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Comparison of Two Survey Methods for Estimating Vegetative Cover

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ABSTRACT

Effective management of natural resources requires survey information regarding initial resource condition. It is not uncommon for sampling methods to change over time or for data from different surveys to be used in support of a common management goal. When data from surveys that utilize different methodologies are combined, error and bias associated with each survey methodology can confound interpretation of results. The Land Condition Trend Analysis (LCTA) program is an U.S. Army inventory and monitoring program that employs standardized methods of data collection, analyses, and reporting. The LCTA program uses a modified point intercept transect methodology. As LCTA program objectives evolve, interests in alternative sampling methodologies have increased. A number of installation LCTA programs have started using variations of the releve method to characterize vegetation. A study was conducted to evaluate the effect of alternative survey methodologies on vegetation characterization. The study consisted of 107 plots randomly established across the study area. Identical survey crews surveyed each plot using standard LCTA and releve methodologies. LCTA methods consistently resulted in larger cover estimates especially at the uppermost height stratum. These differences resulted in LCTA methods classifying more plots as closed forest types than releve methods. The two survey methods tended to agree in more open vegetation types (grasslands and disturbed areas). Differences in survey results are attributed to differences in methodology because the differences could not be solely attributed to differences in area sampled.

INTRODUCTION

Monitoring vegetation on U.S. Army installations allows the detection of impending changes in vegetative types, and enables managers to balance military training with land condition to preserve the long-term viability and usefulness of the land and associated biological systems. The Land Condition Trend Analysis (LCTA) program was developed to inventory and monitor natural resources on the 4.9 million hectares of land managed by the U.S. Army (Doe et al. 1999). LCTA data sets currently exist for more than 50 installations and contain up to 10 years of annual vegetation monitoring data. The original emphasis of the LCTA program was to provide standardized methods to allow comparisons among installations with the ultimate goal of developing regional or national tools to estimate changes associated with various levels of military training (Diersing et al. 1992).

The LCTA program uses a modified point intercept transect method based on prior studies that demonstrated the method to generally be more accurate than other methods (Fenner 1997). Since 1992, local land managers have tried to optimize their scarce sampling resources by changing to methods more common to their region, plant community types, training activities, or resource management objectives (Anon. 1996; Anon. 1999; Cully and Winter 2000; Wang et al. 2001b; Leis et al. 2003; Prosser et al. 2003). Releve methodologies (*sensu* Mueller-Dombois and Ellenberg 1974) have been proposed as one alternative to standard LCTA methods at several installations to reduce inventory costs and provide data consistent with other regional organization's survey data. Common reasons cited for using releve methods were that point intercept methods underestimate total number of species, were less effective for monitoring infrequently occurring species, and exhibited certain types of bias (Leps and Hadincova 1992; Brakenhielm and Liu 1995; Fenner 1997; Dethier et al. 1993; Korb et al. 2003). However, other studies have shown a trade-off between the accuracy of cover estimates and the proportion of the species present that are recorded in the data (McCune and Lesica 1992).

The objective of our study is to quantify differences between standard LCTA and releve survey methodologies on the characterization of vegetation. Our hypotheses are that 1) both the LCTA and the releve methods should detect the same plant community and 2) the detected plant communities from both methods would be classified as the same community under the National Vegetation Classification System (i.e. they would be undifferentiated upon application). This research is important to determine if vegetation sampling data is only relative to the method used or if the data can be used for comparison with those collected using other methods. This question is vital for determining whether the data can be reassembled into a composite national monitoring program.

METHODS

Study Area

The study was conducted at Fort Drum (44.05N, 75.77W) in Jefferson and Lewis counties in upstate New York. Fort Drum is approximately 36,100 ha and classified by Bailey (1995) as being in the Eastern Broadleaf Forest province. Vegetation is typically northern hardwood with open forest and grasslands. Long cold winters and short warm summers characterize the climate with well distributed precipitation throughout the year, averaging 2900 mm (Anon. 1977).

Standard LCTA Survey Plot Protocols

A standard LCTA plot is a permanent 100-m line transect (Diersing et al. 1992). A modified point intercept method is used to quantify vegetation cover at 1-m intervals along the line transect. A 1-m metal rod is used to measure vegetation point intercepts below 1-m and a telescoping range pole is used to measure vegetation intercepts above 1-m. Species identification, transect location, and intercept height are recorded for each vegetation intercept. Data from the 100-m LCTA plots is henceforth referred to as LCTA data.

Releve Survey Plot Protocols

The releve plots were 20-m by 20-m sample plots which are generally referred to as a releve (Mueller-Dombois and Ellenberg 1974; Bonham 1991). The plot size was determined in a preliminary study by creating a species area curve. The 400-m^2 plot size selected exceeded or met National Park Service vegetation mapping plot size guidelines for vegetation typically found at the study area (Anon. 1994). Species were recorded for each height strata (Table 1) and aerial vegetative cover for each strata was visually estimated and assigned a Daubenmire (1968) cover class (Table 2). Total cover for each height strata was visually estimated. Data from these releve plots is henceforth referred to as releve data.

Study Design

One hundred and seven plots were randomly allocated using a stratified random sampling technique (Warren et al. 1990). Within a GIS, landcover and soils data were superimposed. Each unique landcover/soil type was identified as a stratum. The number of plots assigned to each stratum was proportional to the land area in the strata. Plots were randomly located in each stratum such that a 100-m transect would not cross a stratum boundary.

Plots were located based on the predetermined plot locations and an LCTA line transect was established along a randomly selected azimuth. If the line transect crossed a distinct vegetation boundary, another azimuth was randomly selected. A releve plot was subsequently located parallel to the LCTA line transect starting at the beginning of the line transect (Fig. 1). If the releve plot crossed a distinct vegetation boundary, then an alternate releve plot location was selected as shown in Figure 1. Releve plots were located adjacent to LCTA line transects to avoid observer tracking within the releve plot while sampling the LCTA plot.

Numerous studies have demonstrated differences in plant cover among the observers (Sykes et al. 1983; Leps and Hadincova. 1992; Westfall et al. 1997; Kercher et al. 2003; Klimes 2003; Helm and Mead 2004). To account for differences in observers, we used three field crews to measure the 107 plots. The same field crew located and established each co-located LCTA and releve plot. The same individual within a crew measured vegetation cover on each co-located LCTA and releve plot on the same day to prevent confounding observer bias with differences in the sampling methods.

Data Analysis

LCTA data was summarized to conform to the format of the releve data. Total number of species was calculated for each LCTA plot. Total cover by height strata, and cover by species and height strata was calculated by summing all transect locations with vegetative intercepts for the respective species and height strata. Raw data from each releve plot was transformed using the cover class midpoints (Table 2) as the representative data value (Bonham 1991).

Hypothesis 1

A correlation analysis was conducted to assess the strength of the relationship between the two survey cover estimates. The average difference between vegetative cover estimates was calculated as a measure of survey bias between methods. Average absolute difference between cover estimates was calculated to quantify the overall difference in plot estimates. The number of strata by species cover classes that differed between survey methods was calculated.

Because LCTA and releve plots survey different areas, differences between survey results could be attributed to differences in area surveyed or differences in survey methods. To quantify the effect of differences in survey area on survey results, the LCTA line transect was divided into two parts, 0 to 50-m and 51 to 100-m. The 0 to 50-m transect, henceforth referred to as LCTA1, represents line transect data closest to the releve plot. The 51 to 100-m transect, henceforth referred to as LCTA2, represents line transect data most distant from the releve plot. The LCTA1 and LCTA2 datasets were analyzed in the same manner as described for the LCTA and releve data.

Hypothesis 2

The National Vegetation Classification System (NVCS) was used to classify each plot at the Class level to quantify the affect of survey methodologies on classifying vegetation (O'Neil and Hill 2000). Vegetation classes used were closed canopy (60-100% tree cover), open canopy (25-59% tree cover), shrublands (10-24% tree cover) and sparse (<10% tree cover). In this paper, the shrubland class includes shrubland, dwarf-shrubland, herbaceous, and nonvascular classes of the NVCS standard.

In the NVCS hierarchy, the alliance level of the classification scheme identifies the dominant and codominant species that are found in the uppermost stratum of the vegetation. To evaluate the effect of survey methodology on classification of sites at the alliance level, data from LCTA and releve plots were used to identify the dominant and codominant species in the upper stratum of each plot.

RESULTS

Hypothesis 1

Correlation coefficients were calculated for each height strata for the two survey methods (LCTA and releve) and for the two LCTA subplots (LCTA1 and LCTA2) (Table 3). Correlation coefficients for the two survey methods ranged from 0.54 to 0.84 indicating that the results from one survey method explained between 29 to 70% of the variation in the other survey results. Correlation coefficients for the LCTA subplots ranged from 0.66 to 0.91 indicating that results from one subplot explained between 43 to 84% of the variation in the other subplot. The uppermost stratum generally had higher correlation coefficients than lower stratum for both methods and subplot correlations. While LCTA and releve cover estimates are highly correlated, the relationship was not as strong as for the two LCTA subplots that used the same methods but on adjacent areas.

The LCTA methods consistently resulted in higher cover values than releve methods for all height strata. When LCTA cover estimates were converted to releve cover classes, between 1.9 and 22.4% of plot height strata were classified in the same cover class as the releve survey (Table 3). When LCTA subplot cover estimates were converted to releve cover classes, between 9.4 and 28.0% of plot height strata were classified in the same cover class. For LCTA subplots, there was no consistent over or under estimation of cover for either subplot.

The LCTA methods consistently estimated higher cover class values than releve methods on a species height strata basis. Less than 1% of LCTA and releve species by height strata observations were in the same cover class, while almost 24% of LCTA subplot observations were the same class (Fig. 2). Over 44% of releve and LCTA plots differed by 2 or more cover classes while only 8. 5% of LCTA subplots differed by 2 or more classes. Species level cover estimates differed more between the two methods than between areas within the LCTA method.

Comparing LCTA and releve data, 54.3% of all misclassifications by species and height strata involved the 1-5% cover class for one survey method (either LCTA or releve) and 0% cover for the other method. Across all height strata, 67% of misclassifications were in the lowest height strata (0-1m). However, with increasing height strata the percentage of two cover class discrepancies increased from 5.1 to 22.4% of observations.

Average absolute difference was calculated as a measure of the magnitude of difference in cover estimates, while average difference was used as a measured of overall bias of one method to the other. The average difference between LCTA total cover estimates and releve total cover midpoint ranged from 4.4 to 21.0% for different height strata (Table 3). Average absolute differences ranged from 10.8 to 23.3%. The average difference between LCTA subplot cover estimates ranged from –2.2 to 1.0%. Average absolute differences ranged from 9.2 to 13.0% for LCTA subplots. Average difference was substantially larger between methods than between the same methods for adjacent areas. The average absolute difference between adjacent areas with the LCTA method was consistently smaller than between the two methods for all height strata.

The average difference between LCTA cover estimates and the releve cover class midpoints on a species height basis was 4.1%. The average difference between LCTA1 and LCTA2 cover estimates on a species height basis was 8.8%. Differences due to area sampled using LCTA methods were greater than between LCTA and releve methods but resulted in few cover class discrepancies. The higher LCTA cover estimates resulted in more of the observations being classified into broader Daubenmire cover classes resulting in fewer misclassifications.

A total of 431 species were identified by the two survey methods (Table 4). Releve methods identified more species than LCTA methods across all plots. Each survey method identified species not identified by the other method. Though not reported, results on a plot basis were similar to the overall sampling results.

We reject the hypothesis that both methods would detect the same plant community. Each analysis of the data consistently showed substantial differences in descriptions of the plant community.

Hypothesis 2

To examine the effect of survey methodologies on data interpretation, we classified each plot using the NVCS at the class level (Table 5). Over 85% of plots were classified the same when adjacent areas were both sampled with the LCTA method (LCTA1 vs LCTA2) while less than 61% of plots were classified the same with LCTA and releve methodologies (LCTA vs releve). Most classification discrepancies between survey methods were between closed and open classes. LCTA, with higher cover estimates for the topmost height stratum, identified more of the forested plots as closed while the releve method differentiated between classifying the plots as open and closed. At the class level of the NVCS classification system, the differences in methodology resulted in 39% of plots being classified differently.

At the alliance level of the NVCS, plant communities are classified by the dominant and codominant species of the uppermost vegetation layer. To evaluate the effect of survey methodology differences on data interpretation, we identified the dominant and codominant species in the uppermost height stratum. The dominant and codominant species identified by each survey method where compared on a plot basis (Table 6). LCTA and releve methods identified the same dominant and codominant species for 39% of the plots that had cover in the uppermost stratum. The LCTA subplots identified the same dominant and codominant species for only 31% of the survey plots.

We reject the hypothesis that the community descriptions provided by the different methods would result in the same practical interpretation of the plant community and condition. However, this may reflect an overly sensitive test rather than real community differences because LCTA subplots were more different than LCTA vs releve plots.

DISCUSSION

Theoretically, most sampling methods should give comparable information about vegetation composition and abundance because the collected data all reflect the underlying plant community (e.g. Bonham 1991). In practice, different sampling methods have given different representations despite sampling the same plant communities (Hanson and Love 1930; Buell and Cantlon 1950; Heady et al. 1959; Kinsinger et al. 1960; Winkworth et al. 1962; Good and Good 1972; Stohlgren et al. 1998). One justification for this has been that each unique sampling method changes the area, extent, and distribution of the samples (Smith 1980; Ludwig and Reynolds 1988; Stohlgren et al. 1998). Further, plant communities often violate the assumption of spatial homogeneity at many common sampling scales (i.e. they have patterns rather than being uniformly distributed; e.g. Heady et al. 1959; Greig-Smith 1979).

The results of this study show the differences in sampling results from methods that differed in extent, intensity and area. Releve methods identified more species than the LCTA methods across all plots (Table 4). These results agree with previously reported comparison between releve and point type methods (Stohlgren et al. 1998). These results are not surprising since the LCTA method only samples 100 points along a transect while the releve methodology involves inventorying all species on a plot before cover estimates are made. However, the LCTA methodology did find 34 species not identified on the releve plots. The magnitude of this difference is similar to the number of species that were unique to one LCTA subplot. The releve methodology surveyed more species than the LCTA methodology most likely due to sampling intensity. The species only identified by the LCTA methodology can be attributed to differences in sampling area that captured spatial variability within a plant community that was greater than the dimensions of the releve plot dimensions.

An appropriate plot size for a survey depends on the individual vegetation variable sampled. The degree of spatial autocorrelation found in vegetation varies by growth form, size, and species (Wang et al. 2001a, Wang et al. 2001b, Gertner et al. 2002). In our study, total vegetation cover estimates differed more between survey methods (releve vs LCTA) than between areas sampled (LCTA1 vs LCTA2). However, cover estimates of individual dominant canopy species differed more between areas sampled (LCTA1 vs LCTA2) than between methods (releve vs LCTA). Cover of individual species varied over larger areas which dictated a need for larger plot sizes for both the LCTA and releve methods. For these measures, differences in survey results were larger between areas than between methods. For measures like total cover, that varied over smaller areas such that each method's plot size captured the variation, differences in area surveyed was smaller than differences between methods. These results agree with prior studies. Wang et al. (2001b) determined that LCTA plots should be not less than 80-m for woody vegetation but could be as short as 60-m for grass and shrub vegetation. Jalonen et al. (1998) demonstrated larger releve plot sizes were required to accurately inventory species than were required to estimate cover of individual species. The 50-m LCTA subplots used in this study may have been sufficient for grass, shrub, and total cover estimates but insufficient to capture the spatial variability of individual species of woody vegetation. Melman et al. (1991) suggested sensitivity of parameters to plot size be a criteria in sample parameter selection.

Differences in cover estimates from plot surveys do not necessarily mean that the data will be interpreted differently. If differences in survey results are small relative to how the data is aggregated, the data is likely to be interpreted in a similar manner. However, results from this study indicated that sampling methodology altered classification of vegetation at both the more general class level and the more detailed alliance level of classification which in this example would have changed management interpretations.

CONCLUSIONS

Standardization of vegetation survey methods is an objective of several national programs (Diersing et al. 1992; Anon. 1994; Rodwell et al. 1995; O'Neil and Hill 2000). These programs are based on the understanding that different field survey and data analysis methods often result in varying interpretations (Mucina et al. 2000; Bruelheide and Chytry 2000; Hennekens and Schaminee 2001). However, data from legacy vegetation survey programs that adhere to alternative standards will continue to be used in natural resources management. Understanding the effect of field survey methods on data interpretations is critical to utilizing data from these legacy programs.

LCTA and releve methods represent two common standards for characterizing vegetation on U.S. military lands. LCTA methods consistently resulted in larger cover estimates especially at the uppermost height stratum. The differences resulted in LCTA methods classifying more plots as closed forest types than the releve methods. The two survey methods tended to agree in more open vegetation types (grasslands and disturbed areas) because the cover estimates differed less in the lower height strata.

Differences in survey results cannot be attributed to differences in personnel since in this study the same observer measured a plot with both methods. Differences in survey results could not be completely explained by differences in the area sampled. When the same method was used on different areas, cover estimate differences were smaller than the differences between methods. This study indicates that differences in cover estimates for the two survey methodologies are associated with the manner in which each method estimates vegetative cover. This study did not determine which method was the most accurate for characterizing vegetation. The study only assessed the effect of alternate methodologies on vegetation classification. Additional research is required to establish accurate algorithms to convert data between these commonly used sampling methods if data is to be combined during decision-making processes.

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LITERATURE CITED

Anon. 1977. Terrain analysis: Fort Drum, New York. Engineering Topography Laboratory, Alexandria, VA.

Anon. 1994. Field methods for vegetation mapping: Report for the National Biological Survey/National Park Service Vegetation Mapping program. The Nature Conservancy, Arlington, VA.

Anon. 1996. Land Condition Trend Analysis II: Report for workshop held January 23-25, 1996 Linthicum, MD. U.S. Army Environmental Center, Aberdeen Proving Ground, MD. URL: http://srp.army.mil/public/home.jsp.

Anon. 1999. Ecological monitoring on Army lands: LCTA II technical reference manual. U.S. Army Environmental Center, Aberdeen Proving Ground, MD. URL: http://srp.army.mil/public/home.jsp.

Bailey, R.G. 1995. Ecosystem geography. Springer-Verlag, New York, NY.

Bonham, C.D. 1991. Measurement for terrestrial vegetation. John Wiley & Sons, New York, NY.

Brakenhielm, S. and Q.H. Liu. 1995. Comparison of field methods in vegetation monitoring. Water Air and Soil Pollution 79:75-87.

Bruelheide, H. and M. Chytry. 2000. Toward unification of national vegetation classifications: A comparison of two methods for analysis of large data sets. Journal of Vegetation Science 11:295-306.

Buell, M.F. and J.E. Cantlon. 1950. A study of two communities of the New Jersey Pine Barrens and a comparison of methods. Ecology 31:567-586.

Cully, J.F. and S.L. Winter. 2000. Evaluation of land condition trend analysis for birds on a Kansas military training site. Environmental Management 25:625-633.

Daubenmire, R.F. 1968. Plant Communities: Textbook of Plant Synecology. Harper and Row, New York, NY.

Dethier, M.N., E.S. Graham, S. Cohen, and L.M. Tear. 1993. Visual versus random-point percent cover estimations – objective is not always better. Marine Ecology – Progress Series 96:93-100.

Diersing, V.E., R.B. Shaw, and D.J. Tazik. 1992. U.S. Army Land Condition-Trend Analysis (LCTA) program. Environmental Management 16:405-414.

Doe, W., R.B. Shaw, R. Bailey, D. Jones, and T. Macia. 1999. Locations and environments of U.S. Army training and testing lands: An ecological framework for assessment. Federal Facilities Environmental Journal, Autumn 9-26.

Fenner, M. 1997. Evaluation of methods for estimating vegetation cover in a simulated grassland sward. Journal of Biological Education 31:49-54.

Gertner, G., G. Wang, S. Fang, and A.B. Anderson. 2002. Mapping and uncertainty of predictions based on multiple primary variables from joint co-simulation with Landsat TM image and polynomial regression. Remote sensing of Environment, 83(3):498-510.

Good, E.R. and N.F. Good. 1971. Vegetation of a Minnesota prairie and a comparison of methods. American Midland Naturalist 85:228-231.

Greig-Smith, P. 1979. Pattern in vegetation. Journal of Ecology 67:755-779.

Hanson, H.C. and L.D. Love. 1930. Comparison of methods of quadratting. Ecology 11:734-748.

Heady, H.F., R,P. Gibbens, and R.W. Powell. 1959. A comparison of the charting, line intercept, and line point methods of sampling shrub types of vegetation. Journal of Range Management 12:180-188.

Helm, D.J. and B.R. Mead. 2004. Reproducibility of vegetation cover estimates in south-central Alaska forests. Journal of Vegetation Science 15:33-40.

Hennekens, S. and J. Schaminee. 2001. TURBOVEG, a comprehensive data base management system for vegetation data. Journal of Vegetation Science 12:589-591.

Kercher, S.M., C.B. Frieswyk, and J.B. Zedler. 2003. Effects of sampling teams and estimation methods on the assessment of plant cover. Journal of Vegetation Science 14:899-906.

Jalonen, J., I. Vanha-Majamma, and T. Tonteri. 1998. Optimal sample and plot size for inventory of field and ground layer vegetation in a mature Myrtillus-type boreal spruce forest. Annales Botanici Fennici 35:191-196.

Kinsinger, F.E., R.E. Eckert, and P.O. Currie. 1960. A comparison of the line-interception, variable-plot and loop methods as used to measure shrub-crown cover. Journal of Range Management 13:17-21.

Klimes, L. 2003. Scale-dependent variation in visual estimates of grassland plant cover. Journal of Vegetation Science 14: 815-821.

Korb, J.E., W.W. Covington, and P.Z. Fule. 2003. Sampling techniques influence understory plant trajectories after restoration: An example from ponderosa pine restoration. Restoration Ecology 11:504-515.

Leis S., D. Engle, D. Leslie, J. Fehmi, and J. Kretzer. 2003. Comparison of vegetation sampling procedures in a disturbed mixed-grass prairie. Proceedings of the Oklahoma Academy of Sciences 83:7-15.

Leps, J. and V. Hadincova. 1992. How reliable are our vegetation analyses? Journal of Vegetation Science 3:119-124.

Ludwig, J.A. and J.F. Reynolds. 1988. Statistical Ecology: A Primer on methods of computing. John Wiley and Sons, New York, NY.

McCune, B., and P. Lesica 1992. The trade-off between species capture and quantitative accuracy in ecological inventory of lichens and bryophytes in forests in Montana. Bryologist 95:296-304.

Melman, T., H. Dehaes, and W. Vanwijngaarden. 1991. Size dependence of parameters for ecological factors and for nature conservation evaluation of grassland releves. Biological Conservation 55:347-354.

Mucina, L., J. Schaminee, and J. Rodwell. 2000. Common data standards for recording releves in field survey for vegetation classification. Journal of Vegetation Science 11:769-772.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York, NY.

O'Neil, L.J. and A. Hill. 2000. Guidelines for mapping vegetation on Army installations. ERDC TR-00-8, U.S. Army Engineer Research and Development Center, Vicksburg, MS, and SFIM-AEC-EC-CR-99006, Army Environmental Center, Aberdeen Proving Ground, MD.

Prosser C., K. Skinner, and K. Sedivec. 2003. Comparison of two techniques for monitoring vegetation on military lands. Journal of Range Management 56:446-454.

Rodwell, J., S. Pignatti, L. Mucina, and J. Schaminee. 1995. European vegetation survey – update on progress. Journal of Vegetation Science 6:759-762.

Sykes, J.M., A.D. Horrill, and M.D. Mountford. 1983. Use of visual cover assessments as quantitative estimators of some British woodland taxa. Journal of Ecology 71:437-450.

Smith, R.L. 1980. Ecology and field biology. Harper and Row, New York, NY.

Stohlgren, T.J., K.A. Bull, and Y. Otsuki. 1998. Comparison of rangeland vegetation sampling techniques in the Central Grasslands. Journal Range Management 51:164-172.

Wang, G., G. Gertner, S. Wente, and A.B. Anderson. 2001a. Vegetation Classification and Accuracy Assessment Using Image Aided Sequential Indicator Co-simulation. Conference Proceedings of the American Society of Photogrammetry and Remote Sensing (ASPRS), Gateway to the New Millenium Conference, St. Louis, MO. April 23-27, 2001, pp 1-12.

Wang, G., G. Gertner, X. Xiao, S. Wente, and A.B. Anderson. 2001b. Appropriate plot size and spatial resolution for mapping multiple vegetation types. Photogrammetric Engineering and Remote Sensing 67:575-584.

Warren, S.D., M.O. Johnson, W.D. Goran, and V.E. Diersing. 1990. An automated, objective procedure for selecting representative field sample sites. Photogrammetric Engineering and Remote Sensing 56:333-335.

Westfall, R.H., G.K. Theron, and N. Rooyen. 1997. Objective classification and analysis of vegetation data. Plant Ecology 132:137-154.

Winkworth, R.E., R.A. Perry, and C.O. Rossetti. 1962. A comparison of methods of estimating plant cover in an arid grassland community. Journal of Range Management 15:194-196.

Table 1. Releve vegetation strata heights.

Strata	Height (m)
Forb/Grass	Ground to 1.0
Tall Forb	1.0 to 2.0
Shrub	2.0 to 5.0
Tree	> 5.0

Table 2. Daubenmire cover class scale used to visually estimate vegetation cover and class midpoints for summarizing data.

Cover Class	Cover (%)	Class Midpoint (%)
1	0 to 5	2.5
2	5 to 25	15.0
3	25 to 50	37.5
4	50 to 75	62.5
5	75 to 95	85.0
6	95 to 100	98.0

Table 3. Total vegetative cover for LCTA and releve survey methods by height strata.

Measure[1]	Height Strata			
	0-1m	1-2m	2-5m	>5m
LCTA and Releve Survey Comparison				
Correlation	0.63	0.66	0.54	0.84
% plots same cover class	1.9	14.0	15.0	22.4
% plots releve estimates more cover	33.6	28.0	11.2	13.1
% plots LCTA estimates more cover	64.5	58.0	73.8	64.5
Average difference[2]	7.6 ± 2.2	4.4 ± 1.5	21.0 ± 2.2	13.8 ± 2.1
Average absolute difference	17.6 ± 1.6	10.8 ± 1.1	23.2 ± 2.0	17.4 ± 1.8
LCTA1 and LCTA2 Survey Comparison				
Correlation	0.77	0.74	0.85	0.91
% plots same cover class	9.3	24.3	23.4	28.0
% plots LCTA1 estimates more cover	47.7	29.9	35.5	42.1
% plots LCTA2 estimates more cover	43.0	45.8	41.1	29.9
Average difference[3]	-2.2 ± 1.8	1.0 ± 1.3	-0.2 ± 1.5	-2.0 ± 1.6
Average absolute difference	13.0 ± 1.4	9.2 ± 1.0	10.2 ± 1.1	9.7 ± 1.3

[1] Correlation and difference measures calculated using cover class midpoint values for releve data. Percent of plots calculated using cover class values for LCTA and releve data.

[2] Mean and standard error for difference between survey methods. All values significant different than 0 at the p=0.01 level based on a paired two-tailed T test.

[3] No differences between survey methods significantly different from 0 at the p=0.2 level based on a paired two-tailed T test.

Table 4. Comparison of total species identified and species identified by height strata for LCTA and releve survey methods.

Measure	Total Species	
	Number	Percent
LCTA and releve Combined	431	100.0
LCTA Total	320	74.2
Releve Total	397	92.1
Both LCTA and releve	286	66.4
LCTA Only	34	7.9
Releve Only	111	25.8
LCTA1 & LCTA2 Combined	320	100.0
LCTA1 Total	282	88.1
LCTA2 Total	254	79.4
Both LCTA1 and LCTA2	216	67.5
LCTA1 Only	66	20.6
LCTA2 Only	38	11.9

Table 5. Comparisons of survey plot vegetation classification using LCTA and releve survey methods.

		LCTA				
		Closed[2]	Open	Shrub	Sparse	Total
Releve	Closed	21.5[1]	2.8	0.0	0.0	24.3
	Open	19.7	8.4	0.9	0.0	29.0
	Shrub	4.7	3.7	0.0	1.9	10.3
	Sparse	0.0	1.9	3.7	30.8	36.4
	Total	45.8	16.8	4.7	32.7	100.0

		LCTA2				
		Closed	Open	Shrub	Sparse	Total
LCTA1	Closed	42.1	1.9	1.9	0.9	46.7
	Open	4.7	10.3	0.9	0.9	16.8
	Shrub	0.9	0.0	0.9	1.9	3.7
	Sparse	0.0	0.9	0.9	30.8	32.7
	Total	47.7	13.1	4.7	34.6	100.0

[1] Percent of plots

[2] Closed, Open, Shrub, Sparse are closed tree canopy, open tree canopy, shrubland, and sparse classifications respectively.

Table 6. Comparison of dominant and codominant vegetation species in the greater than 5m height strata using LCTA and releve survey methods.

Category	LCTA vs Releve[1]	LCTA1 vs LCTA2
Same[2]	39.3	31.8
Reversed[3]	8.4	0.9
Mismatched[4]	21.5	36.4
No cover >5m[5]	30.8	30.8
Total	100.0	100.0

[1] Percent of plots

[2] Same: same dominant and codominant

[3] Reversed: dominant and codominant reversed

[4] Mismatch: dominant, codominant, or both differ

[5] No cover >5m: both had no cover

Figure 1. Plot design for selecting releve plot, plot location relative to the LCTA line transect.

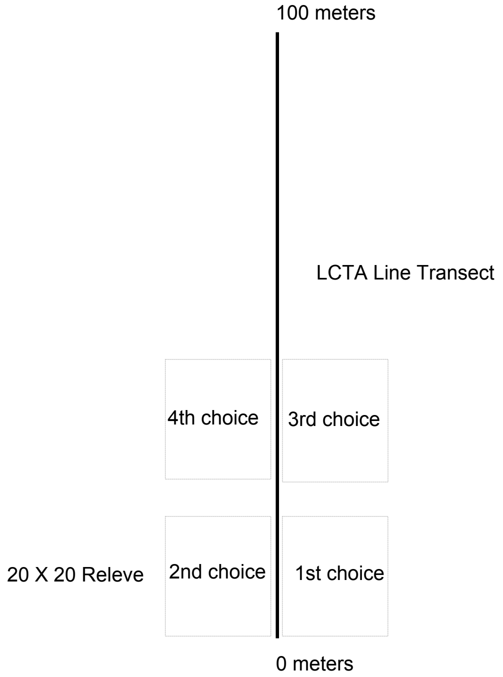

Figure 2. Number of cover class categories difference between LCTA and releve vegetation measurements.