COMPARISION OF THREE VEGETATION SAMPLING METHODS ON OIL AND GAS SITES IN SOUTHWESTERN WYOMING

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Abstract. Oil and Gas (O&G) site reclamation in the Western United States has expanded greatly with the onset of gas development in the last decade. This study compares three different vegetation sampling methodologies to determine which methodology provided the most consistent, repeatable data, as well as resulted in the highest vegetation diversity on reclaimed well sites in southwestern Wyoming. The study area is located in Sweetwater County near Wamsutter, Wyoming.

The three methodologies compared were the Bureau of Land Management (BLM) Rawlins Field Office (RFO) Point Method, Point-Line Intercept Transect Method, and a Modified Daubenmire Line Transect Method. Each sampling methodology was field tested on 30 reclaimed O&G well sites. Quantitative vegetation data variables including total vegetation cover, litter cover, rock cover, total cover (total vegetation plus litter plus rock), lifeform cover, and the number of each lifeform were collected. Multi-Response Permutation Procedure (MRPP) and cluster analysis were used to statistically analyze the quantitative data. Based on the MRPP results, total cover, bare ground, and litter plus rock cover were not significantly different at $p \leq 0.10$ for the BLM RFO Point Method and the Modified Daubenmire Line Transect Method. For those same parameters, the Point-Line Intercept Transect Method was significantly different from the other two methodologies at $p = 0.01$ to 0.10. All three methodologies were not significantly different at $p \leq 0.10$ for total vegetation cover. The cluster analysis demonstrated that the Point-Line Intercept Transect Method had more similar total cover values than the other two methodologies. Qualitative time data was also collected to compare data collection and data summarization time requirements. Overall, the Point-Line Intercept Transect Method is the preferred methodology based on the statistical analyses and the reduced sampling and data summarization time required to perform this method.

Additional Key Words: oil and gas, vegetation methods, reclamation

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Introduction

Oil and Gas (O&G) site reclamation in the Western United States has expanded greatly with the onset of gas development in the last decade. The purpose of this study was to compare the effectiveness of three different vegetation sampling methodologies on reclaimed well sites in southwestern Wyoming. The objectives of this study were to determine which of the three methodologies provided a fair representation of the status of the reclaimed well site and resulted in the highest vegetation cover and diversity, was the most cost effective, and that provided the most consistent and repeatable data. The three methodologies compared were the Bureau of Land Management (BLM) Rawlins Field Office (RFO) Point Method, Point-Line Intercept Transect Method, and the Modified Daubenmire Line Transect Method.

Methods

Site Selection

The study area is located near Wamsutter, Wyoming in Sweetwater County. The study area historically receives less than 10 inches of precipitation per year; in 2009, the Wamsutter station received 9.75 inches from October 2008 to July 2009 (University of Wyoming, 2010). The 30 reclaimed well sites are owned by Forest Oil Corporation. The well sites vary in age, i.e., time since the last seeding. Fifteen well sites were 1-2 years old, five were 3-4 years old, and seven were 5-7 years old. Three wells sites had no age information available.

The BLM has identified six Ecological Site Descriptions (ESDs) within the RFO (BLM 2009). The study area had three different ESDs present – Dry Loamy/Clay Sites, Dry Sandy Sites, and Wet Alkaline/Saline Sites. Thirteen of the 30 reclaimed well sites were classified as Dry Loamy/Clay sites and were characterized as a sagebrush/wheatgrass community with less than 10 inches of precipitation. Nine of the 30 reclaimed well sites were classified as Dry Sandy sites and were characterized as a sagebrush/bunchgrass community with less than 10 inches of precipitation. Eight of the 30 reclaimed well sites were classified as Wet Alkaline / Saline sites and were characterized as either a Gardner's saltbush/bunchgrass or a greasewood community.

Field Vegetation Sampling Methodologies

The three sampling methodologies compared were the BLM RFO Point Method, Point-Line Intercept Transect Method, and a Modified Daubenmire Line Transect Method. Each methodology was field tested on each of the 30 reclaimed O&G well sites. Aerial cover data was

recorded at each sample point for each methodology. Quantitative vegetation data variables including total vegetation cover, litter cover, rock cover, total cover (total vegetation plus litter plus rock), bareground cover, lifeform cover, and the number of each lifeform were collected. Litter included all non-living organic material and did not include standing dead vegetation from the current year's growth; the latter was considered 2009 vegetation. Rock included both rock (> 2 inches at the intermediate axis) and gravel (< 2 inches at the intermediate axis) (BLM 2009). Qualitative data was also recorded at each well site, including the time required to complete each method. GPS coordinates were taken at the start of all transects for each sampling method and the direction of the transects were recorded.

BLM RFO Point Method. This method was created by the BLM RFO to aid in the consistency of reclamation evaluations among operators. The basis of this methodology is to create a paced grid in the field to systematically locate 400 sample points within the reclaimed area of each well site. Each year the sampling start point differs. In 2009 and for the purpose of this study, the sampling start point was located in north or northeast corner of each well pad depending on the geographic placement of the well pad. The distance between the paced grid lines and sample points were dependent on the size of the reclaimed area. The goal of this methodology was to ensure that at least two thirds of the reclaimed area was sampled. The sample points were located approximately every 8 to 10 ft on paced parallel grid lines, which were approximately 16 to 20 ft apart. The distance between grid lines was always twice the distance between sample points; for example, 16 ft between grid lines and 8 ft between sample points. Aerial cover at each sample point was determined using a mounted laser point device placed in the center of the sampler's boot and oriented forward. Cover values were collected on hard copy data sheets and summarized by hand. The summarized data was then entered into an Excel database.

Point-Line Intercept Transect Method. Two 50-meter transects were sampled on each well site. The transect start points and orientation were located in the field. Sample points were located at ½-meter intervals along each 50-meter transect, for a total of 100 points. Aerial cover (first hit) at each sample point was determined using a mounted laser point device oriented to the left side of the transect. Second hits (deflection of the laser from the first hit onto another species) were recorded and only used to calculate species diversity. The first hit readings were used to calculate absolute cover values; with each hit contributing 1% of the total cover value. Litter, rock, lichen, and bare ground percentages were recorded. Hit data from the two 50-meter

transect (N=200) were averaged together to obtain one sample point per well location. Cover values were collected on hard copy datasheets and summarized by hand. This data was then added to an Excel database.

Modified Daubenmire Line Transect Method. Vegetation cover was sampled using a rectangular 20x50cm quadrate placed at 5-meter intervals along the same 50-meter transect used in the Point-Line Intercept Transect method, for a total of ten quadrats per transect. Plots were read on the right hand side of each transect, two frames away from the transect line. Plant cover was estimated within the quadrate utilizing the polygon method, i.e., the percentage of ground covered when a polygon drawn around the extremities of the undisturbed canopy of each plant is projected upon the ground. The absolute total vegetation cover estimates were determined as the percent of the total quadrate covered by all vegetation, excluding species overlap and understory effect. Species overlap was included in the species diversity analysis. The ten quadrats per transect were averaged to obtain a single value for each parameter for each transect. Averages from the two 50-meter transects were averaged together to obtain one sample point per well location for statistical analysis. This data was electronically collected using a personal digital assistant (PDA) in the field and summarized in an Excel database.

Statistical Evaluation

BKS discussed sampling methodologies with a statistician consultant and former professor at Colorado State University, Dr. Charles Bonham, prior to sampling, to determine how the methodologies could be compared.

Multi-Response Permutation Procedure (MRPP). This statistical analysis was used to analyze quantitative vegetation data. MRPP is a non-parametric multivariate tool currently used by researchers at Colorado State University (Reich 1997). MRPP analysis is based on the geometric clustering distance of each variable within the three sampling methodologies, i.e., how tightly the data clusters. Analysis was based on the mean of each vegetation variable by well site by sampling method. Means were used to allow for one sample per well site for each methodology, i.e. data from the two transects for the point-line intercept and modified Daubenmire methods were averaged together to obtain one sample point per well site. The total number of samples for each method was N=30 for the MRPP analysis method. This is generally considered a large data set. The statistical analysis was run on the raw data for each well site and is summarized by

averages in Table 1. MRPP compared total cover, total vegetation cover, and bare ground alone and all combinations of these parameters. Total cover/ total vegetation cover and litter/rock cover were analyzed in combination as a multivariant. Lifeforms were analyzed separately.

Clustering Analysis. Clustering is a multivariant statistical tool that compares the simple linkage of well sites among the different methodologies (Hintze 2006). Clustering statistical analysis was used to evaluate the similarity between well sites. In order to draw conclusions of similarity, dissimilarity of the variables was analyzed. The variables used in the cluster analysis included total cover, total vegetation cover, bare ground cover, litter cover, rock cover, annual grass cover, annual forb cover, cool season perennial grass cover, sub-shrub cover, and full shrub cover. The output of this analysis was a dendrogram graph for each methodology. The dendrograms illustrated the relationship of well sites based on the cover variables.

Results and Discussion

General Cover Analysis by Methodology

Each well site was quantitatively sampled to determine composition and cover by each of the three methodologies. Table 1 provides a summary of each method's mean, minimum and maximum values collected by percent cover and by vegetation lifeform. Second hit data was not included in the percent total cover but was used to calculate species diversity per the methodology. Figure 1 displays average cover by methodology. Figure 2 displays average vegetation cover by lifeform by methodology.

BLM RFO Point Method. Absolute total cover ranged from 7.50% to 56.25% with an average of 43.01%. Absolute total vegetation cover ranged from 3.25% to 38.75% with an average of 26.67%. Based on lifeform, annual forbs had the highest average relative percent cover at 69.75%, followed by cool season perennial grasses at 23.66%. Sub-shrubs accounted for 5%, perennial forbs for 0.97%, full shrubs for 0.56%, annual grasses for 0.09%, and warm season perennial grasses for 0%. Bare ground had an average of 56.99%, ranging between 43.75% and 92.50%. Absolute litter cover ranged between 1.75 and 24.50%, and averaged 13.03%. Rock cover ranged between 0.25% and 12.25% with an average of 3.31%.

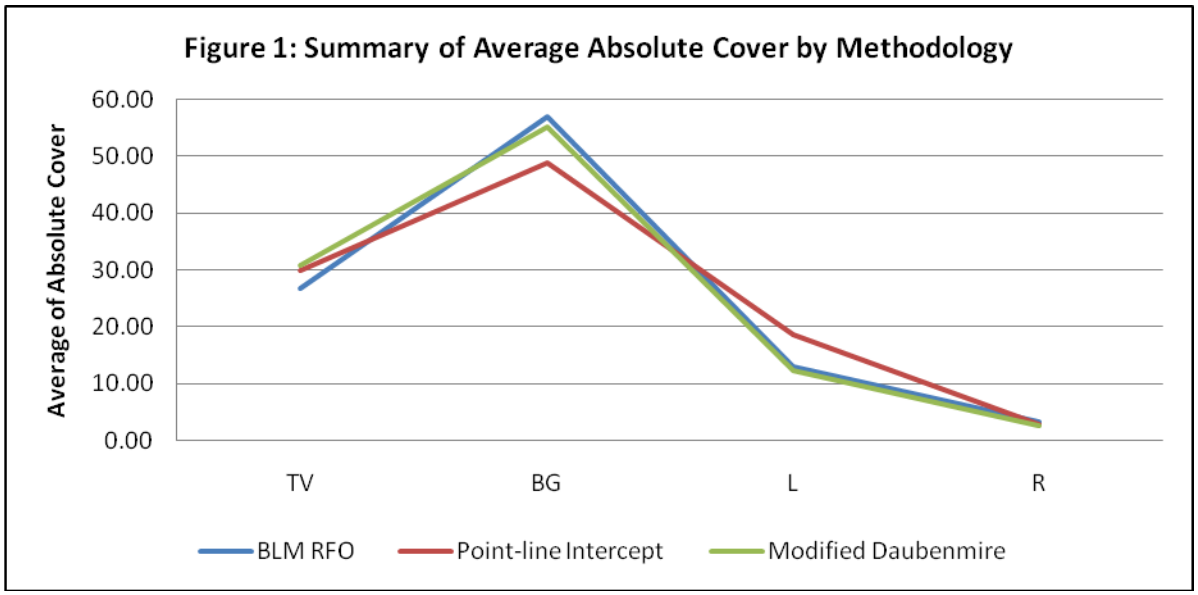
Point-Line Intercept Transect Method. Absolute total cover ranged from 11% to 70% with an average of 51.15%. Absolute total vegetation cover ranged from 1% to 49.50% with an average of 29.83%. Based on lifeform, annual forbs had the highest average relative percent cover at

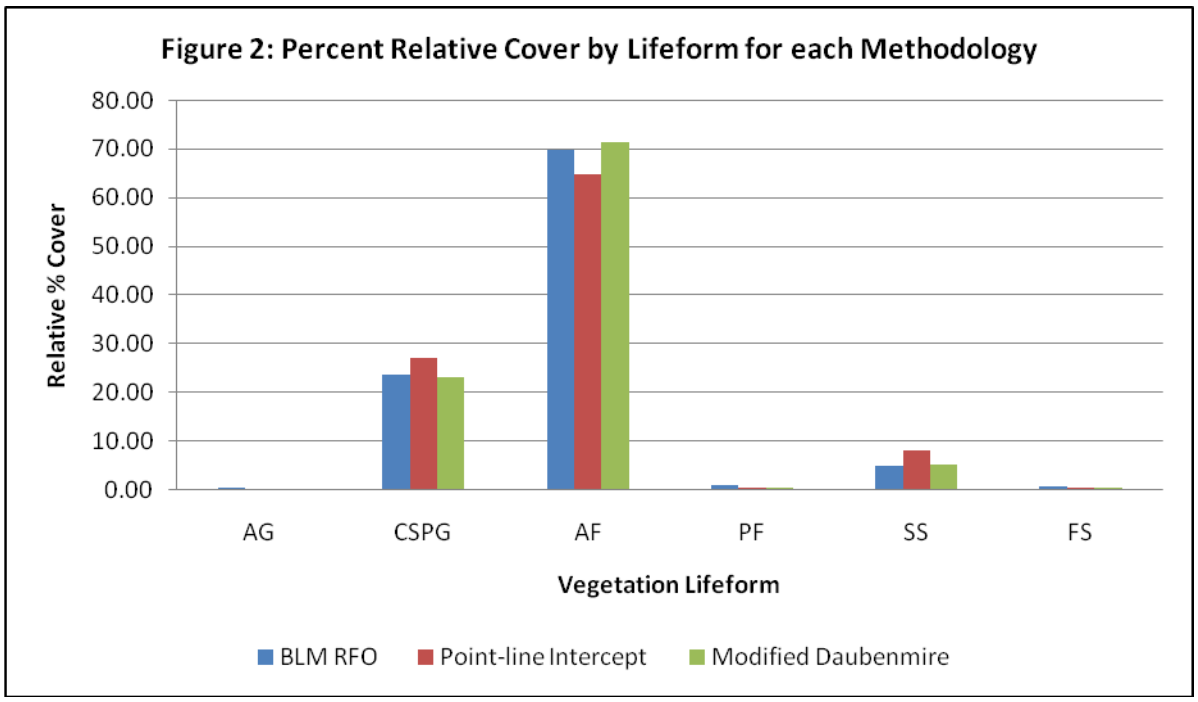
64.75%, followed by cool season perennial grasses at 26.98%. Sub-shrubs accounted for 7.99%, full shrubs for 0.17%, and perennial forbs for 0.12%. There was 0% annual grass cover and 0% warm season perennial grass cover. Bare ground had an average percent cover of 48.85% and a range between 30.00% and 89.00%. Absolute litter cover ranged between 0.50% and 34.50% and averaged 18.55%. Rock cover ranged between 0.00% and 15.50% with an average of 2.77%.

Modified Daubenmire Line Transect Method. Absolute total cover ranged from 11.10% to 69.75% with an average of 44.92%. Absolute total vegetation cover ranged from 2.45% to 56.93% with an average of 30.87%. Based on life forms, annual forbs had the highest relative percent cover for 71.28%, followed by cool season perennial grasses at 23.21%. Sub-shrubs accounted for 5.15%, perennial forbs for 0.38%, and full shrubs for 0.01%. No annual grasses or warm season perennial grasses were accounted for using this methodology. Bare ground cover had an average of 55.09% ranging between 30.25% and 88.90%. Absolute litter cover ranged between 0.70 and 25.83% and averaged 12.20%. Rock cover ranged between 0.00 and 14.78% with an average of 2.58%.

Table 1. Absolute Average Data and Relative Lifeform Data per Methodology

BLM RFO Point Method						Vegetation Lifeform					
	Total Cover (TC)	Total Vegetation (TV)	Bare Ground (BG)	Litter (L)	Rock (R)	Annual Grass (AG)	Cool Season Perennial Grass (CSPG)	Annual Forb (AF)	Perennial Forb (PF)	Sub-Shrub or Half Shrub (SS)	Full Shrub (FS)
Absolute Average	43.01	26.67	56.99	13.03	3.31	0.03	6.31	18.60	0.26	1.33	0.15
Relative Average						0.09	23.66	69.75	0.97	5.00	0.56
Minimum	7.50	3.25	43.75	1.75	0.25	0.00	0.25	0.25	0.00	0.00	0
Maximum	56.25	38.75	92.50	24.50	12.25	0.50	23.50	37.50	5.50	13.00	3.25
Point-Line Intercept Transect Method.						Vegetation Lifeform					
	TC	TV	BG	L	R	AG	CSPG	AF	PF	SS	FS
Absolute Average	51.15	29.83	48.85	18.55	2.77	0.00	8.05	19.32	0.03	2.38	0.05
Relative Average						0.00	26.98	64.75	0.12	7.99	0.17
Minimum	11.00	1.00	30.00	0.50	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Maximum	70.00	49.50	89.00	34.50	15.50	0.00	28.50	45.50	1.00	27.50	1.00
Modified Daubenmire Line Transect Method						Vegetation Lifeform					
	TC	TV	BG	L	R	AG	CSPG	AF	PF	SS	FS
Absolute Average	44.92	30.87	55.09	12.20	2.58	0.00	7.16	22.00	0.12	1.59	0.00
Relative Average						0.00	23.21	71.28	0.38	5.15	0.01
Minimum	11.10	2.45	30.25	0.70	0.00	0.00	0.00	2.30	0.00	0.00	0.00
Maximum	69.75	56.93	88.90	25.83	14.78	0.00	34.73	56.83	2.25	20.90	0.05





Based on the mean by methodology, the Point-Line Intercept Method had the highest percentage of total cover at 51.15% and litter at 18.5%. The BLM RFO Point Method had the highest percent bare ground cover at 56.99% and percent rock cover at 3.31%. The Modified Daubenmire Line Transect Method had the highest percent total vegetation cover at 30.14%. Based on lifeform, the BLM RFO Point Method had the highest percentages of annual grass

cover, perennial forb cover, and full shrub cover. The Modified Daubenmire Line Transect Method had the highest annual forb cover. The Point-Line Intercept Transect Method had the highest percentages of cool season perennial grass cover and sub-shrub cover.

Species Diversity

Each methodology resulted in differing species diversity. Table 2 identifies the average number of species by lifeform that were recorded for each methodology.

Table 2. Average Number of Species by Lifeform for Each Method

Parameters	BLM RFO Point Method	Point-Line Intercept Transect Method	Modified Daubenmire Line Transect Method
# of AG species	0.07	0	0
# of AF species	2.17	1.83	2.6
# of PF species	0.1	0.03	0.17
# of CSPG species	3.8	3.47	3.57
# of SS species	0.73	0.6	0.73
# of FS species	0.23	0.1	0.03
Total (Average)	7.1	6.03	7.1

The BLM RFO Point Method and the Modified Daubenmire Line Transect Method both had an average of 7.1 species identified, while the Point-Line Intercept Transect Method had 6.03 species. The BLM RFO Point Method identified the highest number of annual grasses, cool season perennial grasses and full shrub species. The Modified Daubenmire Line Transect Method identified the most annual forbs and perennial forbs species. Both identified the same amount of sub-shrub species.

Statistical Results

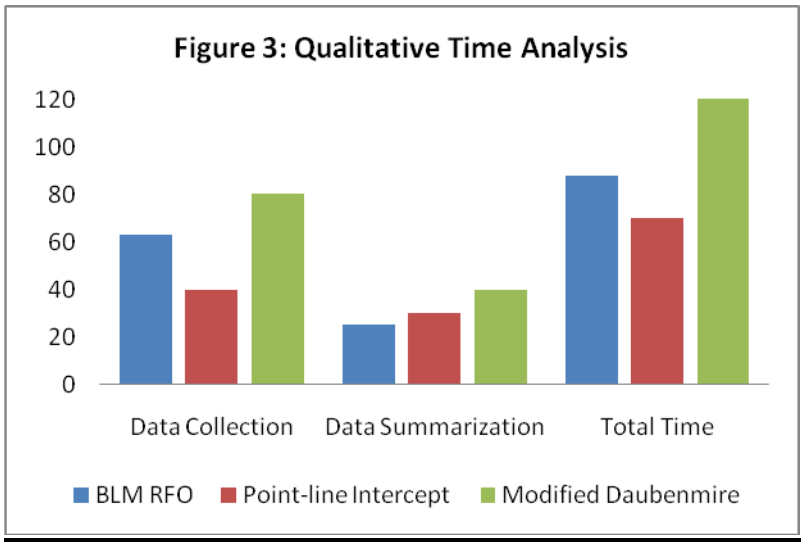
MRPP. Based on the MRPP results, total cover, bare ground, and litter plus rock cover were not significantly different at $p \leq 0.10$ for the BLM RFO Point Method and the Modified Daubenmire Line Transect Method. For those same parameters, the Point-Line Intercept Transect Method was significantly different from the other two methods at $p = 0.01$ to 0.10. For total vegetation cover, all three methods were not significantly different at $p \leq 0.10$.

Clustering Analysis. Based on the clustering results for all the cover variables, the Point-Line Intercept Transect Method grouped six pairs of well sites together as having the most similarity

at a dissimilarity of 0.30. The Modified Daubenmire Line Transect Method grouped five pairs and the BLM RFO Point Method grouped four pairs.

Qualitative Time Analysis

The three methodologies were also qualitatively evaluated on the amount of time required to conduct the surveys and to summarize the data. Figure 3, Qualitative Time Analysis illustrates the average time required to complete each methodology. The Point-Line Intercept Transect Method required the least amount of time to complete with an average of 70 minutes, 40 minutes for field work and 30 minutes for data entry and summarization (2 transects). The BLM RFO Point Method required an average of 88 minutes to complete; 63 minutes for field work and 25 minutes for data entry and summarization. The Modified Daubenmire Line Transect Method required the most time with an average of 120 minutes, 80 minutes for field work and 40 minutes for data entry and summarization (2 transects). No statistics were completed for the qualitative time data.



Variables Not Analyzed

There were multiple variables that could have affected the results of this study. The soils were not tested previously to determine limiting factors such as alkalinity. The age of the well sites and ESD for the well sites were discussed in the methods but not individually analyzed as a factor. The climatic patterns in the area could change the composition of the reclamation whether the year is dry or wet. While these variables exist, the purpose of the study was to

evaluate the effectiveness of three methodologies. All methodologies were conducted on each well site at the same time, and thus these variables were consistent during sampling.

Conclusion

The average cover results indicate the Point-Line Intercept Transect Method had the highest amount of cool season perennial grasses cover and total cover. The Point-Line Intercept Transect Method on average had slightly lower total vegetation cover than the Modified Daubenmire Line Transect Method; however, it required less time to complete the Point-Line Intercept Transect Method field sampling and data summarization. Therefore, this methodology is more economical because more sample points can be done in a day than the other two methodologies.

Based on MRPP analysis, total vegetation cover for all three methodologies is not statistically different at the $p = 0.10$ but total cover values were significantly different for Point-Line Intercept Transect Method and the other two methodologies at $p = 0.01$ to 0.10. This indicates the Point-Line Intercept Transect Method produces greater total cover values than the other two methods. All three methods were equal statistically regarding total vegetation cover. Based on the clustering analysis, the Point-Line Intercept Transect Method is more consistent in data collection as it formed more groups of similarity between well sites for the multivariate cover parameters at dissimilarity of 0.30. The Point-Line Intercept Transect Method is the preferred methodology based on both quantitative and qualitative data analyses.

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