughout the season. These times should, at the minimum, coincide with cattle entering and exiting each AGM pasture. Photos would also need to be taken at the same times in the corresponding TGM pasture pair for comparative purposes.

Economics of the labor, maitenance, time for monitoring, gasoline, equipment, checking cattle, fencing, providing water, doctoring cattle, etc. will be addressed by addition of Marshall Frasier (Colorado State University, Department of Agricultural and Resource Economics).

Scientific Monitoring Data for Management Decisions

Response Variables

Response measures will include soil, vegetation, livestock, and wildlife parameters that have either been selected to (1) examine specific mechanisms by which adaptive grazing management is hypothesized to achieve desired objectives, or (2) quantify the degree to which desired objectives are being achieved. Although response measures will be measured each year, we anticipate the most robust comparisons will be made comparing year 5 (2018) to year 1 (2014). Pre-treatment data was taken in 2013 on all pastures.

Suggested response variables measured in each pasture pair prior to/during/following each AGM grazing period to quantify effects of the AGM treatment over the entire grazing season include: 1) height density using Robel pole, 2) livestock distribution and foraging behavior (via GPS collars and pedometers), 3) diet quality through fecal Near Infrared Spectroscopy, and 4) soil water (via Sentek probes).

Response variables that will be quantified annually in all pastures include those taken in June (species composition, basal and foliar cover, vegetation structure, bare ground, litter, grassland birds), August (aboveground net primary productivity), and October (end of grazing season residue). Additionally, soil stability, soil C and soil N will be taken in year 1 (2014) and year 5 (2018).

Livestock distribution and foraging behavior; dung distribution and livestock diet quality

Distribution of yearling steers and foraging behavior will be evaluated during 2014-2018 using GPS units mounted on collars (Lotek LR3300, Lotek Engineering, Newmarket, Ontario) placed on 2 steers each in 5 randomly chosen TGM pastures, and 10 steers in the AGM treatment. Collars will be deployed for the full 5-month grazing season with batteries replaced at 4-week intervals. Steer locations will be recorded at 5-min intervals. A previously-developed regression tree model based on 2009-2011 deployments (Augustine and Derner, 2013), will be used to predict when steers are grazing versus walking, standing or resting. These data will quantify the location and proportion of time spent grazing by steers in the 2 different treatments. Livestock energetics will be assessed using pedometers.

Diet quality of cattle will be monitored weekly using fecal Near Infrared Spectroscopy (NIRS) by sampling 10 fecal pats from each pasture in pasture pair which has steers grazing in the AGM pasture (e.g., if steers are grazing in the AGM pasture Nighthawk, then fecal pats sampled in that pasture and the corresponding TGM pasture 15E for pasture pair 1). Fecal NIRS has been shown to be robust and may help explain difference in steer gain among pastures (e.g., Walker 2010).

Vegetation and soil responses

Variables include 1) vegetation species composition, 2) basal and foliar cover of species, 3) bare ground exposure, 4) litter cover, 5) vegetation structure (Robel pole), 6) aboveground net primary production (ANPP), 7) soil water, 8) end of season residue, and in year 1 and year 5 only 9) soil stability, 10) soil carbon, and 11) soil nitrogen. These data will be jointly obtained with the Stakeholder Group (pending schedules and travel ability) and data will be provided to the Stakeholder Group for feedback input for possible modifications in their adaptive management plans. Soil stability will be assessed using soil stability kits (Herrick et al. 2001) by collecting 2 samples at each of the 4 transects in each plot. Triplicate soil cores (1 inch diameter x 12 inches deep, incremented into 0-2 inch, 2-6 inch, and 6-12 inch depths) will be collected in 2014 and 2018 at the 2 transects in each plot where cages have been located for aboveground production. Soil and root fragments will be ground to a fine powder and analyzed for total organic carbon and total nitrogen using a Carlo–Erba NA 1500 elemental analyzer. Soil water will be automatically measured hourly in each pasture from a Syntek probe installed to a depth of 1 yard at the center of one of the plots in each pasture. Soil water readings will be taken at 4 inch increments.

Grassland bird responses

Densities of 6 grassland bird species [Horned Lark (*Eremophila alpestris*), Mountain Plover (*Charadrius montanus*), McCown's Longspur (*Rhynchophanes mccownii*), Western Meadowlark (*Sturnella neglecta*), Lark Bunting (*Calamospiza melanocorys*), and Grasshopper Sparrow (*Ammodramus savannarum*)] will be measured in a grid of 4 survey points per pasture each year in June. This community encompasses a broad gradient of habitat associations, from species associated with sparse, prostrate grassland (Mountain Plover, Horned Lark), to species associated with tall, dense grassland (Lark Bunting, Grasshopper Sparrow). Breeding bird abundance will be estimated in each grid using standard 5-min point counts (Ralph et al. 1993). Counts will be conducted between sunrise and 10:30am, with counts repeated at each point on 3 different mornings. Observers will record the distance to each bird (measured with a rangefinder), plus means of detection (visual vs. aural), microhabitat type, and bird behavior and sex. Densities of each species will be estimated using Program Distance (v6) to model detection rates of each species and sex as a function of distance from the survey point (Buckland et al. 2001). Field and analytical methods follow protocols used for past studies at CPER and at the western Great Plains (Augustine 2011; Augustine and Baker 2014).

Livestock weight gains

Yearling steers (initial weights of approximately 650 pounds) will be randomly allocated to the two grazing treatments. Steers will be weighed at the beginning (in mid-May) and end (early October) of the summer grazing season. Seasonal livestock gains (pounds/head) will be calculated as the difference between these two weights, average daily gains (pounds/head/day) will be determined by dividing the seasonal gains by the actual number of days grazed, and beef production (pounds/acre) will be determined by summing seasonal gains for all animals in each treatment and dividing by the number of hectares (3,200 acres).

Monitoring Schedule

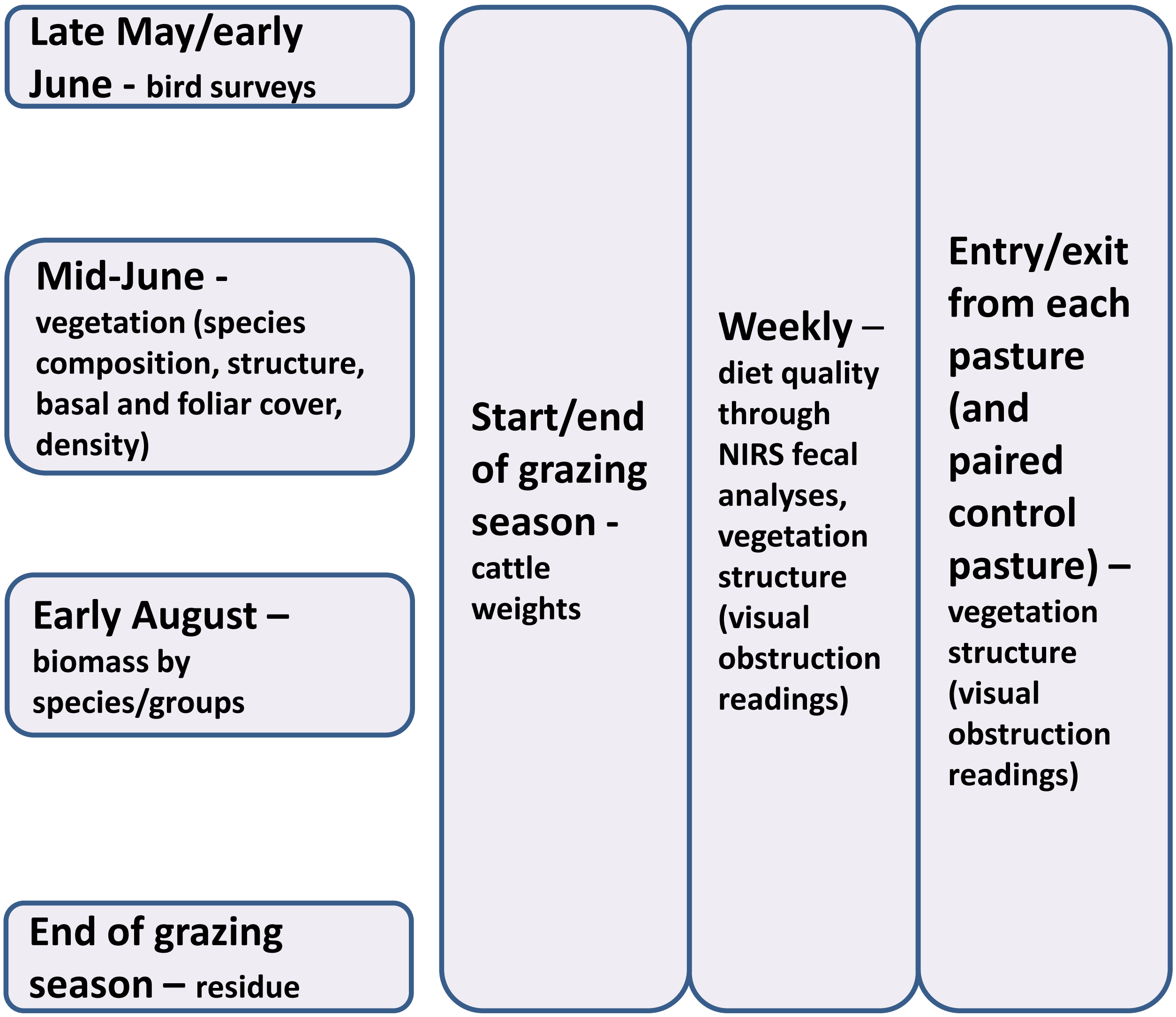


Figure 7. Schedule of monitoring activities.

Appendix A: Adaptive Grazing Management Experiment

Vegetation Sampling Protocol

(*Note – units are metric*)

Study Sites: 10 AGM pastures, 10 TGM pasture, 5 TGM+P pastures; see map

Plot and Transect Layout: 4 circular bird-sampling *Plots* per pasture (125 m radius). Within each *Plot* (P1-P4), there are four, 30-m vegetation *Transects* (T1-T4).

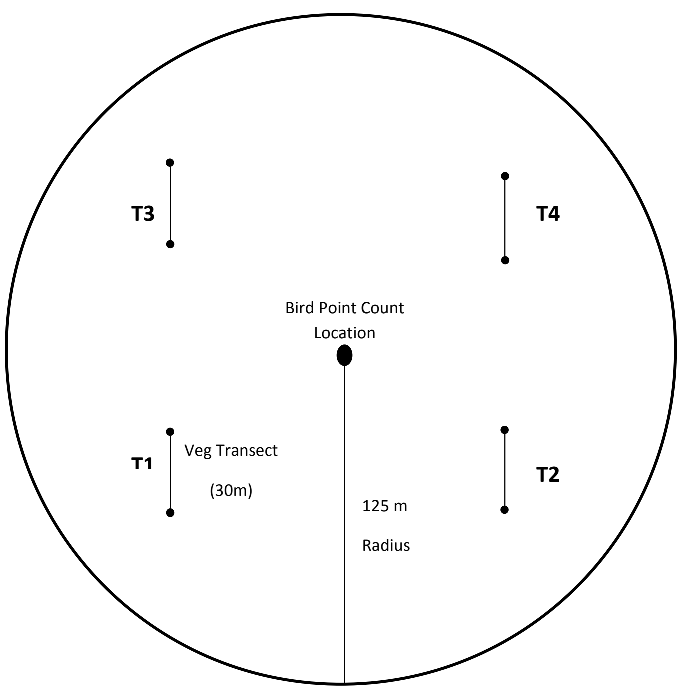
An exception is that pastures with salt flats (7NW, 7SE, 17N, 17S, 20NW, 20SE) have 6 circular bird-sampling plots and 24 vegetation transects per pasture.

Total of 112 Plots and 448 Transects across all 25 pastures (see Figure 8).

Treatments: AGM = Adaptive Grazing Management; TGM = Traditional Grazing Management, TGM+P = Traditional Grazing Management plus Prairie Dogs

Transect = 30 m long, with orange stake at beginning (south) and orange stake at end (north).

Plot and Transect Identification Protocol: Plots numbered P1-P6 within each pasture; Transects labeled T1-T4 within each plot (e.g. P2T4), with T1=SW, T2=SE, T3=NW, T4=NE.



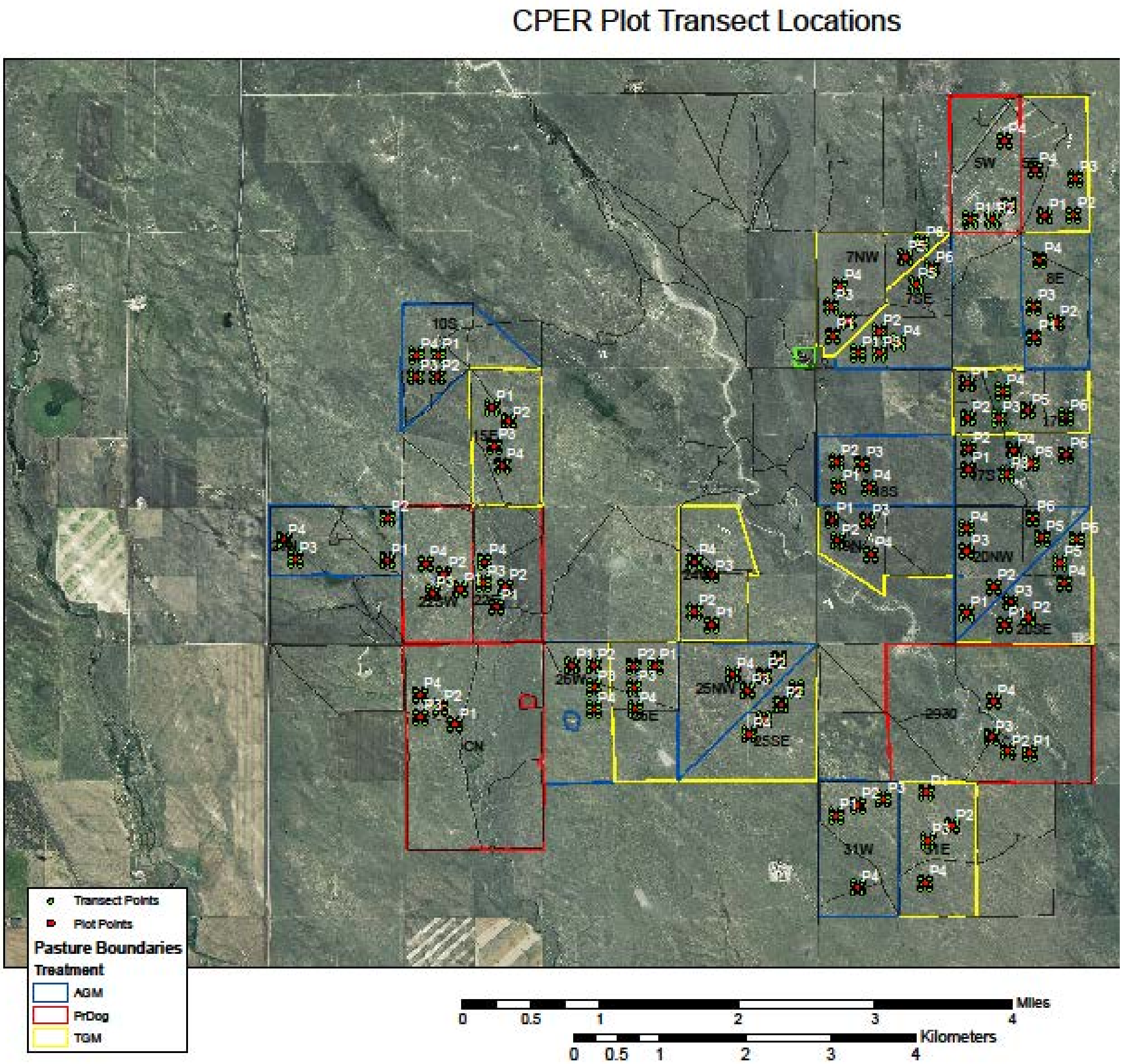


Figure 8. Map of plot and transect locations.

Measurements along each transect:

Every 50 cm up to 25 m	Line point intercept: Pin contact for canopy and basal cover	50 interceptions per transect; 200/plot total
Every 3 m up to 24 m	Robel pole in 2 directions, 0.25 m^2 circular plot for uncommon spp.	8 quads/VOR stations per transect; 32 total per plot
Inside 2 cages located at 10 and 20m, 2 m west of transect	ANPP: Biomass Harvest within 0.18 m^2 quadrat	2 cages at half of all transects (T1 and T4); 4 cages per plot
Full length of each transect	ARFR density/ dimensions in 1-m wide belt; All other shrubs and cattle dung counts in 2-m belt	120 m of belt transects per plot

<u>Grazing cage placement, early May:</u>

Set out grazing cages along transects in early May, 2 cages each at T1 and T4 (none at T2 and T3). Place cages at 10m and 20m along transects, 2 m west of the transect. If cage contains a shrub (e.g. ATCA, YUGL), a harvester ant mound, or disturbance from burrowing, shift it 1 m north.

<u>Measurements done in June:</u>

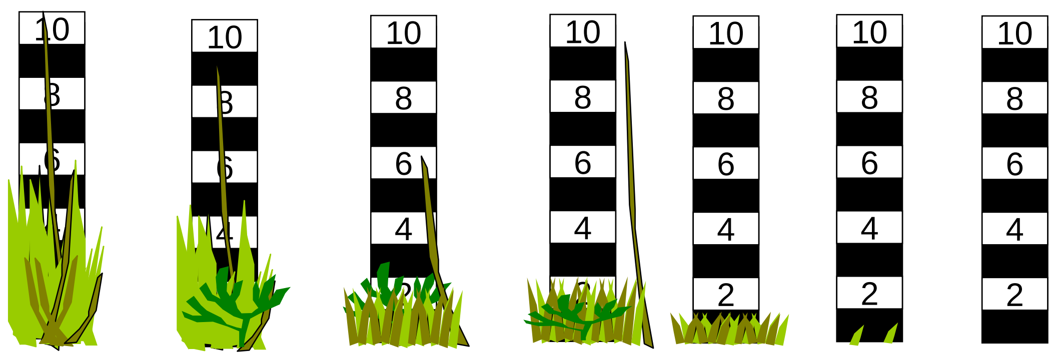
Line Point Intercept. This measure produces foliar cover and basal cover. Start at 50 cm on tape, and take a reading every 50 cm out to 25 m. When doing these measurements, restrict foot traffic to the east side of the tape. At each 50 cm location, use laser point device (ensure laser is level and vertical) to record the basal contact of the pin (BARE, Litter = LIT, Lichen = LICH, DUNG, DCR = DeadCrown, or basal cover of a plant species). Also count the number of contacts the pin makes with any canopy species; on the datasheet, record these contacts separately for each species (species code and number of contacts of each species). Also record any contacts with standing dead material (code = SD). If the pin contacts dead biomass that is still attached to a plant base but is lying horizontal or nearly horizontal on the ground, count that as a basal litter contact. In some rare cases, if the pin contacts a piece of non-attached dead biomass that is above ground level, record it as a canopy contact with species code = LIT. The last intercept will be at 25.0 m.

Visual Obstruction and Maximum Plant Height Readings (= Robel Pole measurements) Use poles previously constructed for use at CPER (3cm wide PVC pole with 1cm increments marked as below; viewed from height of 1 m above ground and 4 m away from the pole). Take readings from E and W directions, perpendicular to the transect. First, record the highest band which has some type of vegetation in front of the pole (record in the "high" column). Second, record the highest band for which some portion is visible but for which the band below it is completely obstructed by the vegetation (record in the "low" column on datasheet). Also record the plant species causing the obstruction in the band associated with the "low" reading (see diagram).

Start at 3 m along the tape, and take readings every 3 m out to 24 m (8 stations and 16 readings per transect).

Robel Pole Method Examples:

High reading:	10	9	6	2	1	1	0
Low reading:	4	3	2	2	1	0	0
Species:	BOGR	BOGR	SPCO	BOGR	BOGR	BOGR	BARE



Uncommon Species Circular Plots = Place a circular, 0.25m^2 plot centered over the point the tape at 3-m intervals along the tape, after completing the robel pole measurement at that point. Count the number of individuals of **each species of forb** (record each species separately), the number of **STCO**, **SIHY, ARLO, and SPCR** individuals (bunches), the number of **PASM** and **DISP** tillers, and the number of **OPPO** cladodes (live cladodes only). For **SPAI,** estimate canopy cover as determinations of individuals is problematic.

<u>Measurements done during 1st two weeks of August:</u>

ANPP: Harvest of all aboveground biomass by functional group or species within functional group – e.g., harvest C3 PG separately (Bogr+Buda; Stco, Pasm, Sihy, Cael, C4OtherG; C3AG; PForb; AForb; SS) in 0.18m^2 quadrat in center of each cage.

<u>Measurements done in summer when time is available:</u>

ARFR: Count density of ARFR within 0.5 m on each side of each transect (1-m wide belt transect)

All other Shrubs and Subshrubs (ATCA, GUSA, EREF, CELA, CHNA, YUGL):
Count total number individuals of each species within 1 m of either side of each transect (2-m wide belt transects).

For ATCA and CELA only: Measure height/length/width of the first 8 individuals encountered on each transect (32 total per plot), or measure all individuals in the transect if less than 8.
Note - all measurements are made across *live* biomass, and in *centimeters*. If more than 8 individuals of a given species is encountered in a belt, then stop recording height/length/width for that species, and just count the number of individuals.

Measurements done in Oct (end of grazing season):

Residue: For each location where ANPP was determined in August, place the $0.18m^2$ quadrat 3 m south of each cage, and take a Robel pole reading from both the East and West directions (just like in **Visual Obstruction and Maximum Plant Height Readings)** with the pole in the middle of the quadrat. Harvest entire quadrat; bag all biomass together. Will develop regression equations for each ecological site to estimate residue in future years.

Appendix B. Adaptive management plans suggested by the Stakeholder Group – from September 18-19, 2012 meeting

Building on commonalities identified in the prior Stakeholder meeting on September 18 & 19, the proposed grazing plans developed by small (four sub) groups had a number of similarities. All four plans recommended a rotational grazing strategy with 1-2 herds of steers. Some pastures (1-2) would be deferred from grazing each year, and they would be rotated such that no pasture was grazed at the same time every year. All plans incorporated year-long rest in at least one pasture per year. During drought years, three plans suggested that the rested pasture would be grazed in order to provide emergency forage. All groups noted that inherent variability in ecological sites would alter their recommendations for individual pastures (e.g. timing and duration of grazing). These commonalities will form the basis of the "straw man" adaptive management plan that the research team will write for the Stakeholder Group to evaluate.

Differences among plans point towards decisions that will have to be made by the Stakeholder Group. They include the following:

- One herd of 200 (two groups) vs. two herds of 100 (one group) vs. one herd of 150 and one herd of 50 (one group)
- Two pastures rested (three groups) vs. one pasture rested (one group) each year
- For mountain plover habitat, patch burning small (15-80 acre) areas in the non-grazing season (one group) or intensely grazing small (40-acre) areas for a short period of time using electric fence.

Group	Participants	Plan
A	Ted, Seth, Casey	In an average precipitation year, one herd of 200 steers rotates through the eight pastures over 135 days (~17 days/pasture; 12.8 acres/yearling/season). Some pastures are deferred (in order of rotation) to promote fourwing saltbush each year—pastures wouldn't be grazed at the same time each year, which would have the benefit of increasing among-pasture diversity. Rest two pastures for two consecutive years (starting with sandy pastures, 18S, 20NW years 1 and 2; 31W, 25N5 years 3 and 4). They also liked the suggestion of making their rests rotate (so that one pasture is always coming into rest). In a wet year, rest three sandy pastures (17S, 8E). In a dry year, use it all for built-in flexibility. In addition to grazing, they suggested prescribed burn in the non-grazing season to increase within-pasture diversity (60-160 acres/year total; 2-4 burns a year at 15-80 acres each; based on 20-50 year fire interval). Would have the benefits of increasing within pasture diversity, plover habitat increases and cactus removal.
B	Dana, Leonard, William	In an average precipitation year, two herds of 100 steers each rotate through four pastures, spending about 34 days in each pasture (12.8 acres/head), while resting two pastures. Start in different pasture each year. Consider production potential for each pasture when setting actual rotation times. For this year, those pastures could be: May 15, 7SE (salt flat) and 17S (salt flat); June 19, 8E and 18S (both saltbrush); July 27, 20S and 31W (both saltbush); September 30, 21N and 20NW; Rest

		26W and 25NW (both sandy plains). Rational rotation so you start and end in a good place. Also, electric fence two 40 acre plots of loamy uplands (21N and 20NW) to graze hard for a short period of time for mountain plover. Adjust 20 days into each cycle—evaluate conditions to decide what to do next. Grassbank rested pastures and residual in grazed pastures (e.g. salt flats). In dry years, graze rested pastures. Also salt flats may produce more grass later in the year to use. Alternative system (twice over): Same rotation, but quicker first pass to hit the cool seasons while they are productive (10 days) and slower second pass (24 days).
C	Rachel, Jason, Pat	One herd of 200 steers rotates through 8 pastures, based on season/critical growth period—if grazed during critical growth period one year, rested in that time the next year. Two pastures are rested each year. They felt this would achieve habitat and grassbanking in dry years goals. Overall, the group stated their plan was very similar to Group A. They also noted that they want to base estimates on ecological sites rather than generic assumptions we have today.
D	Kim, Steve	A larger herd of 150 steers rotates through the 7 non-sandy (mostly loamy) pastures, at about 20 days per pasture. Graze each pasture at different times every year (deferring). May rest 1 loamy pasture per season. In the sandy pastures, one is rested while the other two have 50 head of steers total for the whole season. They noted that they tried to look at their grazing plans spatially, and keep operating costs low.

Appendix C. Monitoring to assess whether Objectives identified by the Stakeholder Group are being met, and to inform yearly AGM decisions/modifications to grazing plan			
Objectives	**Indicator**	**Method**	**Comments/Questions**
Increase biomass and abundance of C_3 grasses and non-shortgrass native plants	Basal cover of C3 (cool season) grasses and other non-shortgrass native plants	* Grid of permanent monitoring points or transects per pasture, * What to measure at each plot (visual estimate of cover in 50 x 20 cm quad?) or transect (line-intercept measurements along X transects, each X m long, distributed in what pattern)? * Measurements should be distributed over minimum of 40 ac per pasture to coincide with bird monitoring plots (10 ac per bird plot)	
Increase variation in veg structure, composition & density within and among pastures	Mean, variance and range in vegetation height-density, bare soil cover, and litter cover	* Vegetation visual obstruction reading (Robel pole) recorded at same plots or transects as above * Visual or line-intercept estimates of bare soil and litter?	
Maintain or increase density and size of fourwing saltbush and winterfat shrubs	Density and mean crown volume	* Permanently marked individuals measured annually? * Shrub density or cover based on permanent transects, or aerial photography	
Increase livestock weight gain	Weight gain per animal over 138 day grazing season	Steers weighed at start and end of grazing season each year	
Reduce economic impact of drought	Number of days that animals are removed from the experiment due to drought; differences in weight gain (vs. control pastures) in dry/drought years	Days of grazing, and steer weight gains as above, but analysis focused only on dry/drought years	
Maintain or reduce operating costs	Person-days required to implement AGM vs TGM	Person days	
Increase population of mountain plovers	Number of mountain plovers in AGM vs TGM pastures	At least four point counts per pasture; will also have data from prairie dog colonies in other pastures for comparison	
Maintain populations of McCowns longspur, western meadowlard, horned lark	Number of each species in AGM vs. TGM pastures	At least four point counts per pasture	
Increase populations of grasshopper sparrow, Cassin's sparrow, Brewer's sparrow and lark bunting	Number of each species in AGM vs. TGM pastures	At least four point counts per pasture	

Maintain control of prairie dog populations (no prairie dogs)	Acres of active prairie dog colony in each pasture	Annual GPS monitoring of all colony boundaries (in Sept or Oct each year)	

Table 2. Monitoring to assess whether hypothesized mechanisms are contributing to attainment of Objectives

Mechanism	**Hypothesis**	**Method**	**Comments/Questions**
Livestock distribution	AGM results in more even distribution of cattle grazing within a given pasture and graze period	GPS Collars	
Tiller defoliation patterns	AGM results in more even distribution of cattle grazing within a given pasture and graze period	Permanently marked PASM (Western wheatgrass) tillers in each pasture	
Cactus abundance	Reduced cactus abundance enhances livestock weight gains	Measurements of cactus abundance in permanent grids where plant species composition is being monitored (40 acres per pasture); additional plots/transects measured in patches treated with herbicide or fire	
Acres treated to reduce cactus abundance	Reduced cactus abundance enhances livestock weight gains	GPS size of areas treated with herbicide or fire or any other method designed to reduce cactus density	
Dung deposition distribution	AGM results in more even redistribution of nitrogen as dung/urine within a pasture	Dung count transects	
Vegetation structure & bird density spatial coherence	AGM effects on vegetation heterogeneity increases evenness of the bird community	Spatial congruence of tall/short structure and tall/short-associated bird species	