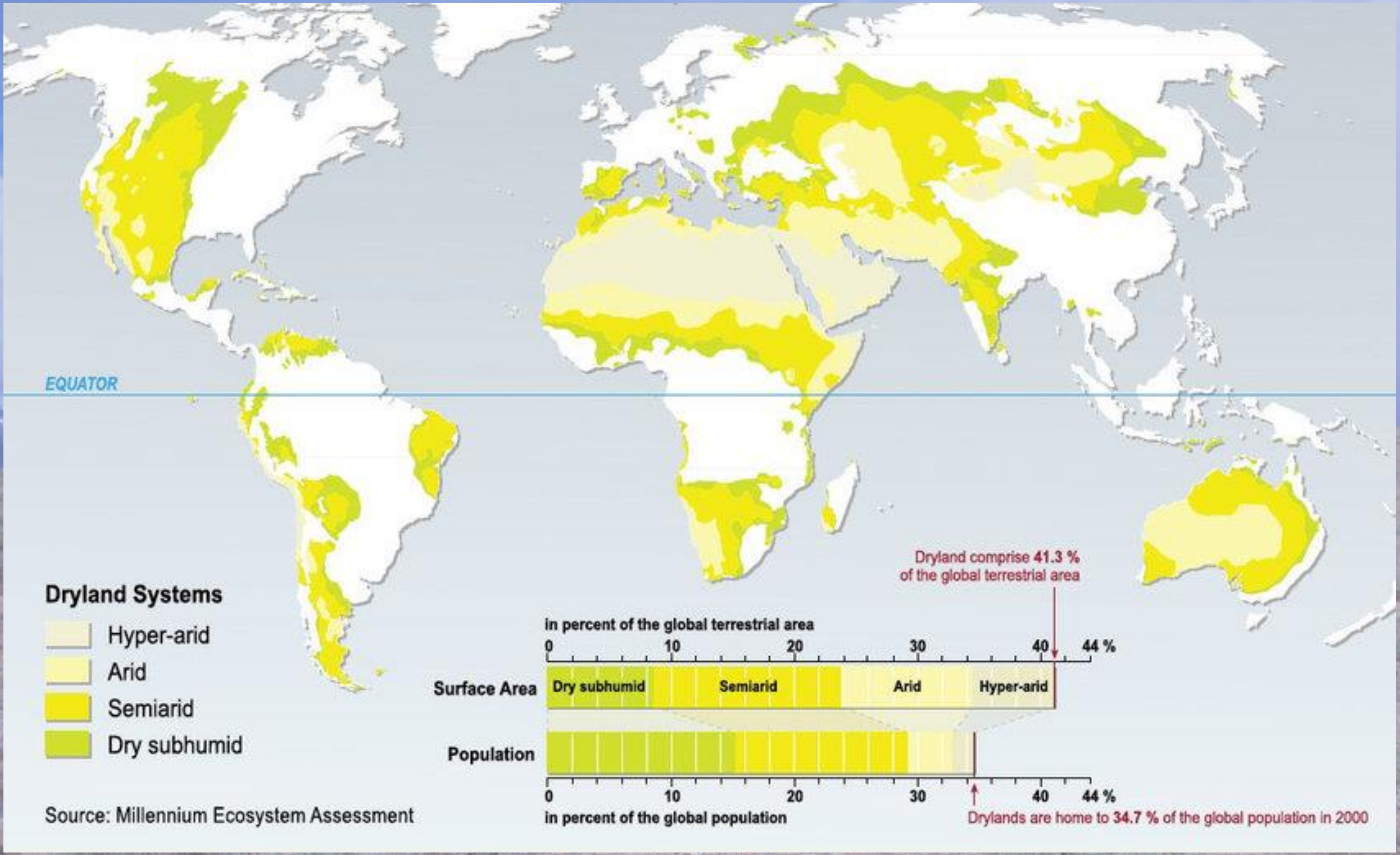
Determining Appropriate Field-Based Grazing Intensity Measurements for Multi-Scale Rangeland Management

Alexander Laurence-Traynor

Thesis Defense


EQUATOR
Dryland Systems
Hyper-arid
Arid
Semiarid
Dry subhumid
Source: Millennium Ecosystem Assessment
Dryland comprise 41.3 % of the global terrestrial area
in percent of the global terrestrial area
0 10 20 30 40 44 %
Surface Area
Dry subhumid
Semiarid
Arid
Hyper-arid
Population
0 10 20 30 40 44 %
in percent of the global population
Drylands are home to 34.7 % of the global population in 2000

What effect does grazing have on the landscape?

- Grazing is the primary land use of rangelands
- Grazing has influence on wildlife habitat, wildfire, invasive species
- Understanding these interactions requires us to take accurate unbiased measurements

Current field-based grazing intensity techniques

1. Visual estimation techniques
    - E.g. landscape appearance and ocular estimates of utilization

2. Measurement techniques
    - E.g. residual forage height measurements and frequency of grazing

3. Exclusion techniques
    - E.g. paired ungrazed and ungrazed plots

Current challenges with rangeland monitoring

- Influence of environmental conditions and annual variability (Biondini et al., 1998)
- Heterogeneity in grazing intensity (SRM Rangeland Assessment and Monitoring Committee, 2018)
  - Particularly at moderate levels
- Relevance of grazing indicators to other land uses (Atkinson, 1997; Toevs et al., 2011).
- Sampling bias (Jasmer and Holechek, 1984)

Opportunities for rangeland monitoring

- Influence of environmental conditions and annual variability
- Heterogeneity in grazing intensity
- Relevance of grazing indicators to other land uses
- Sampling bias

Improving understanding of spatial and temporal distribution of grazing

Integrating remote sensing with field based measurements

Improving understanding of field based sampling and explore methods for reducing bias

Objectives

Objective 1: To evaluate the repeatability of commonly used utilization monitoring methods with particular focus on the influence of:

-> Observer experience and technical skill

Objective 2: To evaluate the sensitivity, precision, and accuracy of different utilization monitoring methods across four stocking rate levels:

-> Comparing field estimates to actual cattle locations

Objective 3: To evaluate several different 'calibration' techniques for improving visual estimates of grazing intensity

Methodology

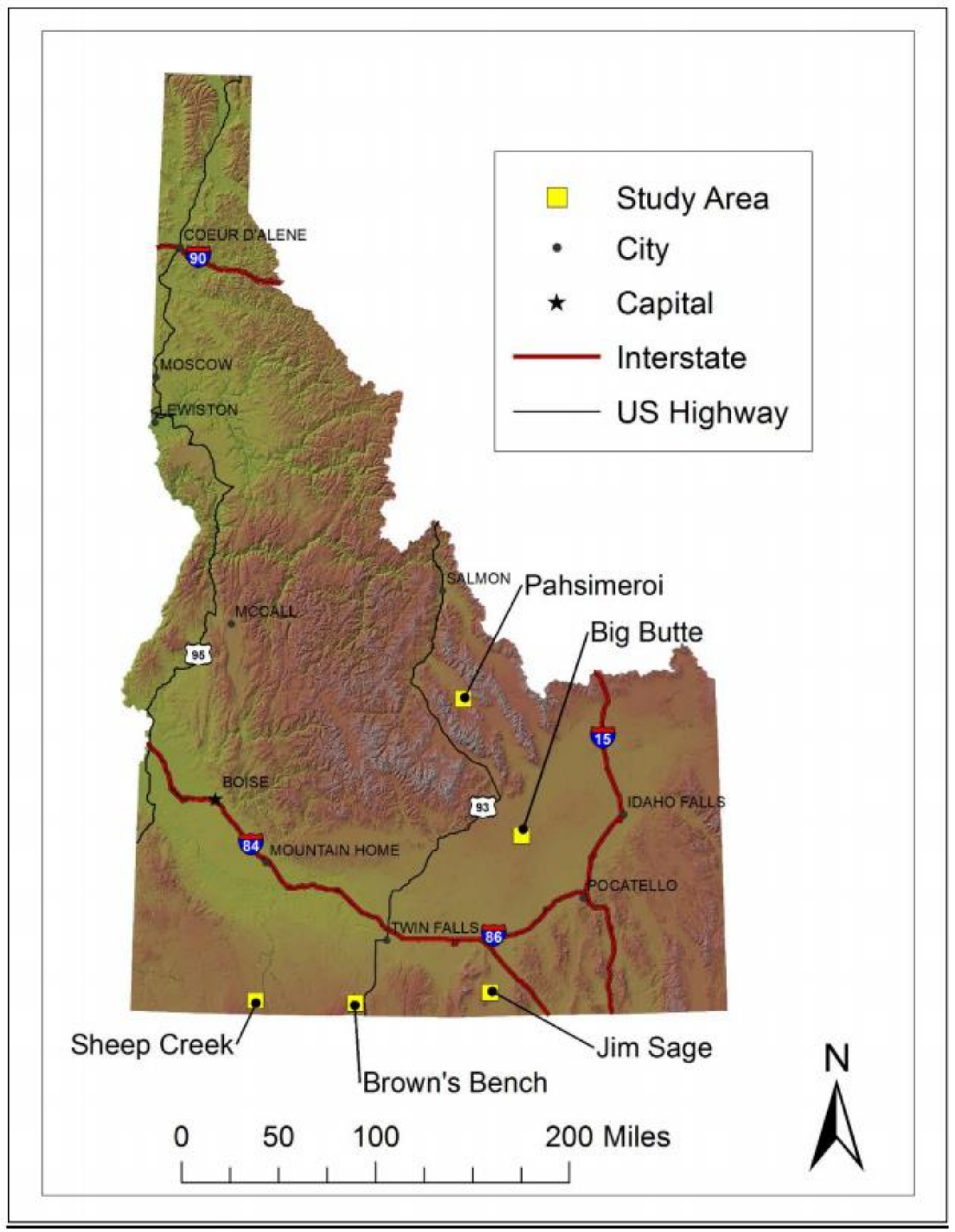
Objective 1. Field technique evaluation – Grouse and Grazing project & Zumwalt Prairie

Objective 2. Comparison of field data to cattle locations – Zumwalt Prairie

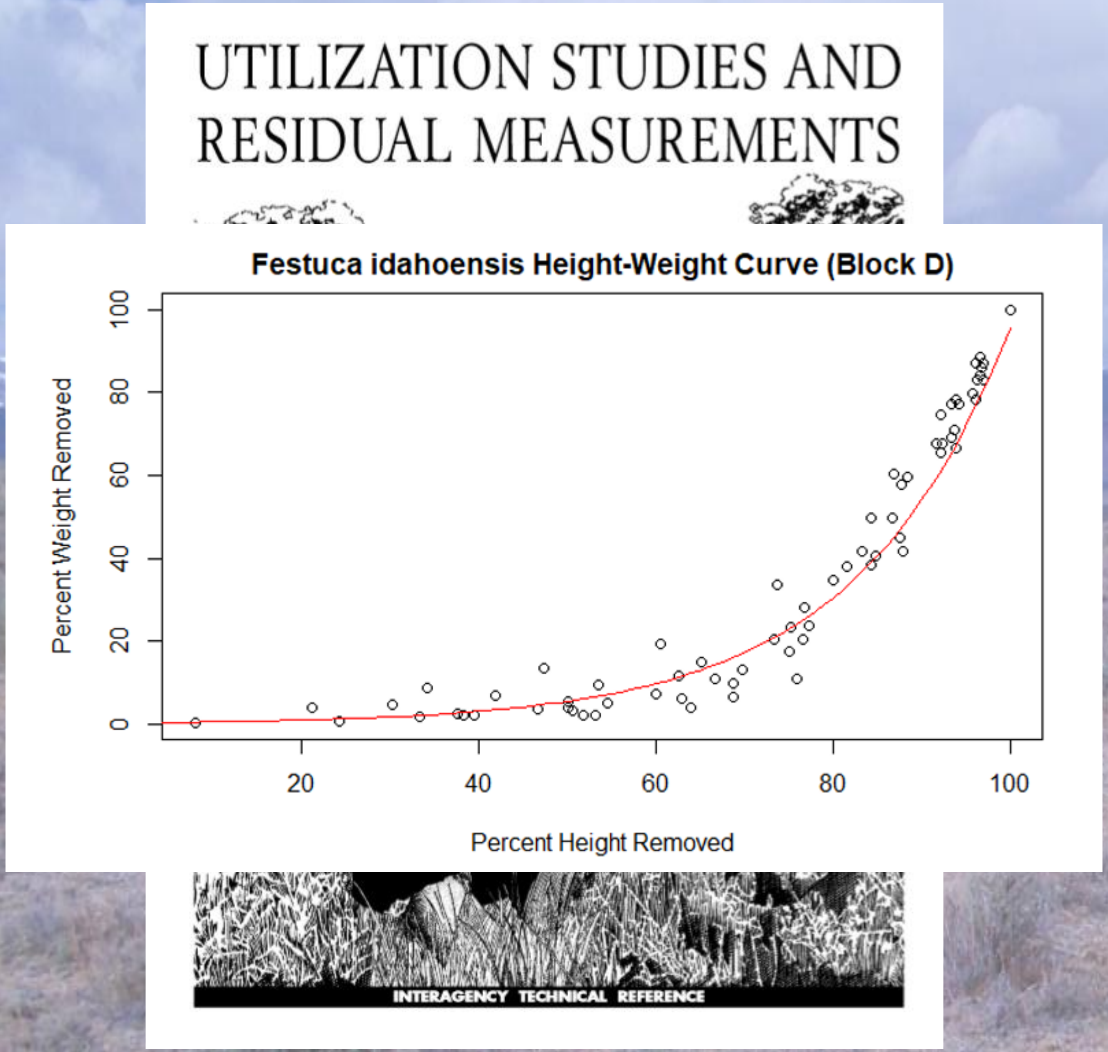
Objective 3. Calibration of visual estimates – Zumwalt Prairie

Methodology – Grouse and Grazing

- Project objective: evaluate effect of spring grazing on greater sage grouse nest survival
- Data collection began in 2014
- 5 study sites – Pahsimeroi, Jim Sage, Browns Bench, Sheep Creek, Big Butte
- Collects utilization data using 4 different widely used methods



Height-weight measurements



Bureau of Land Management, 1999

- Methodology consistent with BLM technical reference 1734-03
- Measure heights of ungrazed and grazed grasses to estimate height removed by grazing
- Calculate weight removed using species & location specific height-weight curves - Julson 2017

Landscape Appearance

Utilization Class	Description
0-5%	The rangeland shows no evidence of grazing or negligible use.
6-20%	The rangeland has the appearance of very light grazing. The herbaceous forage plants may be topped or slightly used. Current seed stalks and young plants are little disturbed.
21-40%	The rangeland may be topped, skimmed, or grazed in patches. The low value herbaceous plants are ungrazed and 60 to 80 percent of the number of current seedstalks of herbaceous plants remain intact. Most young plants are undamaged.
41-60%	The rangeland appears entirely covered[a] as uniformly as natural features and facilities will allow. Fifteen to 25 percent of the number of current seed stalks of herbaceous species remain intact. No more than 10 percent of the number of low-value herbaceous forage plants are utilized. (Moderate use does not imply proper use.)
61-80%	The rangeland has the appearance of complete search[b]. Herbaceous species are almost completely utilized, with less than 10 percent of the current seed stalks remaining. Shoots of rhizomatous grasses are missing. More than 10 percent of the number of low-value herbaceous forage plants have been utilized.
81-94%	The rangeland has a mown appearance and there are indications of repeated coverage. There is no evidence of reproduction or current seed stalks of herbaceous species. Herbaceous forage species are completely utilized. The remaining stubble of preferred grasses is grazed to the soil surface.
95-100%	The rangeland appears to have been completely utilized. More than 50 percent of the low-value herbaceous plants have been utilized.

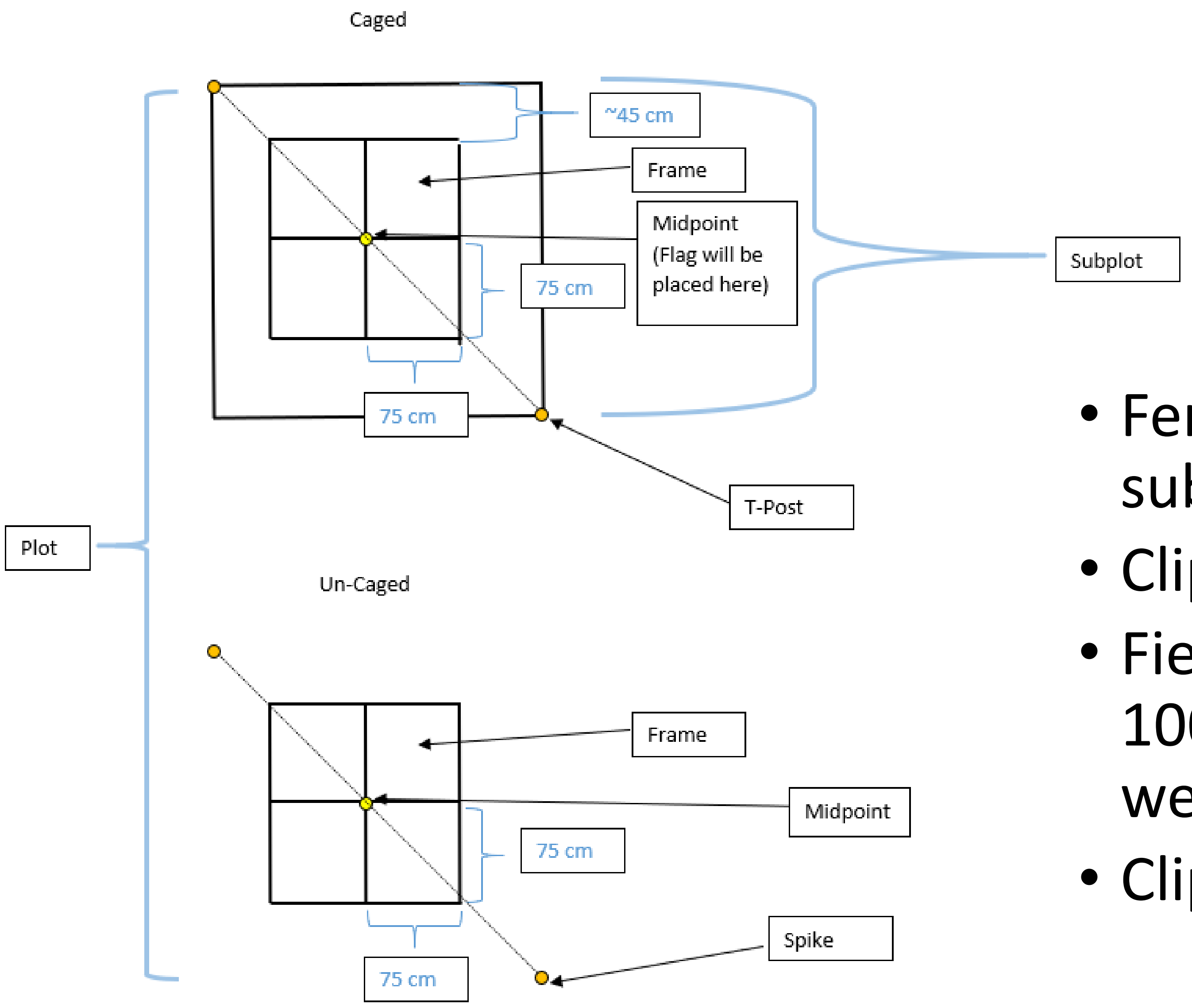
[a] "covered" means that foraging ungulates have passed through the area

[b] "complete search" means that foraging cattle have spent considerable time foraging in the area and were not just passing through

Bureau of Land Management, 1999

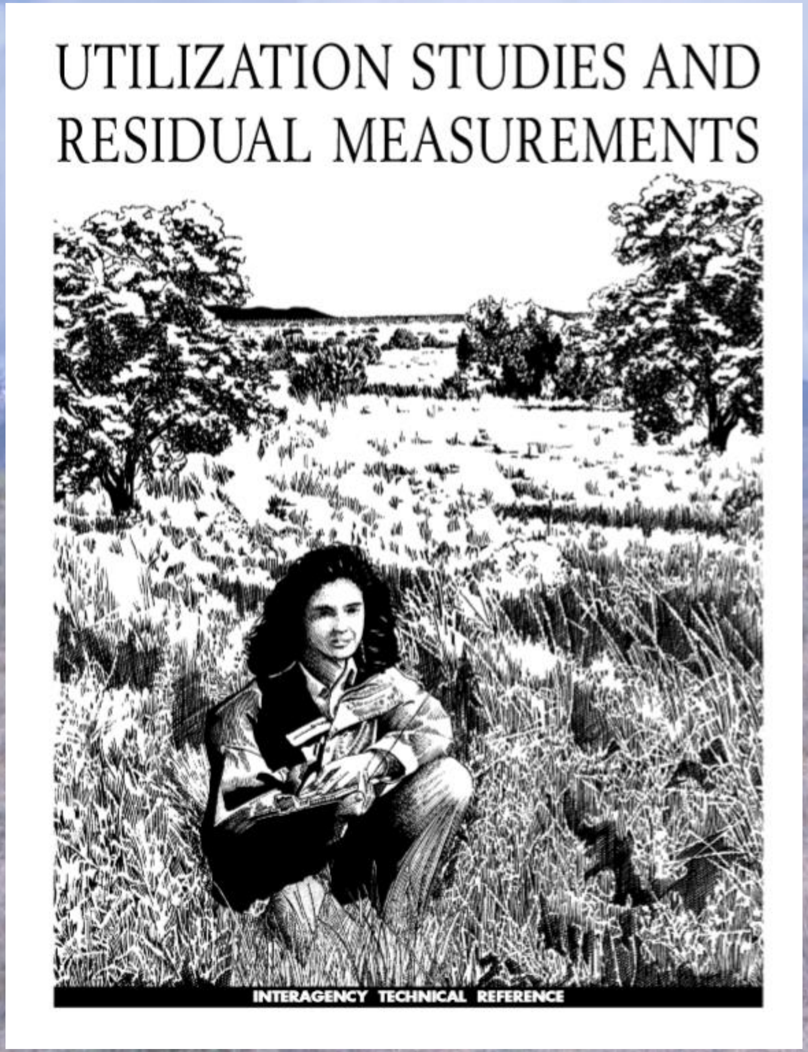
- Methodology consistent with BLM technical reference 1734-03
- Plot based method which classifies area based on intensity and distribution of visual signs of grazing

Paired-plots



- Fenced exclosure + grazed subplots
- Clipped late July/August
- Field weights + 100g/species for lab dry weights
- Clipped by species

Ocular Estimates

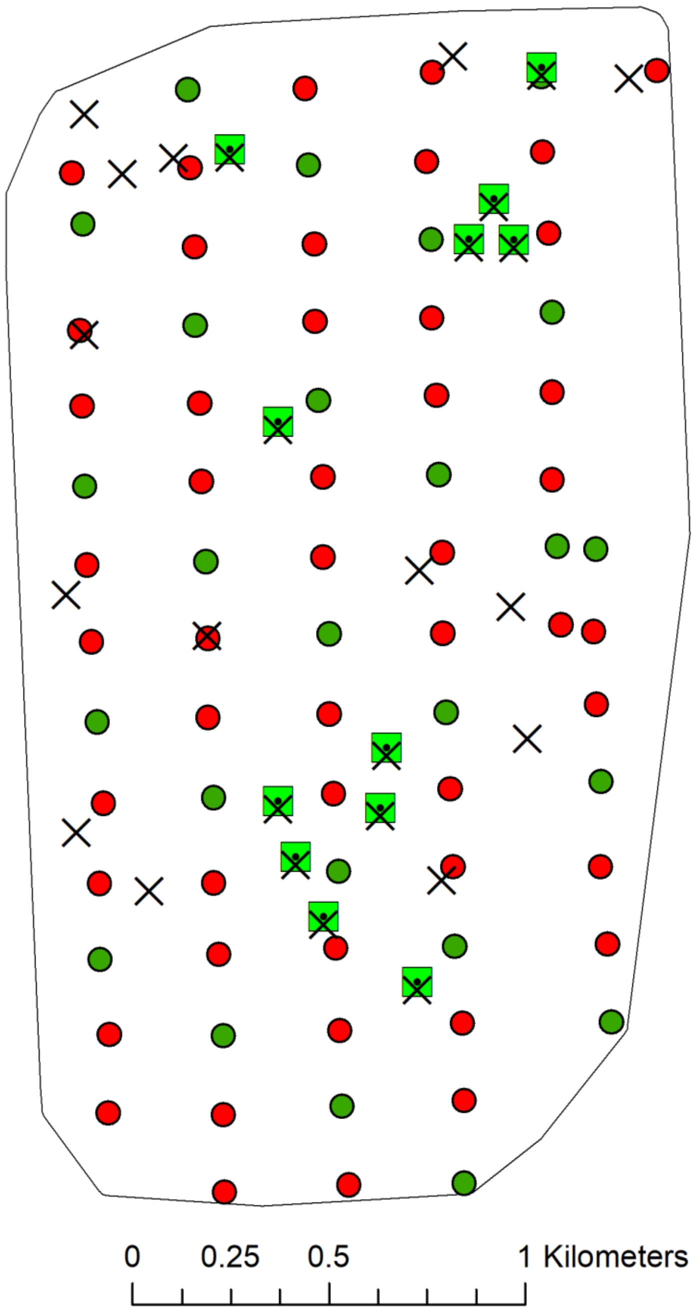


Bureau of Land Management, 1999

Visual estimates of % weight removed by grazing on individual plants

Focuses on several ‘key forage species’

Can also use this method to calculate *Frequency* (proportion of grazed versus ungrazed)



Sample Design

- Randomly located vegetation plots:
  - Ocular estimates (~20 plots/pasture)
  - Paired-plots (12/pasture)

- Systematic transects:
  - Landscape appearance (60-300 plots/pasture)
  - Grass height plots (20-100 plots/pasture)

Vegetation Plots
Grazing Exclosures
Landscape Appearance
Landscape Appearance and Grass Heights

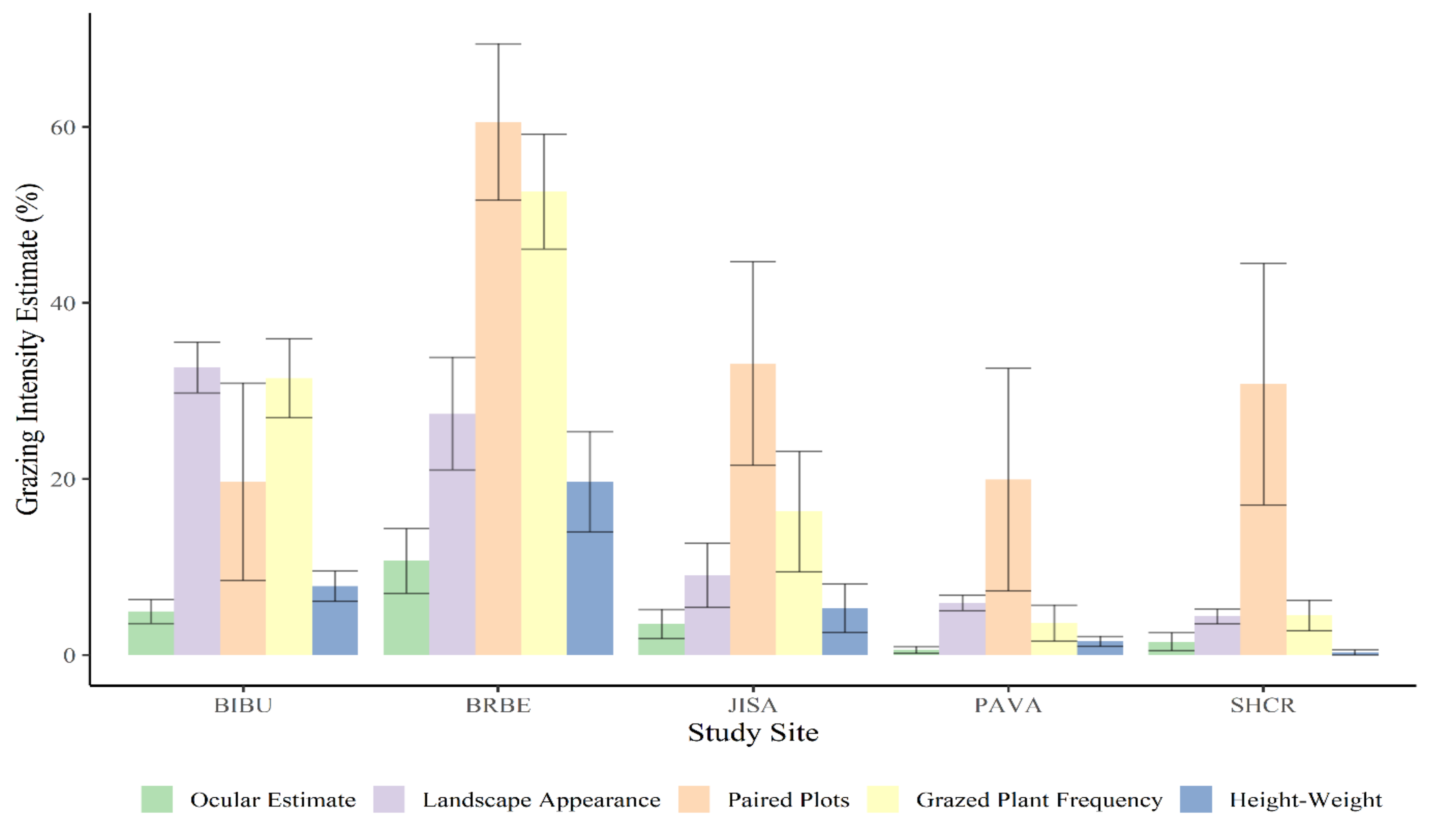
Objective 1 – Data analysis

- Exploratory analysis using simple linear regression comparing different methods across multiple years, observers, plant communities, and scales

- Stepwise selection using AIC to identify variables which explained the largest proportion of variation in grazing intensity estimates

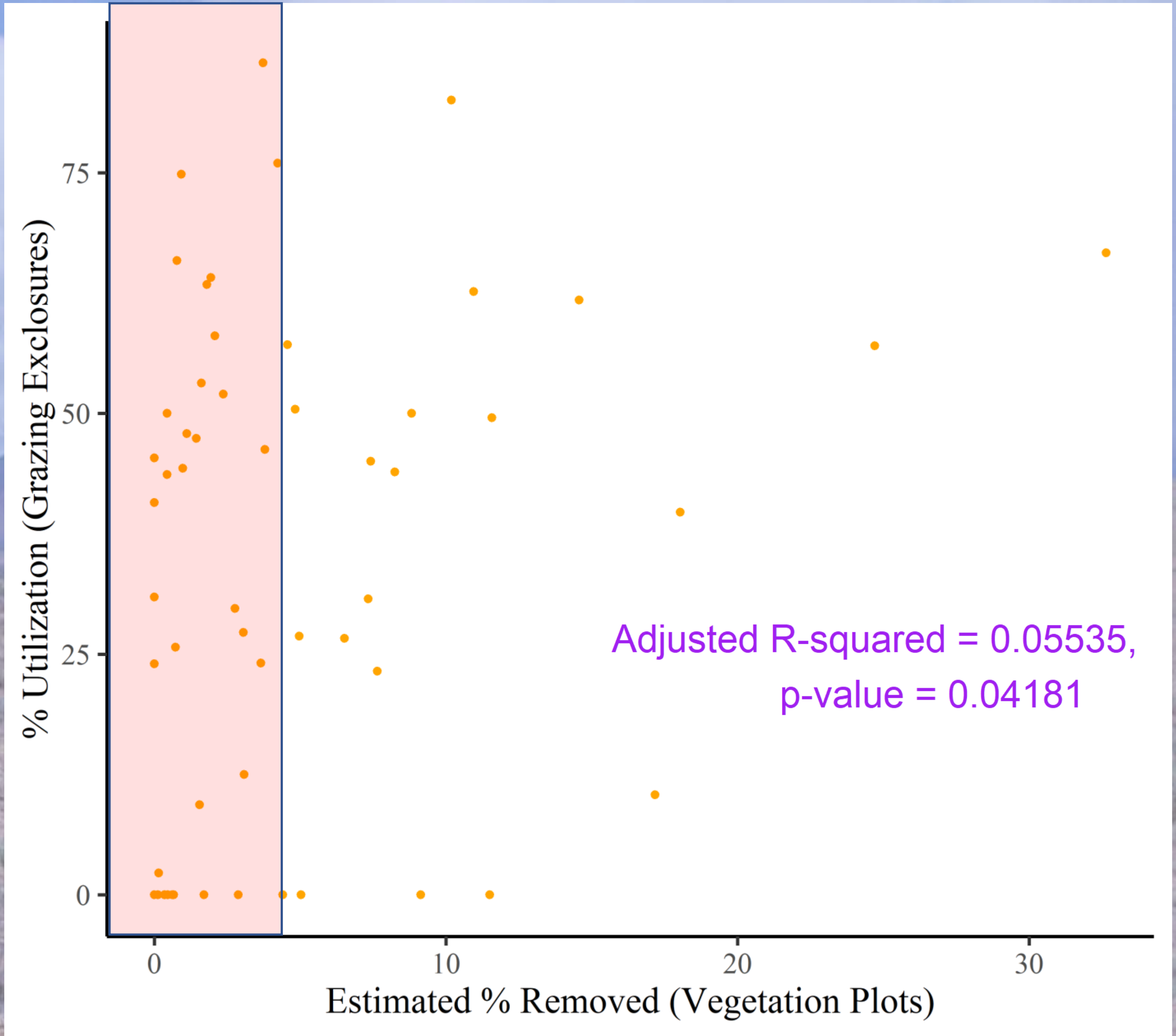
Included plot/pasture covariates including plant community characteristics, observer characteristics, time spent at plot, site, year

Pasture-scale estimates

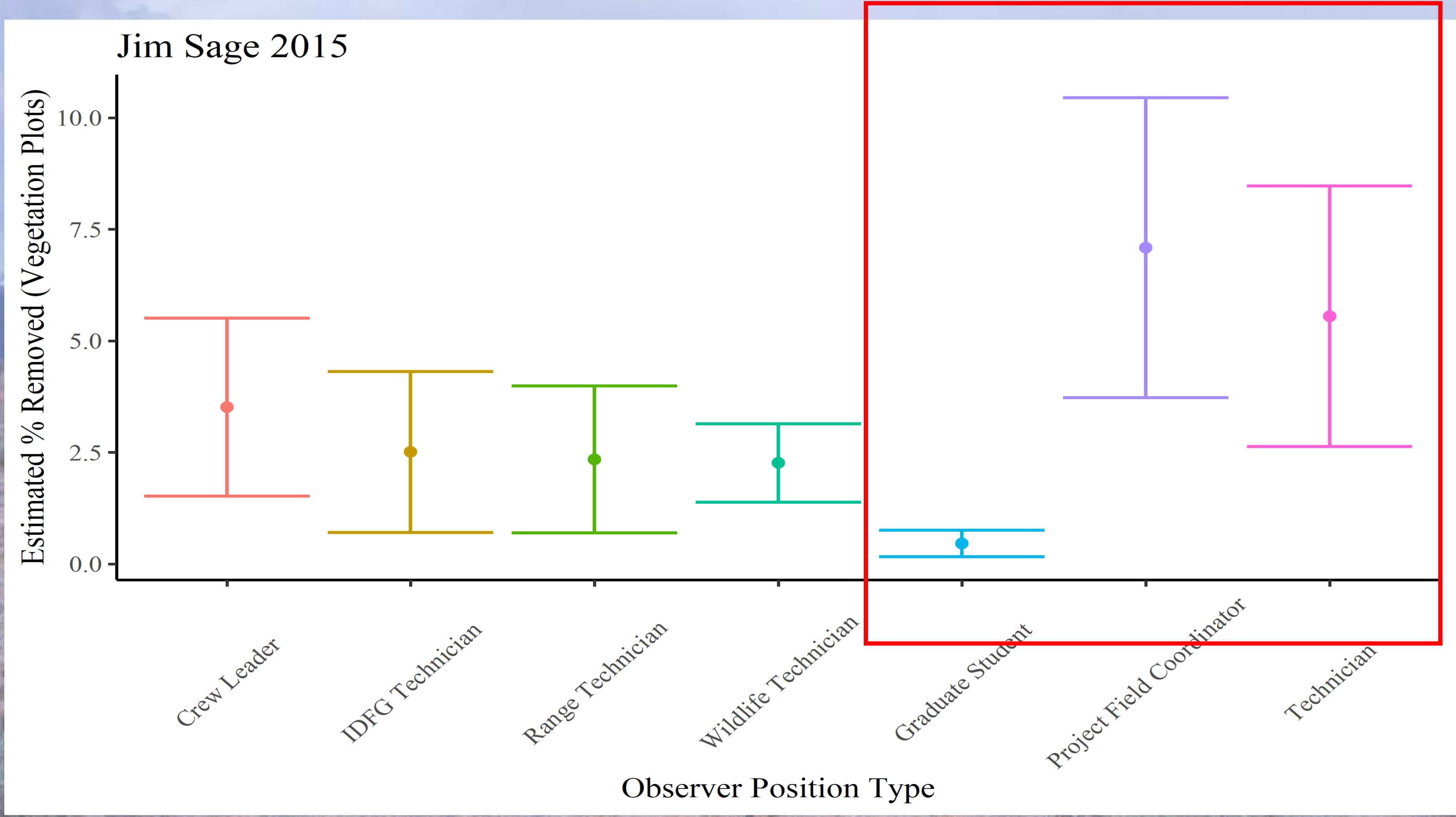


Ocular Estimates

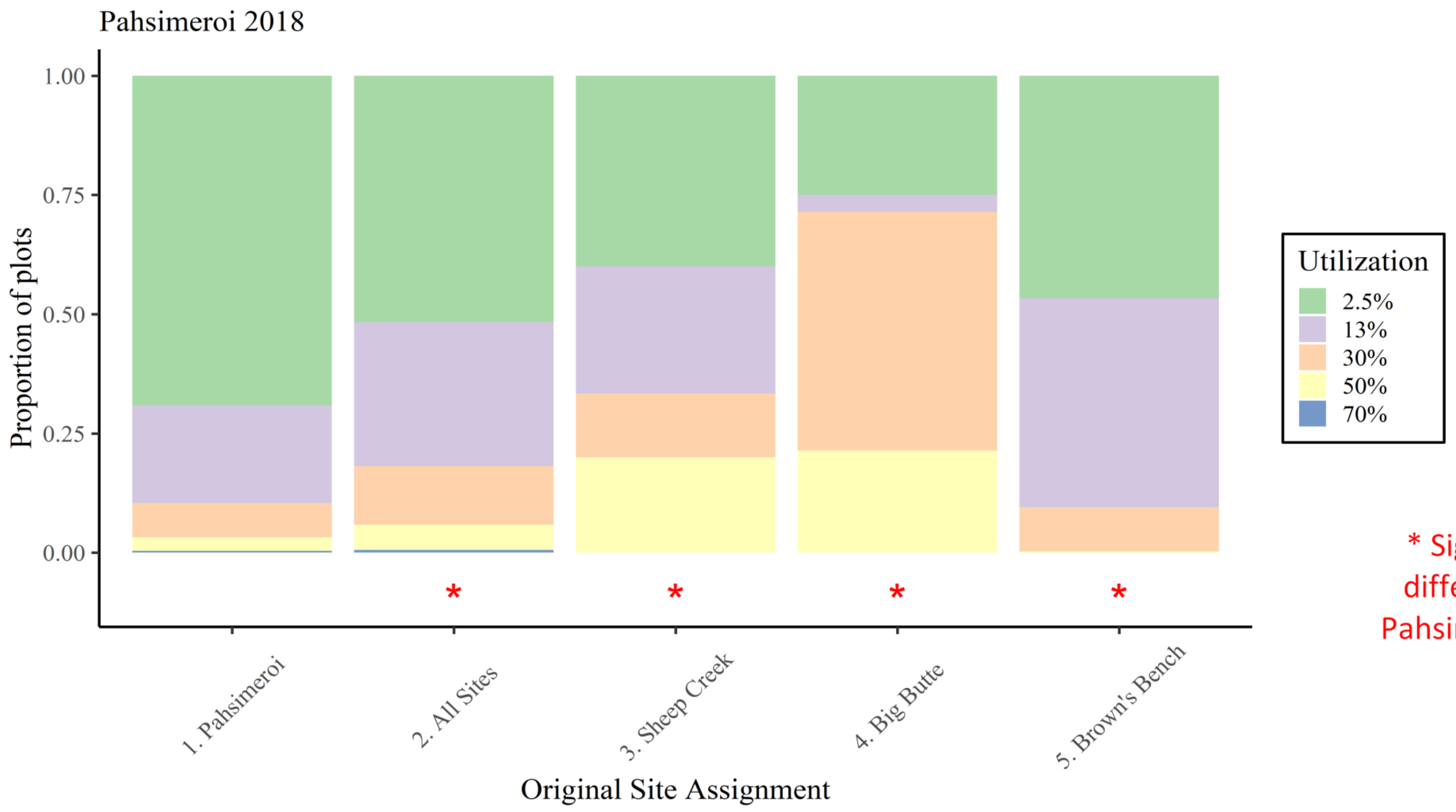
- Ocular estimates showed no relationship to paired plots at same location
- Systematic bias favoring lower estimates (<5% use)
- Improves slightly when using grazed frequency



Ocular Estimates and Observer Experience



Landscape Appearance



* Significantly different from Pahsimeroi at α = 0.005

Model Comparison

Method (Indicator)	Adjusted R^2 Simple Model	Adjusted R^2 Best Model	Additional Variables
Landscape Appearance	0.130	0.278	Observers identity, observer experience, dominant PG &SH
Ocular Estimates (% Use)	0.061	0.250	Observers identity, observer experience, grass height
Ocular Estimates (Frequency)	0.124	0.586	Observers identity, grass and shrub height
Height-Weight	0.035	0.300	BRTE cover, dominant shrub/grass, observer experience
Paired plots	0.258	0.258	NA

Discussion

Landscape appearance and ocular estimates had large differences between observers

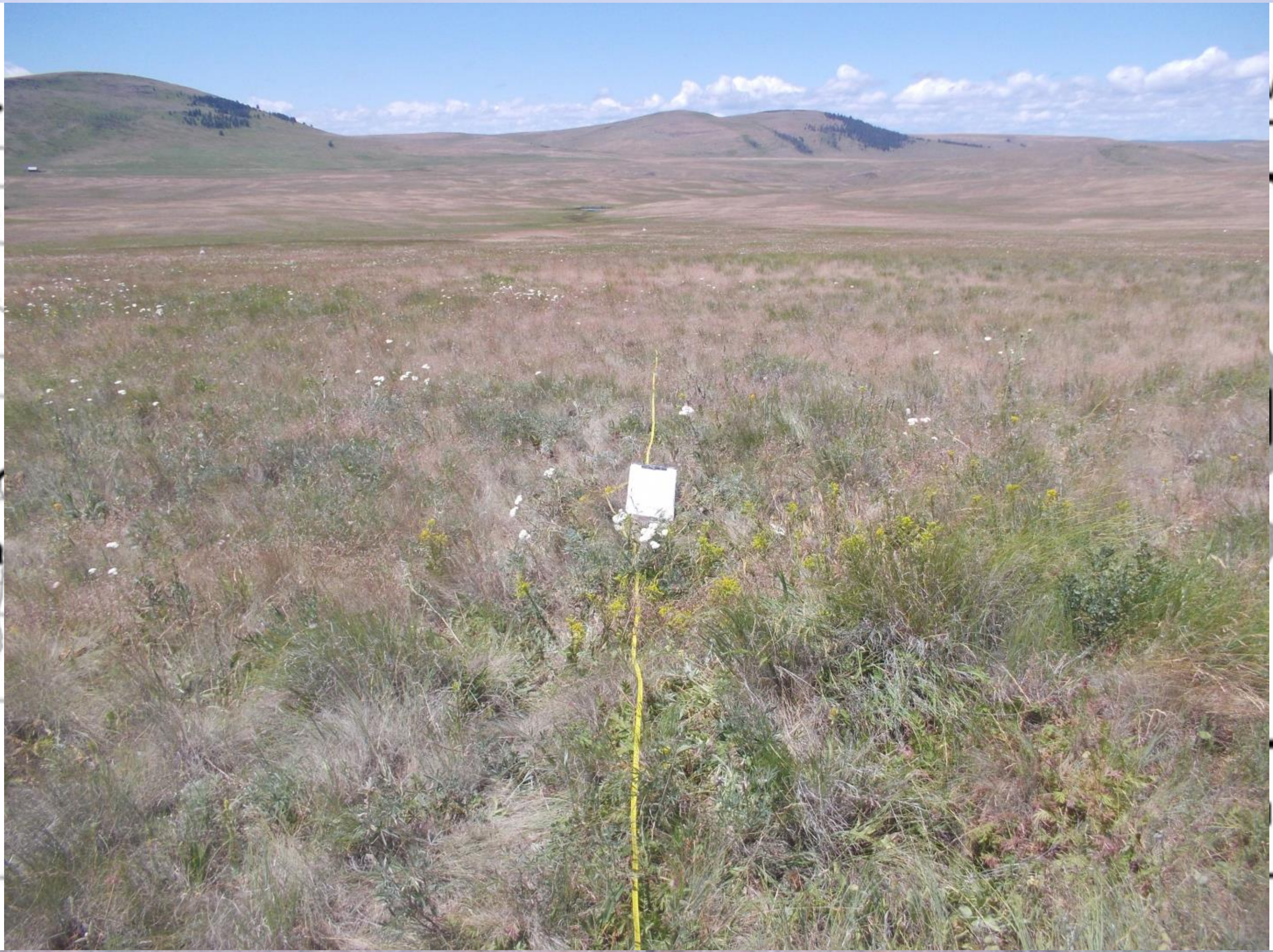
Utilization estimates (particularly qualitative methods) are influenced by WHERE you have recently worked

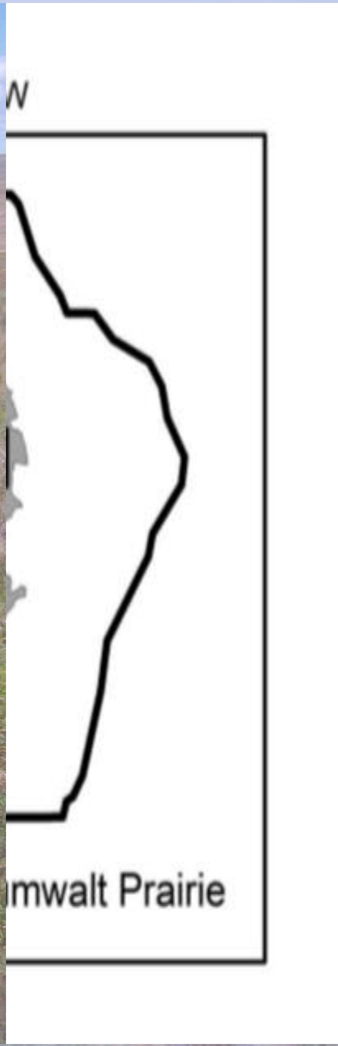
- Moving between study sites with different *plant communities* and *levels of grazing*

Visual estimates at individual plants showed poor precision

- Calculating frequency (Yes/No instead of % use) improved this
- But what about accuracy?

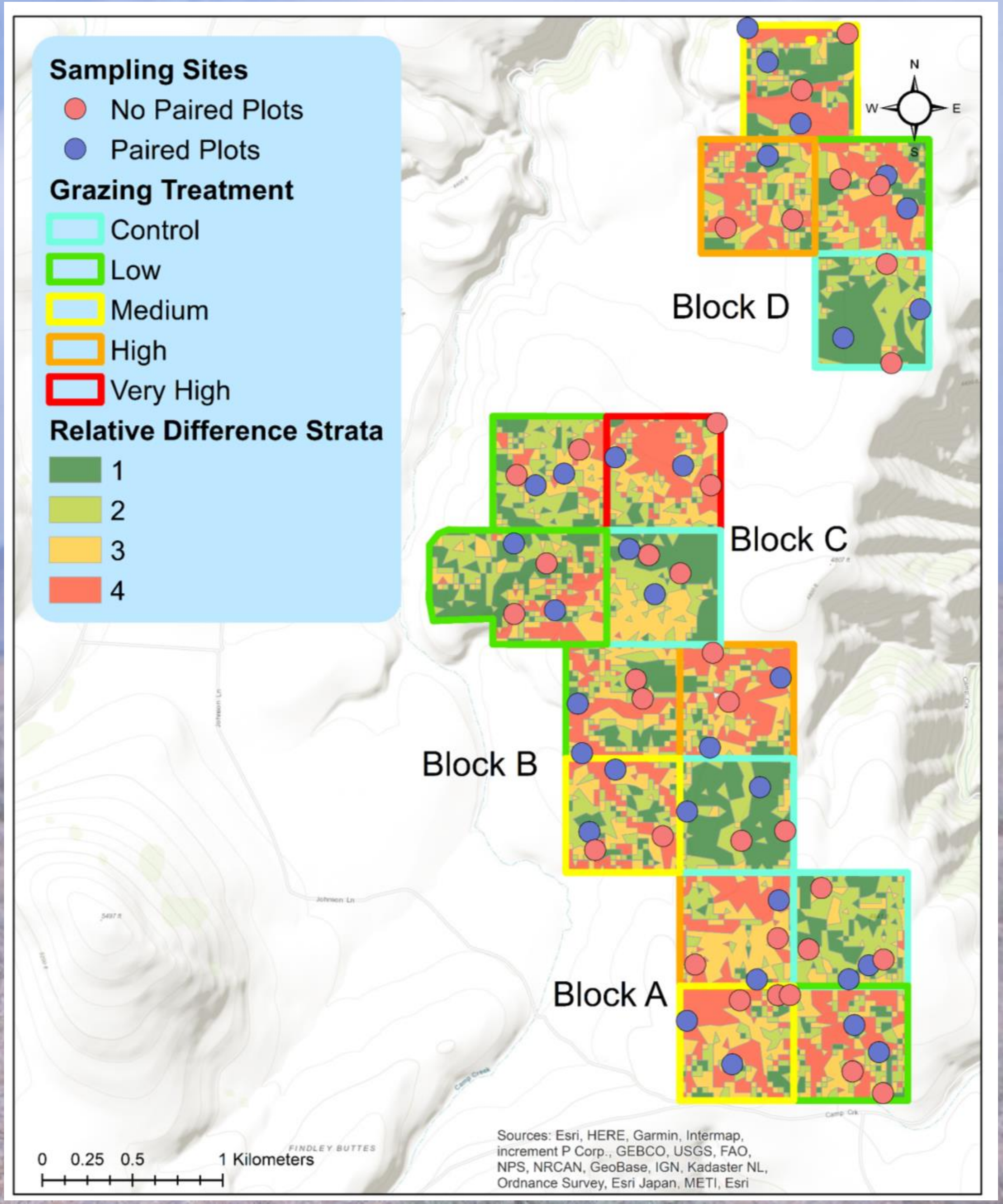
Methodology – Zumwalt Prairie





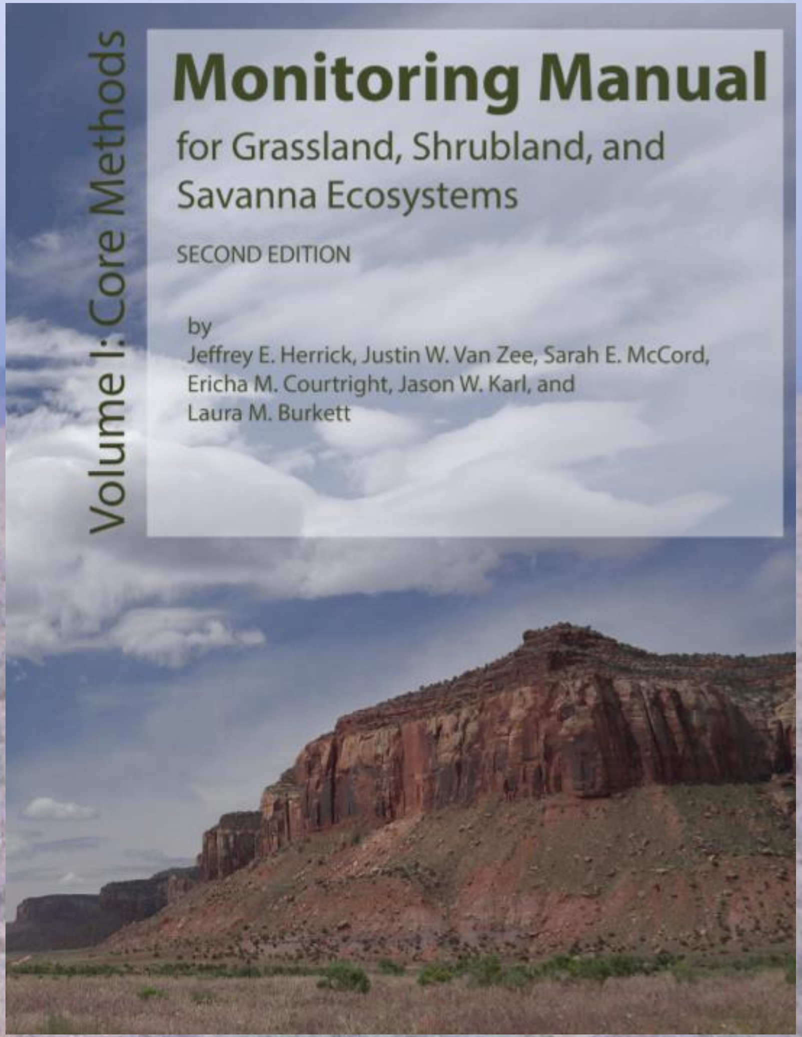
Methodology – Zumwalt Prairie

- Plot based sampling – spatially balanced, stratified random sampling design using Landsat 8 biomass models (Jansen et al. 2016)
- 4 by 4 randomized factorial experimental design – 4 levels of grazing intensity and 4 'calibration' techniques randomized to 4 blocks



Line-point intercept measurements

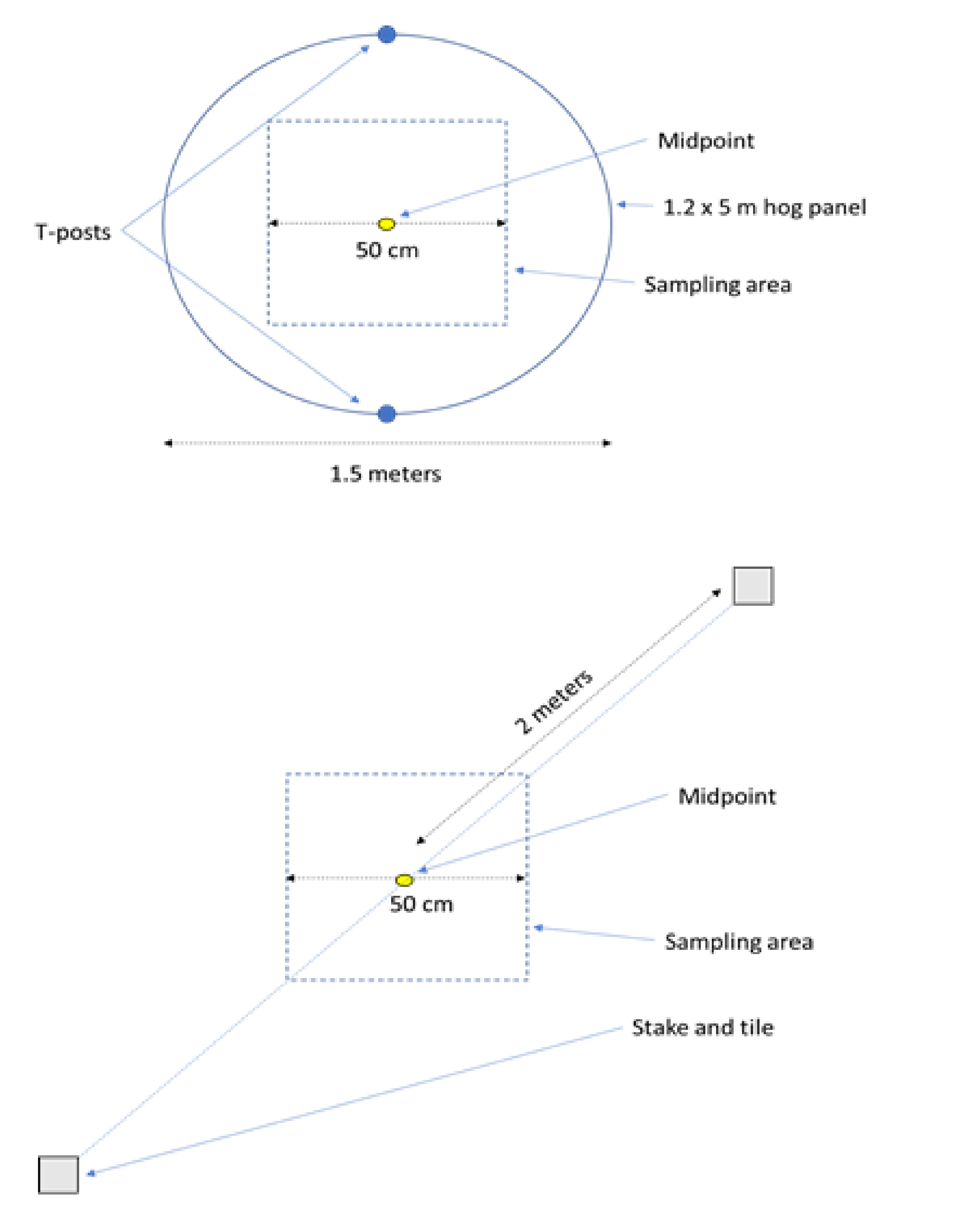
- Based on standard monitoring methods from Herrick et al. 2017
- Recorded % cover of all plant species, litter, rock, and ground cover
- At each observation recorded whether any plant showed signs of grazing or not:
  - % Cover of grazed plants
  - % of key forage species grazed



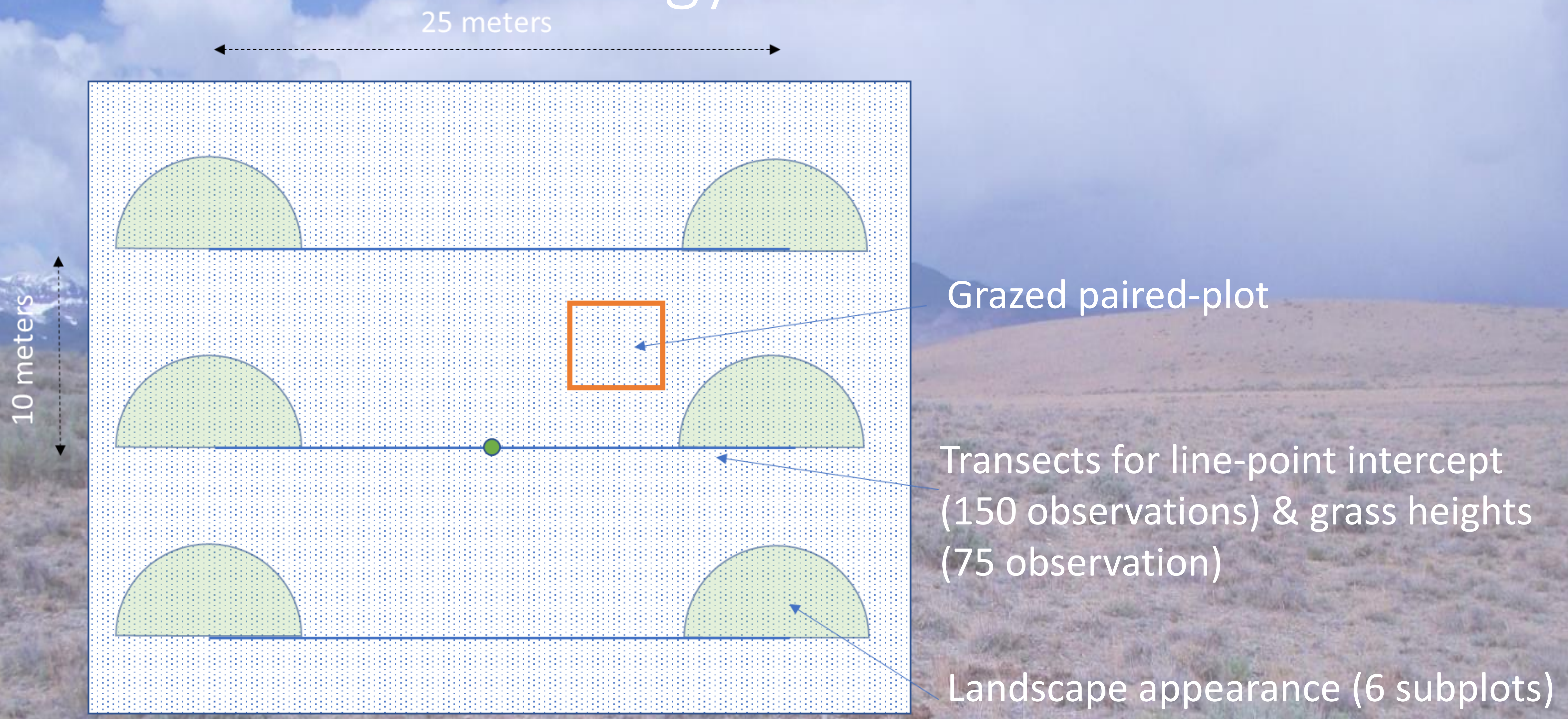
Herrick et al. 2017

Grazing exclosure – paired plots

- Methodology consistent with BLM technical reference 1734-03
- Plots paired based on visual observations of species composition and cover



Methodology – Zumwalt Prairie



Landscape Appearance ‘Calibration’

4 alternative sequences of data collection:

1. Line point intercept calibration
2. Paired plot calibration
3. Height-weight calibration
4. No calibration

% Cover of grazed plants

% Difference of wet weight - caged and uncaged subplots

% Utilization based on height weight curves

Cattle GPS Collars

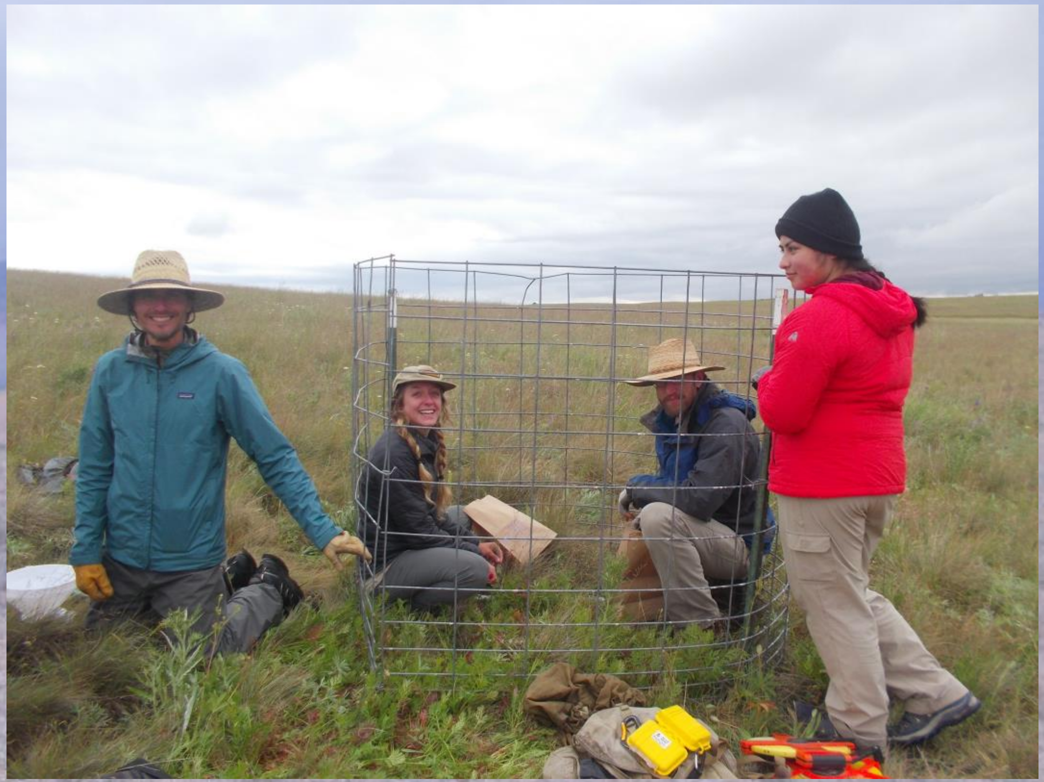
- Mixed herd of 267 yearling heifers and cow-calf pairs
- 52 low cost GPS collars deployed June 14th – July 24th spread randomly throughout herd (Karl and Sprinkle 2019)
- 4 stocking rates based on grazing duration within each paddock: 0, 2, 3,and 4 (5) days

Crew Training Exercises

One week of intensive training prior to data collection

Biweekly training exercises to increase consistency between observers

- Observe same transect/plot
- Repeat until all estimates are within +/- 5% of crew mean
- Discuss discrepancies and method details

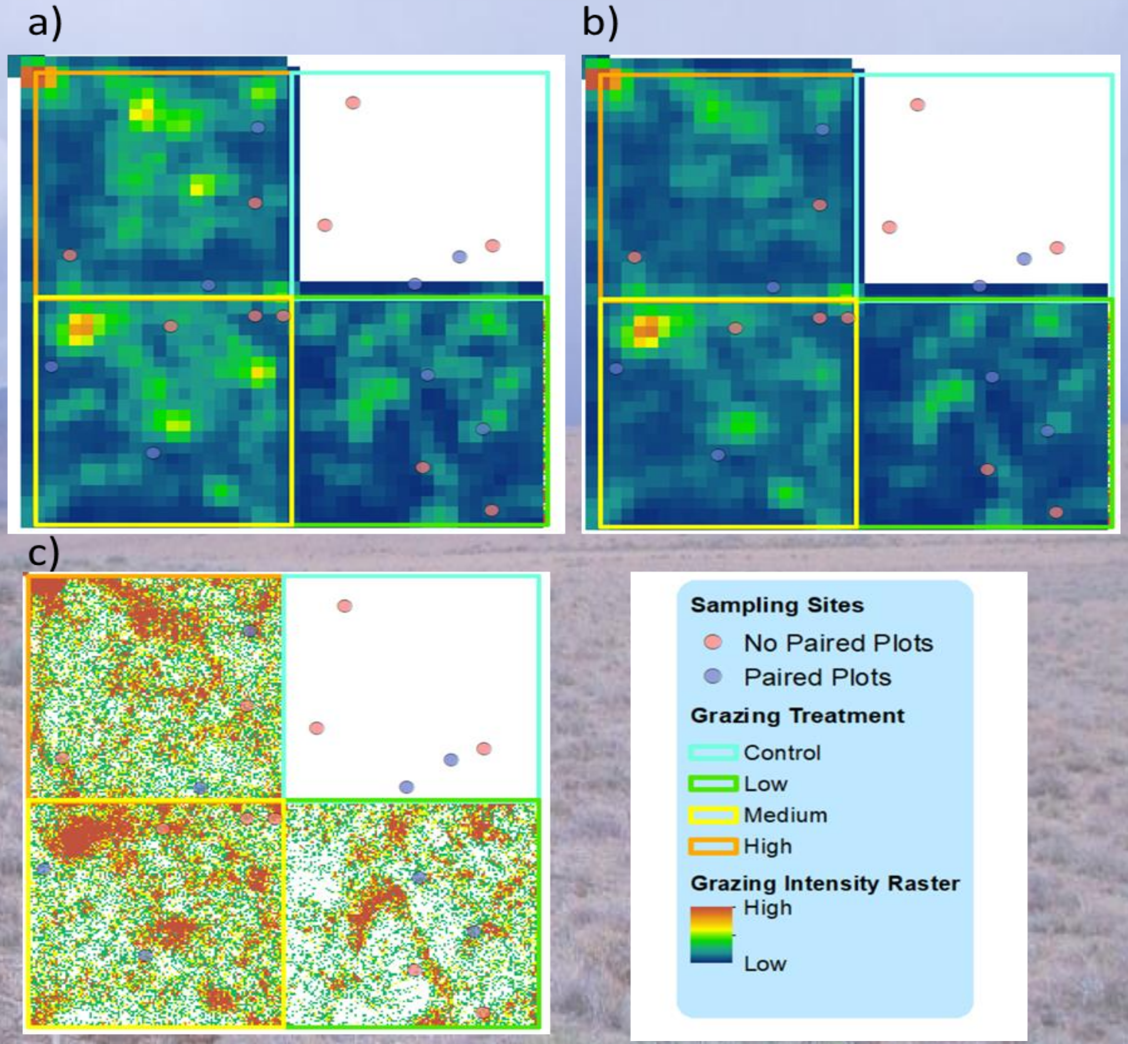


Objective 2 – Data analysis

- Convert cattle GPS locations to grazing intensity rasters (Kawamura, 2005, Calenge et al., 2019))

- Compare with field-based measurements using quantile/linear regression at multiple scales – plot/paddock/block/site

ACCURACY



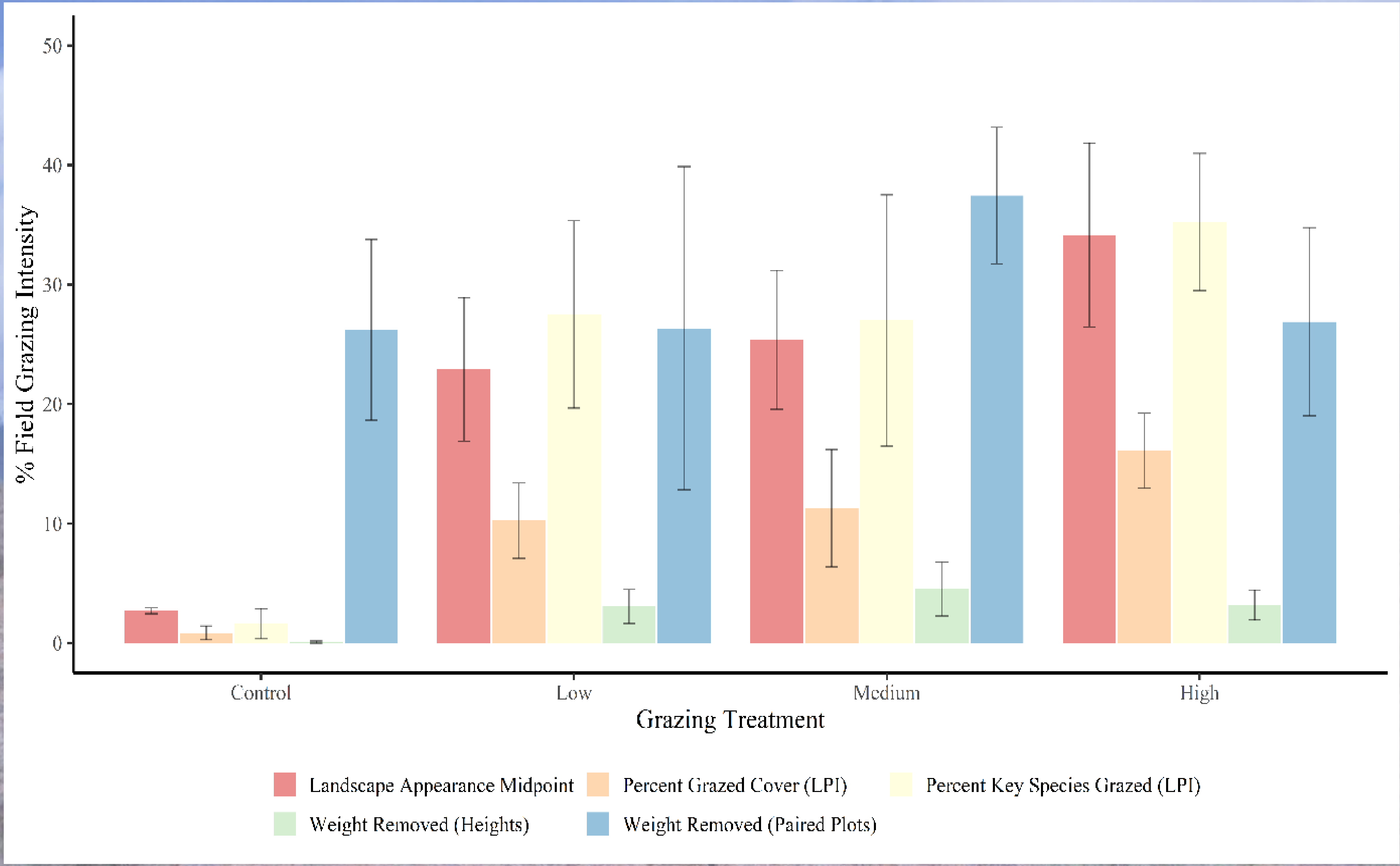
Objective 2 – Data analysis

- ANOVA and post hoc multiple comparisons of field estimates against different stocking rates for each method → **SENSTIVITY**
- Best subset regression to identify variables which explained the largest proportion of variation in grazing intensity estimates → **PRECISION**
    - Bootstrapping with replacement (500 reps)

Objective 3 – Data analysis

Correlation analysis of landscape appearance with other field methods and GPS-based grazing intensity for each calibration type

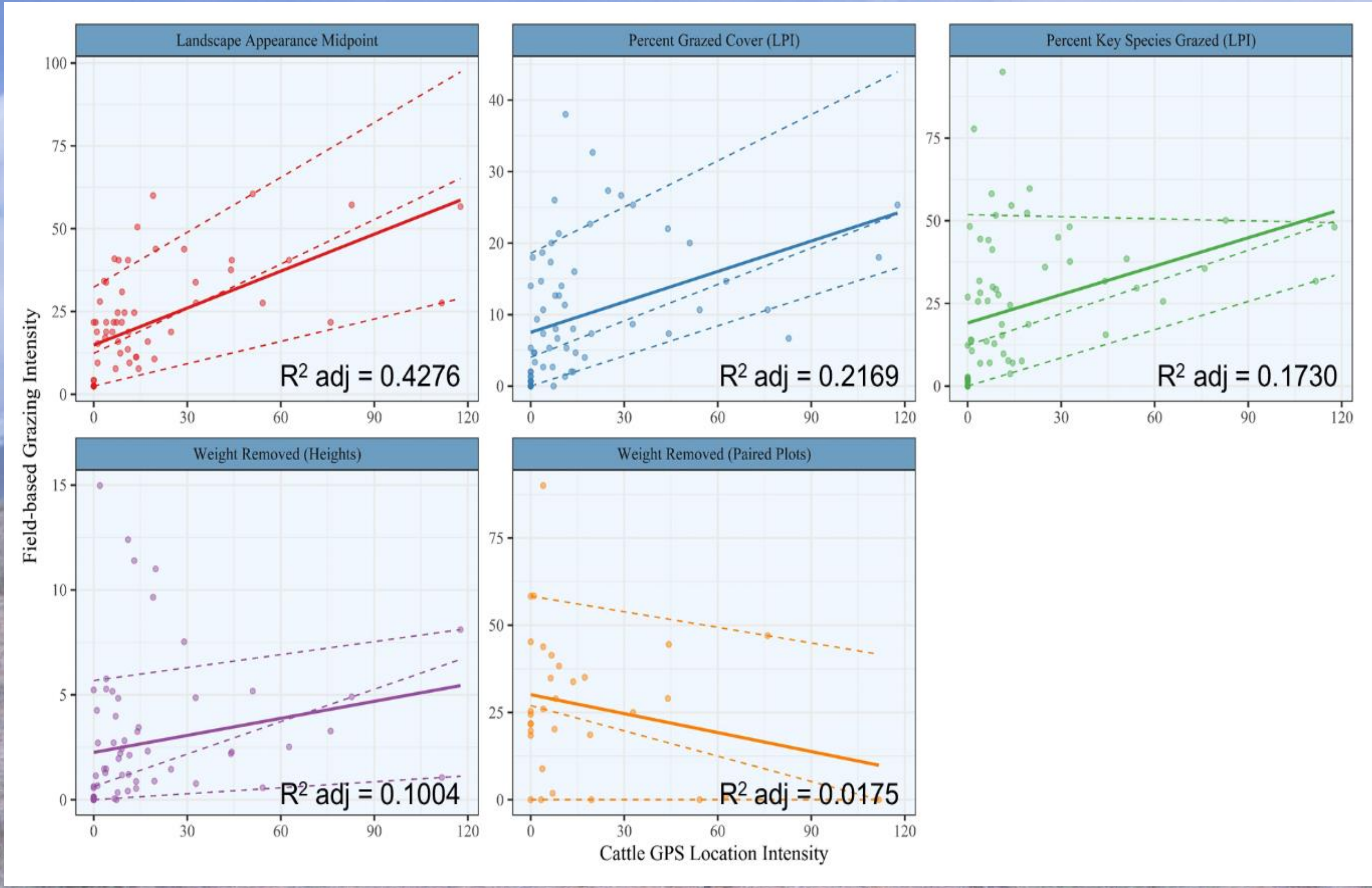
-> Spearman's rank

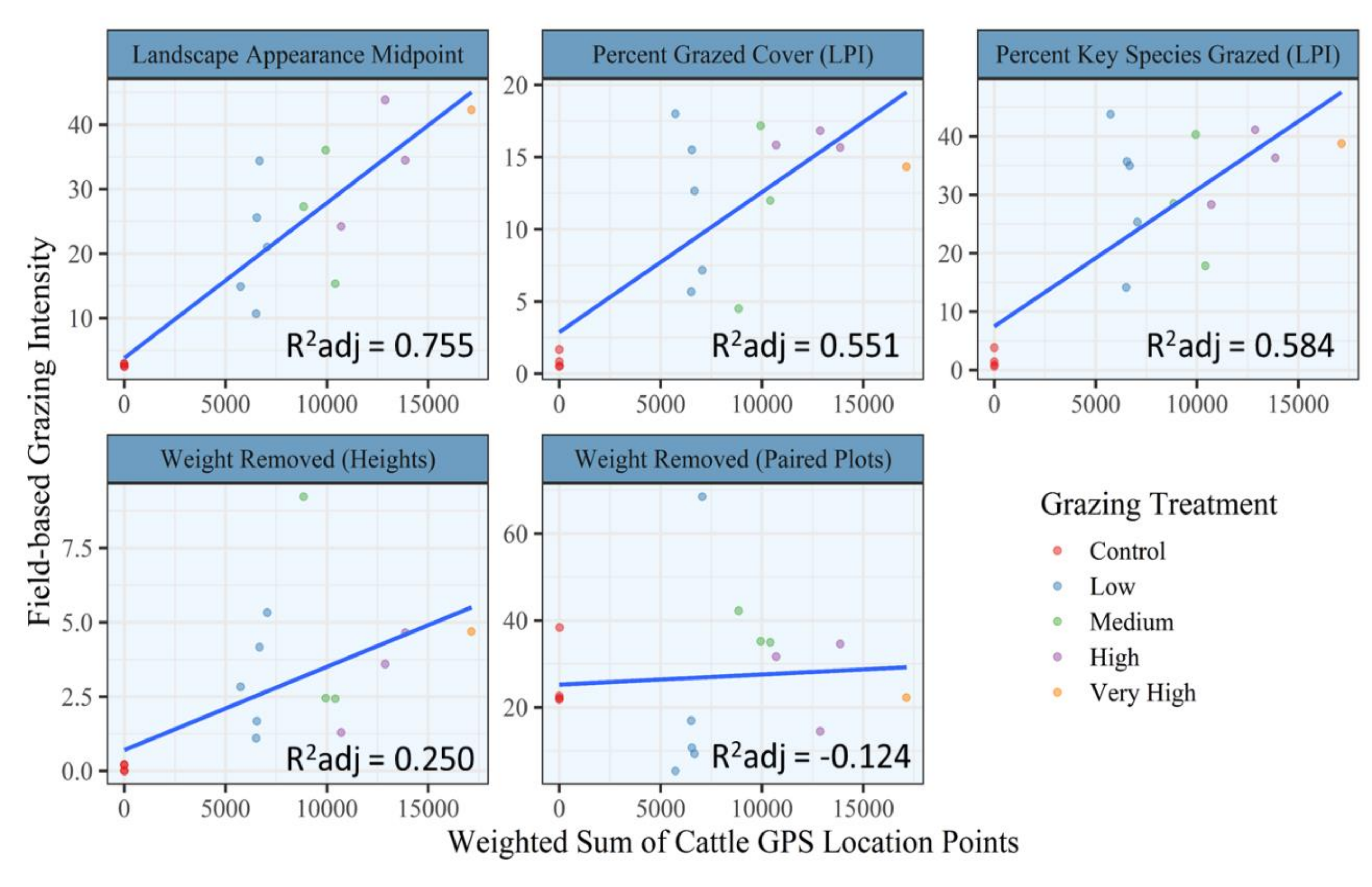


50
40
30
20
10
0
% Field Grazing Intensity
Control
Low
Medium
High
Grazing Treatment
Landscape Appearance Midpoint
Percent Grazed Cover (LPI)
Percent Key Species Grazed (LPI)
Weight Removed (Heights)
Weight Removed (Paired Plots)

Dependent Variable	Number of Variables	Adjusted R^2	AICc	Model P-value	Observer LA 1	Observer LA 2	Observer LA 3	Observer HW 1	Observer LPI2	Observer LPI3	Observer LPI4	Observer LPI5	Calibration Visual	Calibration Height	Calibration Paired plot
Landscape Appearance	9	0.76	476.64	1.93E-10	-11.34***	NS	NS	NS	NS	NS	18.26**	NS	-	-	-
Grazed Cover	11	0.61	434.21	2.05E-07	-4.01.	NS	NS	-	NS	NS	NS	NS	-	-	-
Key Species Grazed	6	0.64	529.97	1.81E-10	-	-	-	-	15.06**	NS	NS	-14.39**	-	-	-
Height Weight	10	0.73	278.20	2.56E-10	-1.34.	-1.42.	-1.99*	-2.36**	-	-	-	-	-2.89***	-2.09**	-1.53*
Paired Plots	8	0.52	278.96	0.02147	NS	NS	NS	-	NS	NS	NS	-	-	-	-

Dependent Variable	Annual Grass	Litter	Perennial Forb	Perennial Grass	Rock	Total Foliar Cover	Block B	Block C	Block D	High Grazing	Medium Grazing	Low Grazing	Ungrazed Grass Heights	Raster Std Dev	Grazing Intensity Raster
Landscape Appearance	-	-	-	-	-	-0.28*	11.50***	9.08**	8.39*	19.32***	11.97**	10.66**	-	NS	NS
Grazed Cover	0.17**	-	-	0.24**	-	-	NS	NS	NS	15.11***	14.30***	9.04**	-	-	0.0071*
Key Species Grazed	0.29**	NS	-	-	-	-	-	-	-	34.63***	29.99***	18.50**	-	-	0.01.
Height Weight	-	-0.12*	0.054**	-	-	-0.11**	2.01*	3.02***	6.58***	-	-	-	-0.16*	-	0.0021**
Paired Plots	-	-	-	NS	-3.49.	-2.31**	NS	-17.32.	NS	-	-	-	-	-	-0.027.


Landscape Appearance Midpoint
Percent Grazed Cover (LPI)
Percent Key Species Grazed (LPI)
Weight Removed (Heights)
Weight Removed (Paired Plots)
Field-based Grazing Intensity
Cattle GPS Location Intensity
R2 adj = 0.4276
R2 adj = 0.2169
R2 adj = 0.1730
R2 adj = 0.1004
R2 adj = 0.0175


Landscape Appearance Midpoint
Percent Grazed Cover (LPI)
Percent Key Species Grazed (LPI)
Weight Removed (Heights)
Weight Removed (Paired Plots)
R^2adj = 0.755
R^2adj = 0.551
R^2adj = 0.584
R^2adj = 0.250
R^2adj = -0.124
Field-based Grazing Intensity
Weighted Sum of Cattle GPS Location Points
Grazing Treatment
Control
Low
Medium
High
Very High

Calibrating Landscape Appearance with other Methods

Spearman's rank correlation between landscape appearance midpoints					
Calibration Method	Grazed cover	Key species grazed	Height-weight	Paired plots	Grazing Intensity from GPS
1. Line-point intercept	0.79	0.87	0.19[ab]	-0.33	0.62
2. Paired plots	0.77	0.73	0.72[a]	0.22	0.80
3. Height-weight	0.58	0.76	0.85[b]	NA	0.86[f]
4. None	0.73	0.78	0.64	NA	0.61[f]

Correlations between landscape appearance and other methods were higher when using each methods respective calibration

Closest relationship between Landscape appearance and GPS-based grazing intensity when **calibrating with height-weight method**

Management Implications

- Paired-plots showed poor sensitivity, accuracy and precision
  - Heavily affected by spatial heterogeneity in plant communities and grazing intensity
- We can improve the accuracy and precision of visual estimates
  - Training and calibration are important tools to minimize bias
  - Leverage increasing trend of ‘citizen- science’ style monitoring
- Improved precision at broader scales
  - Using stratified sample design to capture variability helped

Management Implications

- No perfect method – collecting a diversity of data creates resilience

- Most suitable method depends on stocking rate:
  - LPI and height-weight methods more appropriate for higher grazing intensity levels

- Incorporating use-based methods into long-term/rangeland health monitoring

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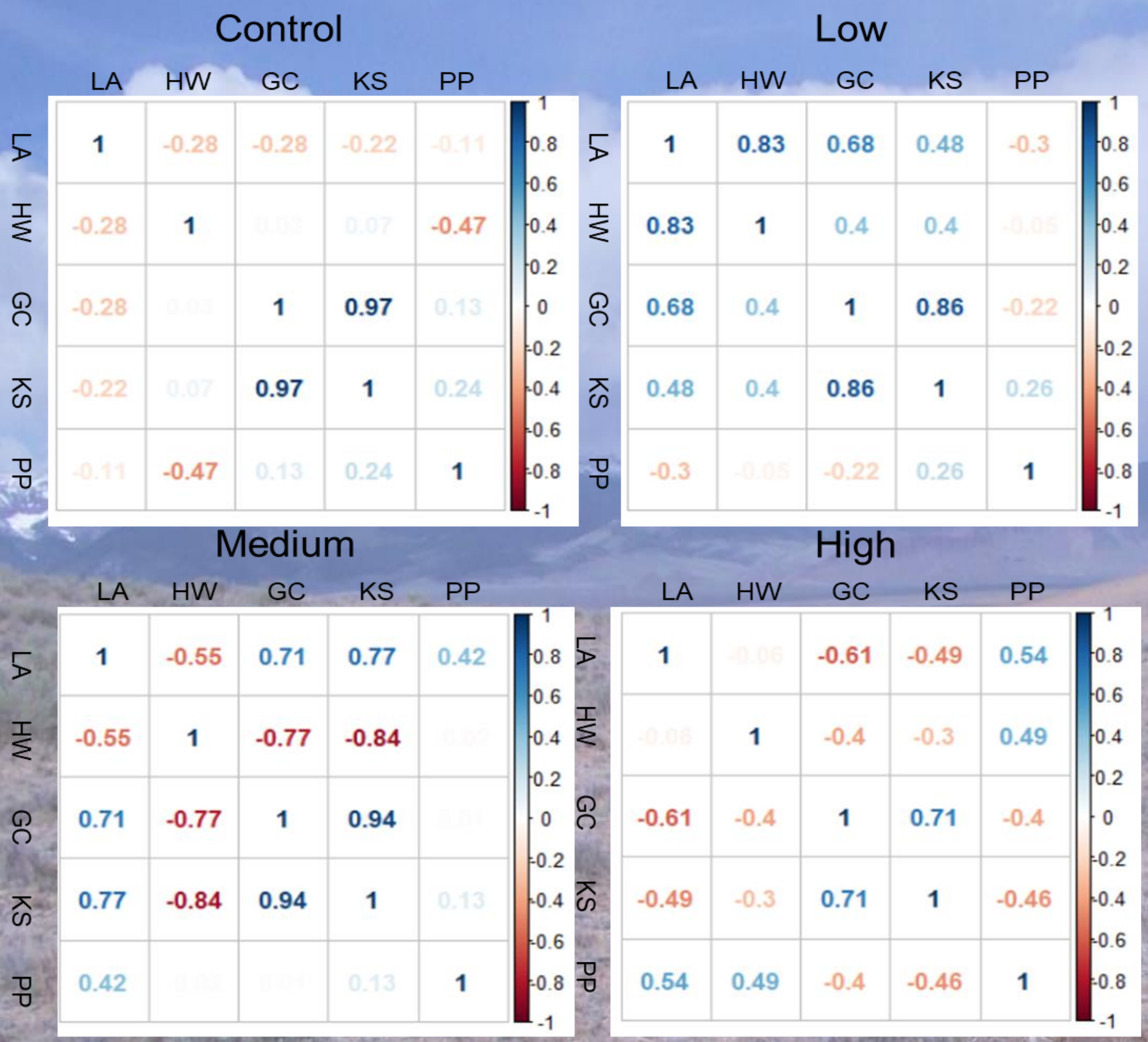
Pearson’s Correlation with Different Rasters

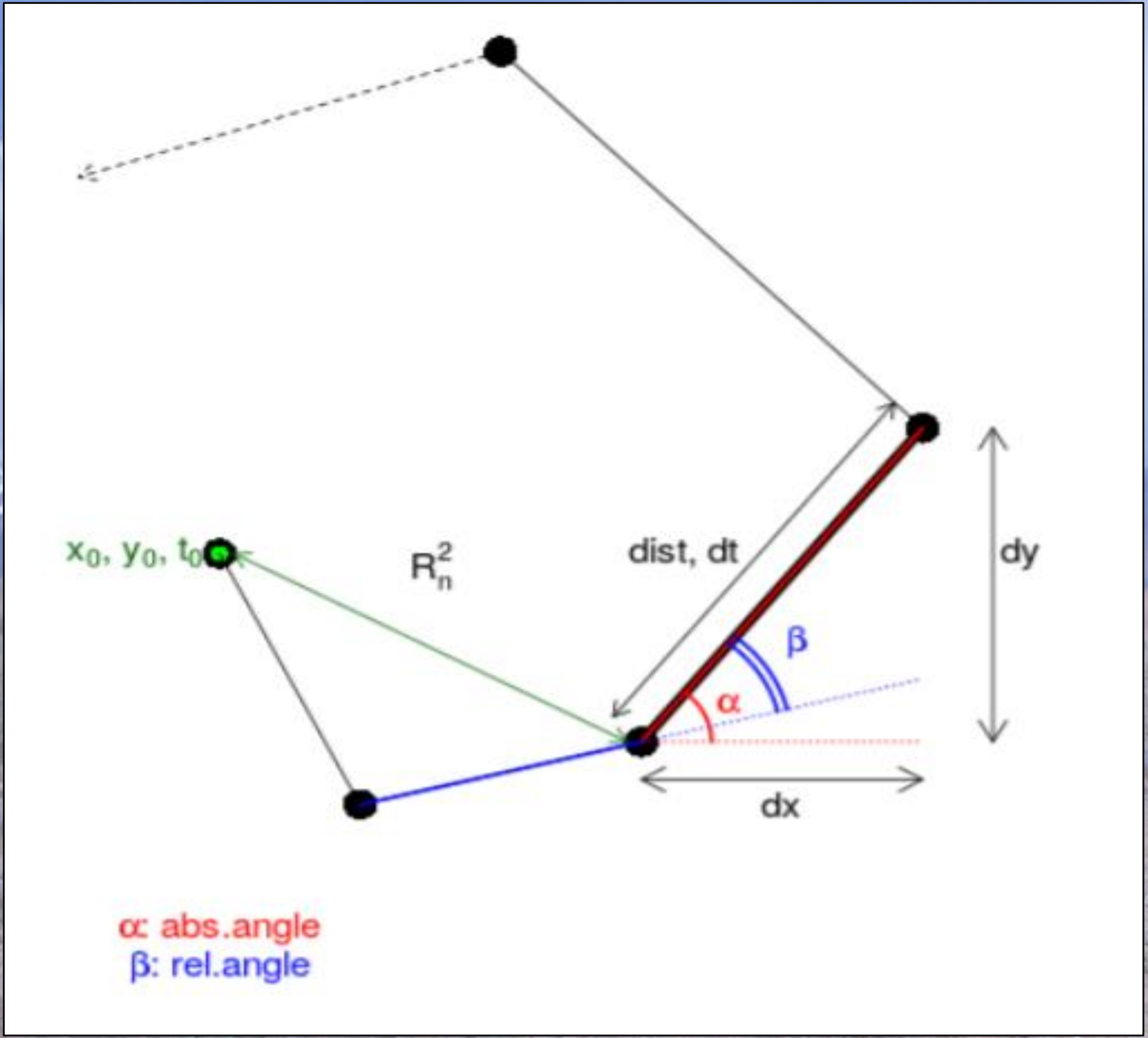
Field Techniques	Grazing Intensity Rasters		
	Basic	Filtered	Fine
Landscape Appearance	0.64885	0.65422	0.56745
Height-weight	0.35071	0.31623	0.14142
Paired Plots	0.12247	0.13038	0.17321
% Cover of Grazed Plants	0.45277	0.46583	0.44159
% Cover of Grazed Key Species	0.39623	0.41952	0.34641

Quantile Regression Coefficients

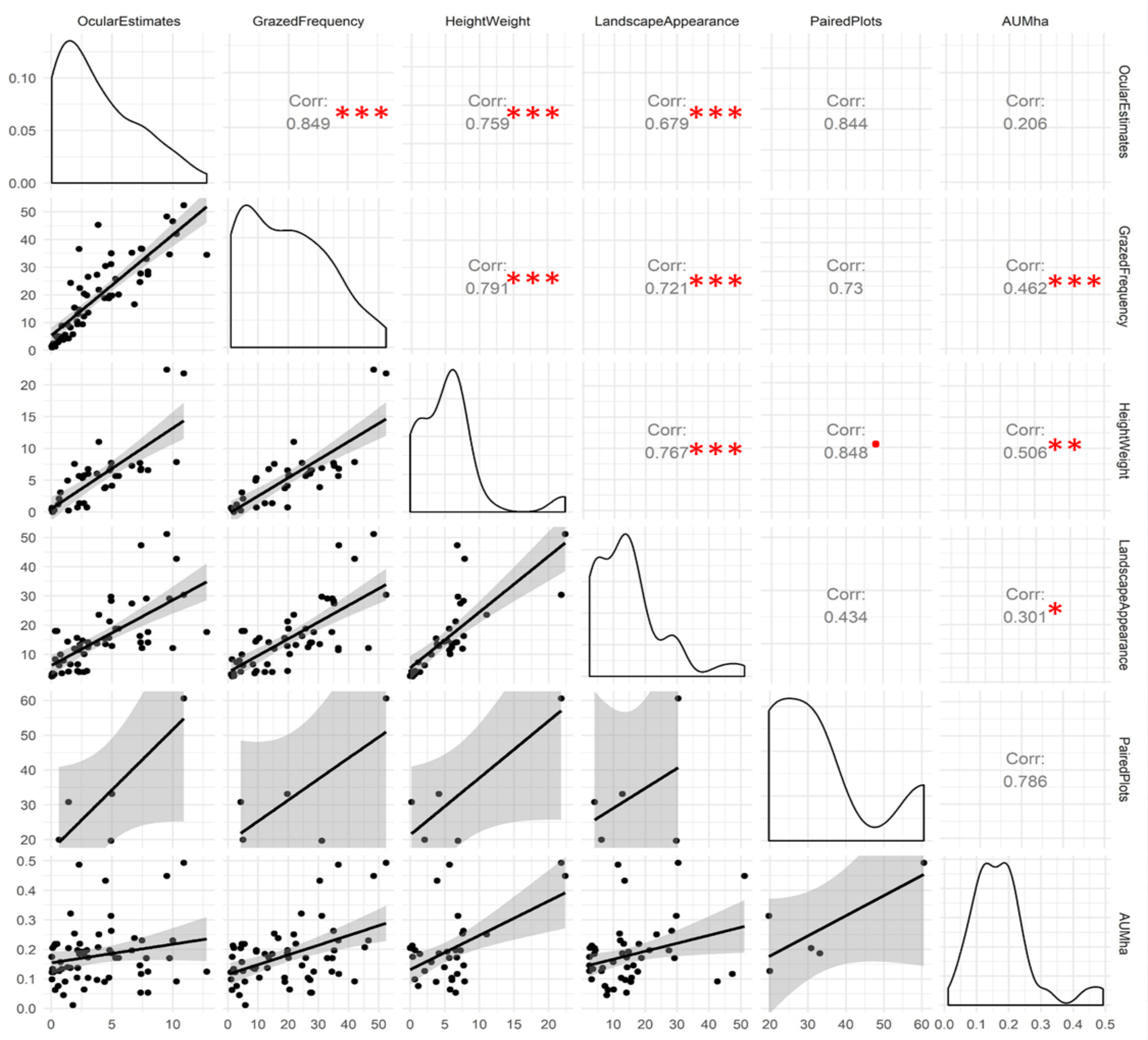
Field Techniques	10th percentile		50th percentile		90th percentile	
	Slope	p-value	Slope	p-value	Slope	p-value
Landscape Appearance	0.378	0.000	1.088	0.000	1.069	0.043
Height-weight	0.037	0.000	0.112	0.002	0.310	0.164
Paired Plots	0.000	1.000	-0.419	0.351	-0.824	0.507
% Cover of Grazed Plants	0.167	0.000	0.473	0.000	0.406	0.454
% Cover of Grazed Key Species	0.380	0.001	0.974	0.000	0.874	0.378



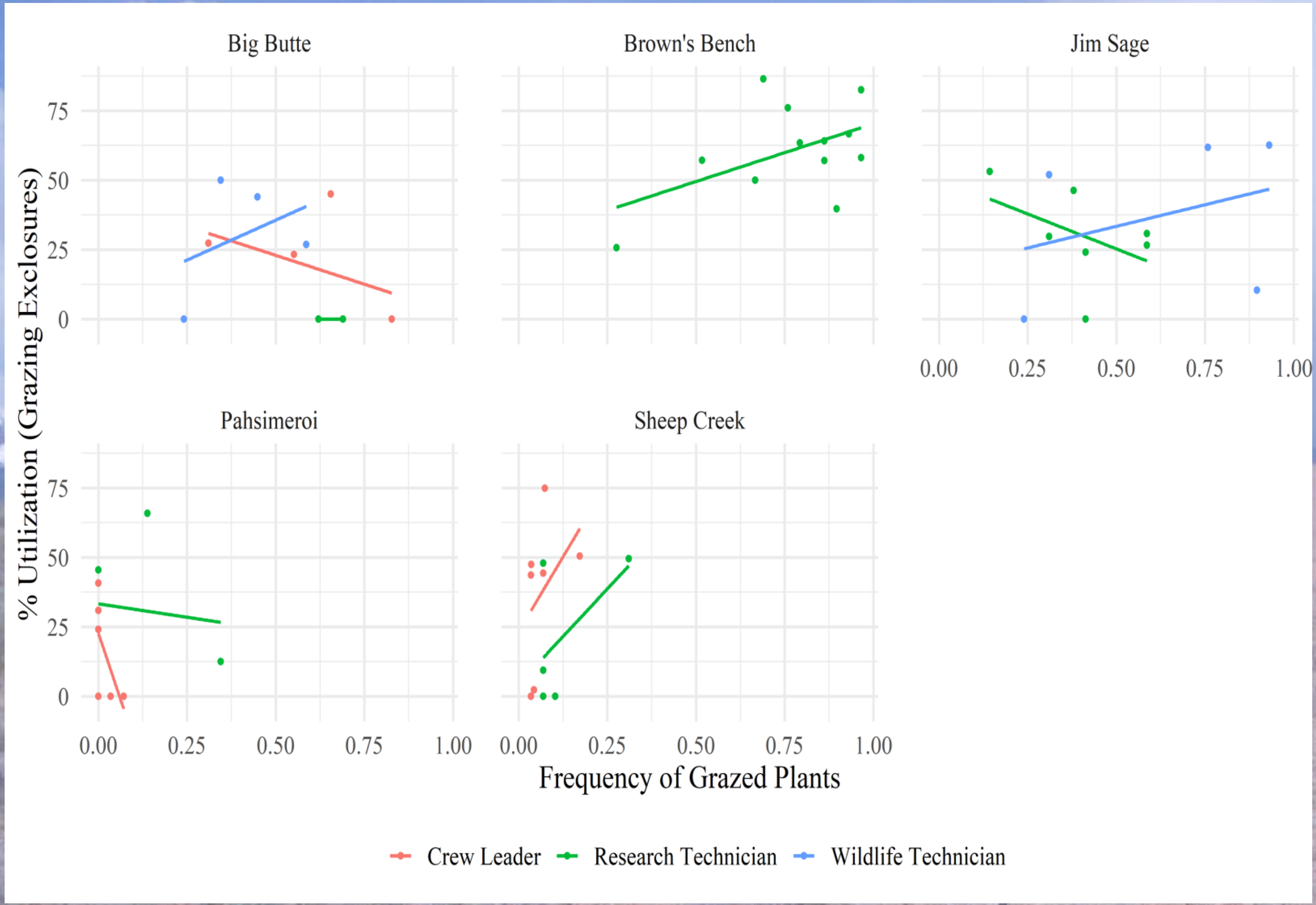
Pairwise Correlation Coefficients



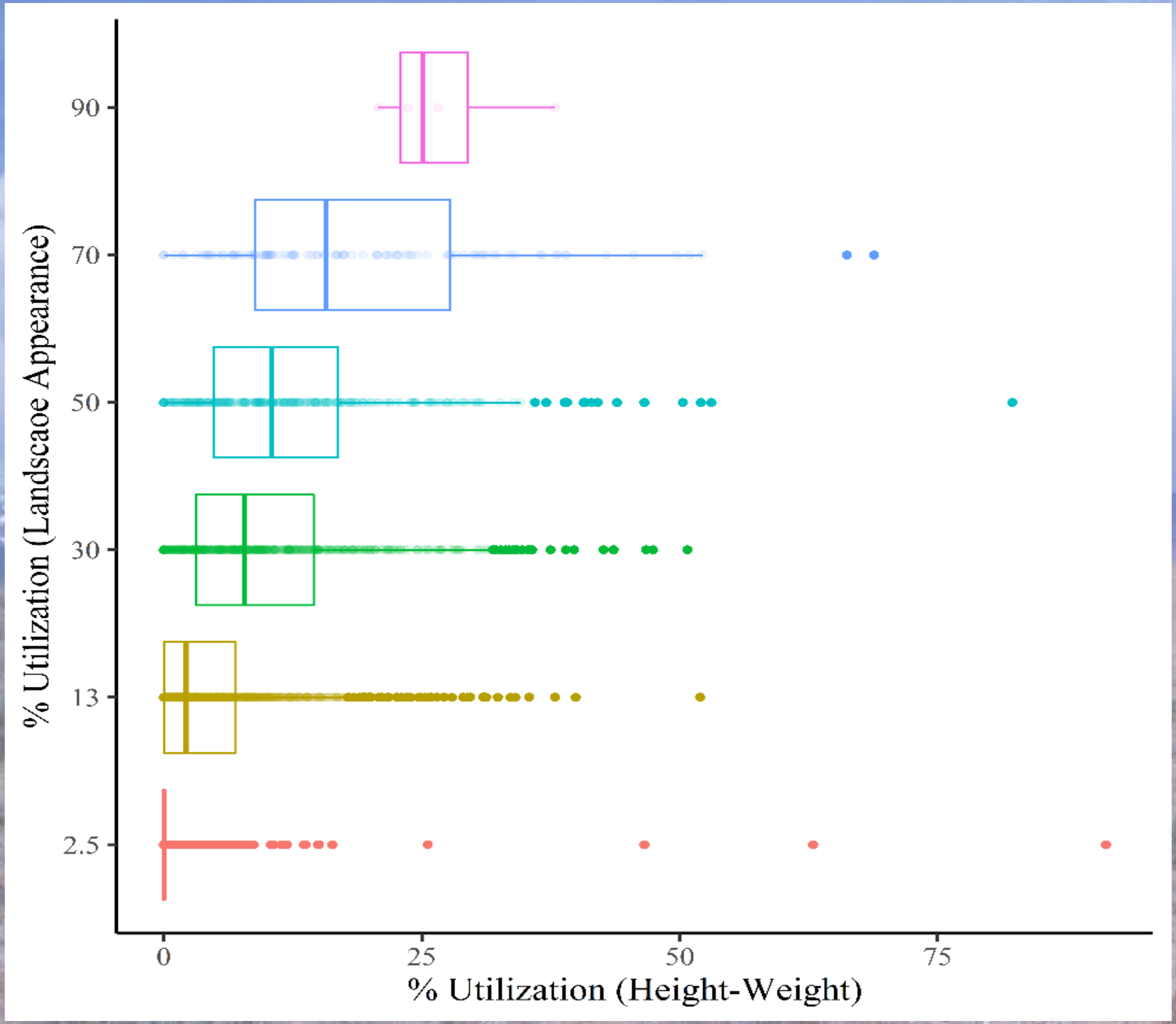
At each step the distance (dt) and turning angles (α and β) between two GPS locations (collected 10 minutes apart) were calculated. Cattle travel velocity can then be calculated to filter erroneous GPS records



Pairwise Correlation Coefficients



Multiple regression of frequency of grazed plants (derived from plant-based ocular estimates of utilization), utilization from paired-plots at the same locations in 2018, and observer job title grouped by study site. Overall, including observer title as a covariate helped to explain variation in the frequency data (adjusted R^2 increased by 6%).



Relationship between utilization estimated from grass heights and visual estimates using landscape appearance collected at the same sampling locations. Estimates from height measurements suggest much lower levels of utilization compared to landscape appearance.

Objective 1 – Data analysis

- Exploratory analysis using simple linear regression comparing different methods across multiple years, observers, plant communities, and scales

- Stepwise selection using AIC to identify variables which explained the largest proportion of variation in grazing intensity estimates

Included plot/pasture covariates including plant community characteristics, observer characteristics, time spent at plot, site, year