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Robustness of the Point-Line Method for Monitoring Basal Cover

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The point-line method is a robust estimator of basal cover with respect to population distribution, average plant size, and the non-randomness of a disturbance. A graphical modeling approach can evaluate the overall effectiveness of any vegetation inventory procedure.

Keywords: range condition, range inventory, robust measures

Introduction

Range condition classification historically has been used to delineate rangeland health (Joyce 1993). Over the past decade, the Department of Defense (DOD) has initiated a program, entitled Land Condition-Trend Analysis (LCTA), to monitor the response of soils and vegetation to training activities on military lands (Tazik et al. 1992). The LCTA method closely follows techniques for estimating range condition by providing erosion indicators and measures of bare soil and plant cover by species. These data are obtained from field plots containing a 100-m point-line transect along which a point reading is made every meter. The point-line method has been described by Bonham (1989).

Disturbance patterns due to military training activities are mostly non-random. Vegetation perturbation from bivouac activities probably are non-random in relation to LCTA point-line transects because of the size of platoon and company bivouac areas. For example, the trampling pattern within and around a medium-sized army tent is approximately 10 m by 20 m (personal observation). Tread marks left by tracked vehicles during field exercises are a dominant form of non-random disturbance.

Monitoring designs should be stable, powerful, and robust if they are to detect meaningful changes in vegetation with an acceptable error (Green 1979). Stable designs have an acceptable probability of false conclusions concerning vegetation change (Type-I error); powerful designs have an acceptable likelihood of actually detecting vegetation change (complement to Type-II error). Robust methods are those that produce data that are not influenced by extraneous factors (i.e., factors not considered when collecting data), particularly when estimators are

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based upon small samples. Frequency measures are not robust, for example, because they are affected by plot size and shape (Bonham 1989) and plant size (Cook et al. In press).

The objective of this study was to evaluate the robustness of the LCTA point-line method using a graphical modeling approach. Specifically, we wanted to determine the method's ability to measure changes in basal cover in relation to aggregated disturbance patterns and non-random vegetation distributions.

Methods

Evaluating the robustness of the point-line technique for monitoring changes in basal cover is a formidable task in the field; the cost of creating treatments is prohibitive and numerous replications are needed to ensure adequate precision. Therefore, a computer simulation approach was used because it allowed easy measurements of specified population distributions with a large number of replications.

We used Turbo Pascal (Version 6.0)[4] as a programming language to develop graphic computer models of a simulated shortgrass steppe community on the Pinon Canyon Maneuver Site (PCMS) in southern Colorado (Shaw et al. 1989). The PCMS serves as a training area for mechanized infantry and armor forces located at Fort Carson, Colorado. The shortgrass community was defined in terms of the dominant species, blue grama (*Bouteloua gracilis* (H.B.K.)Lag.), with an initial basal cover of 12%. Our rationale was that a monitoring system should be able to follow the dynamics of blue grama, which typically constitutes 50-90% of the community biomass (Shaw et al. 1989), if it is to be minimally effective.

We used a scale of 1 cm per pixel to generate vegetation models. Such a scale portrayed a community of 10.24 m by 7.68 m on one screen of a 8514A monitor. Thus, a simulated community large enough to contain a 100-m transect, randomly situated, was represented by 11 separate, but linked, graphic screens.

Each of the 100 points along a point-line transect was expressed as a single pixel. Although the resultant "points" were 1 cm^2, they still provided an unbiased estimator of cover because an observation was always dichotomous; i.e., each pixel was always completely covered by a plant or not covered at all. Therefore, the point was no less dimensionless than the vegetation.

Treatment effects examined how average plant size, plant distribution, and disturbance mode influenced the ability of the point-line method to predict basal cover.

Two plant sizes, 8 and 12 cm in diameter with standard deviations of 2 and 3 cm, respectively, were simulated. These size distributions were based upon field measurements of shortgrass steppe vegetation from comparable locations because specific plant size data were unavailable from PCMS.[5] All plants were circular.

Three plant distributions were generated: Random, moderately contagious, and highly contagious. We created moderately and highly contagious distributions by defining random clusters (mean radius of 1 m, s = 0.5 m) within the simulated sampling space. Plants were given a 50% probability of being inside the cluster circles in the moderately clumped distributions; this probability increased to 95% for the high degree of clumping. The circles and distributions were devised following the algorithm shown in figure 1.

We used three modes of disturbance to create decreases in basal cover of the simulated populations. Disturbance was random when each plant had an equal chance of being eliminated. The second and third disturbance modes assumed that plants were being killed by the actions of a tracked vehicle, the M-1 main battle tank. Loaded M-1 tanks weigh about 55,000 kg and can cause substantial damage to grassland vegetation (Shaw and Diersing 1990). Each M-1 tank tread is 0.63 m wide, and the distance between the treads is 2.24 m. Tank "tread marks" were randomly overlaid on the sampling space until they "destroyed" sufficient plants to bring blue grama basal cover down to the desired treatment level. The probability that a plant was eliminated when passed over by a tank tread was 0.5 for the second disturbance mode and 1.0 for the third disturbance mode.

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[4] *The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.*

[5] *Unpublished data from School of Agribusiness and Environmental Resources, Arizona State University, Tempe. On file with second author.*

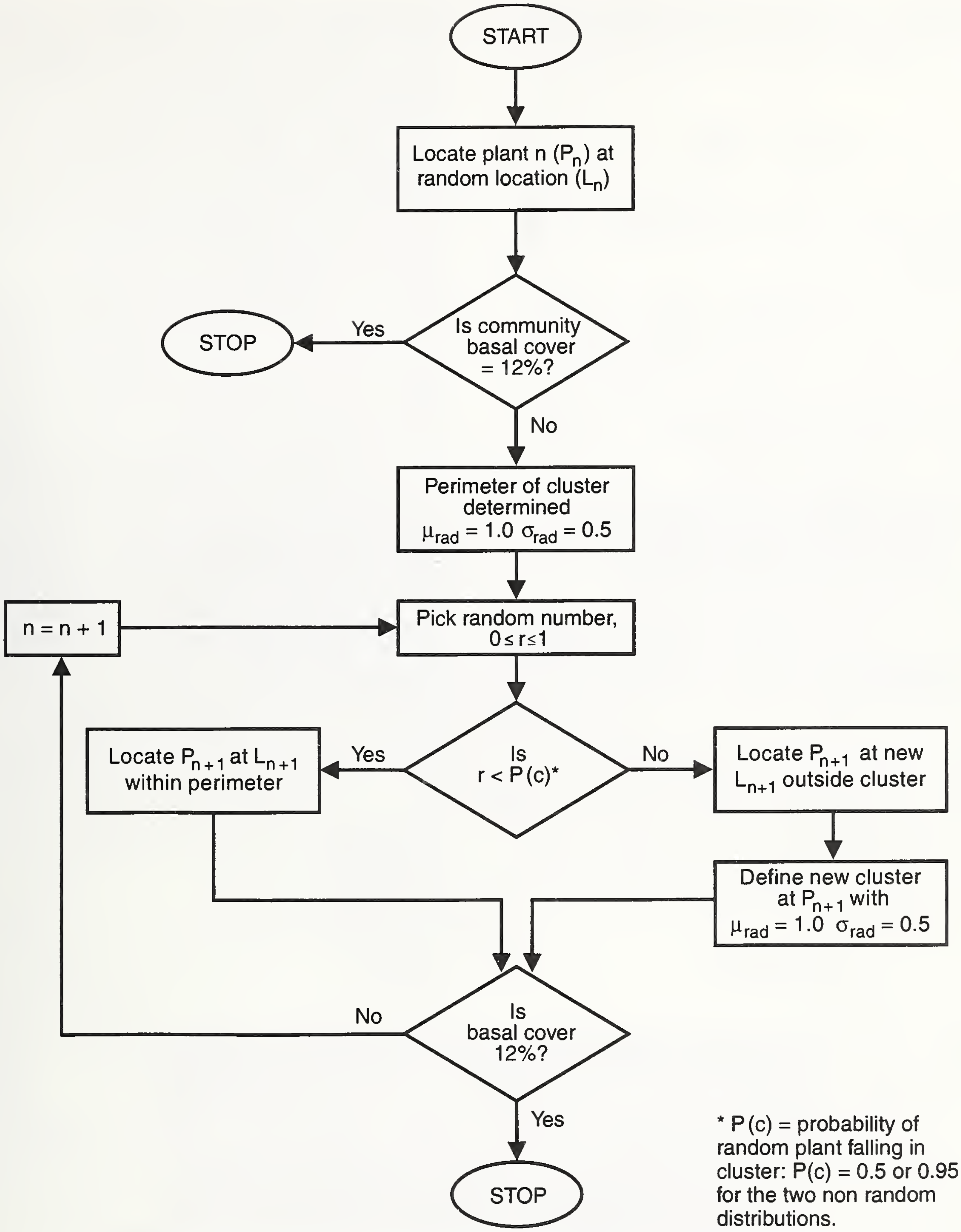

Figure 1.—Flow diagram of algorithm for locating plants in a simulated shortgrass steppe following a contagious distribution.

The algorithm for situating tread marks conformed to the following sequence: (1) A "tank" would enter the sampling space at a random point on its perimeter and in a random direction; (2) when the tread marks encountered a plant, the algorithm would ascertain whether the plant was eliminated from the population (P = 0.5, 1.0); (3) the tank would then move on in a straight line until it came upon another plant, exited the sampling space, or reached the desired reduction in basal cover; and (4) once a tank exited the sampling space, the process repeated itself until the reduced plant cover was attained.

Simulations followed the Monte Carlo method of approximating the solution to a problem by sampling repetitively from a random process (Springer et al. 1968). Each plant size, vegetation pattern, and disturbance mode combination of simulated shortgrass vegetation was sampled with 10,000 randomly located "permanent" LCTA line transects. Basal cover was estimated for each transect from the 100 evenly spaced points. Resampling and disturbance took place iteratively until reduced population basal covers of 10%, 8%, 6%, 4%, and 2% were reached.

We evaluated the robustness of the simulated point-line method by comparing its power to detect different cover changes across a range of sample sizes. Sample size was adjusted by combining from 1 to 10 transects. Grouping of transects assumed homogeneity within the sample space. Power, the probability of detecting an actual change in basal cover (1.0 - P [Type-II error]), was estimated from comparisons of areas under actual distribution curves resulting from the sampling-disturbance-resampling iterations (fig. 2). A more detailed discussion of power curves has been provided by Tanke and Bonham (1985).

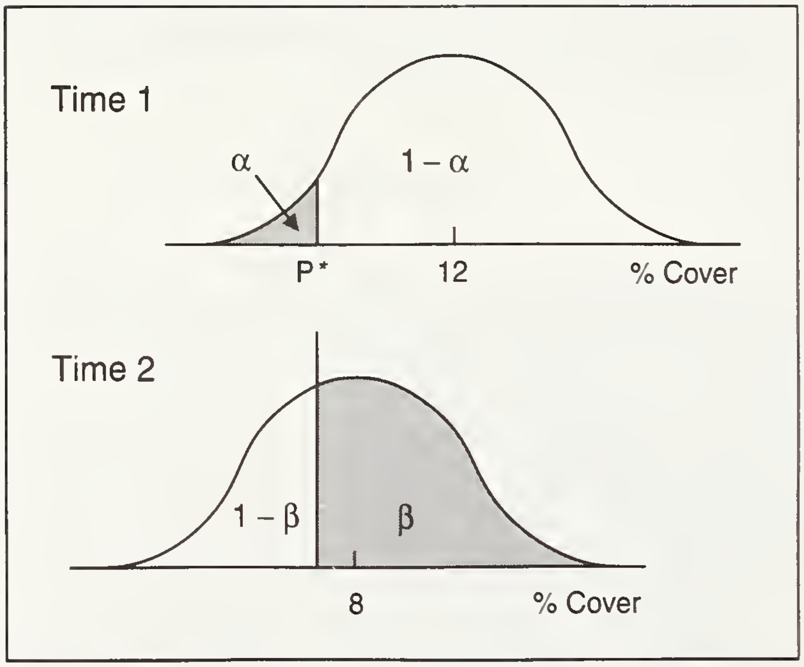

Figure 2.—Type-I and Type-II errors (2-tailed) portrayed for a hypothetical population where plant basal cover has decreased from 12% (time 1) to 8% (time 2). The area under the normal curve (1 - ß) corresponds to the sampling design's power.

The effects of plant size and disturbance mode on robustness of the point-line method was studied by observing a decrease in basal cover from 12% to 10% and 6%, respectively. As a comparison, the effect of population non-randomness was examined by observing basal cover decreases from 12% to 10% and 8%. If the null hypothesis of no treatment effects was to be accepted, the common reduction to 10% basal cover would result in similar power curves; moreover, the reduction to 8% cover would be intermediate to the two sets of curves testing reductions to 10% and 6%.

Type-I errors were set at approximately P = 0.05 for all power calculations. Error could not be set precisely at 0.05 because discrete populations were used.

Results and Discussion

The point-line method appeared to be robust with respect to both mean plant size and mode of disturbance throughout the treatment ranges. The probability of detecting a 2% decrease in basal cover of shortgrass steppe, from 12% to 10%, was $0.06 < P < 0.1$ when a single transect was used for all parameters of these two variables (fig. 3). With a sample size of 10 transects, the probability of detecting the same 2% decrease rose to only $0.34 < P < 0.43$. The small differences associated with treatment effects for plant size and disturbance mode had no statistical or apparent biological significance, regardless of the sample size.

When a larger change in basal cover (12% to 6%) was appraised, the lack of differences because of plant size and disturbance mode was even more obvious (fig. 3).

The lack of a confounding effect between plant size and estimates of basal cover is a result of the point spacing along the 100-m transect. As long as the point spacing is great enough for $P[n+1 \mid n] = P[n+1]$ where $P[n]$ and $P[n=1]$ refer to the probability of hitting vegetation on two adjacent points along the transect, no interaction should exist. In general, such independence occurs when point spacing is greater than average basal diameter of the plants (Fisser and Van Dyne 1966).

The degree of non-randomness in plant distribution, like plant size and disturbance pattern, had no discernible effect on the power of the point-line method to detect a decrease in basal cover (fig. 4). The scale of simulated plant community patterns was smaller than the 100-m point-line transect. If the pattern scale had been larger than the transect length, we would have expected a sensitivity of the sampling method to the degree of contagion because the transect could have been contained in homogeneous areas not representative of the entire population.

Figure 4 shows the power curves for two reductions, from 12% to 10% and 8%. The lower set of curves followed the same shape as for the comparable curves in figure 3, as expected, given the lack of a treatment response. Power curves displaying a reduction in cover from 12% to 8% were intermediate to those with reductions to 10% and 6%.

The three sets of power curves shown in figures 3 and 4 depicted a relatively constant variation of about ±6-10% basal cover, when comparing individual curves in each set, for any given sample size (number of transects). This variation approached zero when the power rating exceeded 0.9, and was also small at power ratings less than 0.1. The simulated sample means of basal cover had an accuracy of less than 0.5% ($P < 0.05$) because of the large number of iterations in the Monte Carlo method; thus, this range in prediction represents a random error in the power rating predictive model (Gelb 1974).

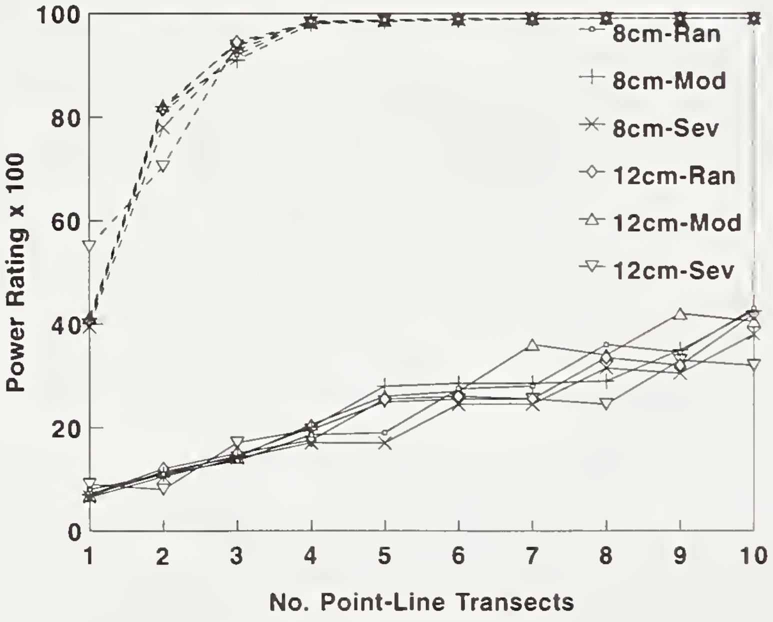

Figure 3.—Effect of plant size and disturbance pattern on power curves for a decrease in basal cover from 12% to 10% (solid lines) and 6% (dashed lines) of simulated shortgrass steppe. α ≈0.05 (the exact error could not be specified for a discrete population).

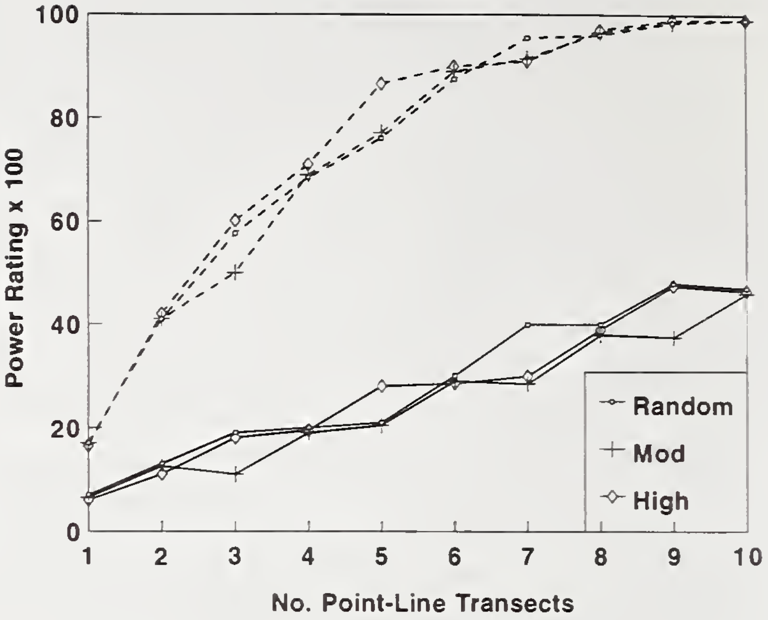

Figure 4.—Effect of three plant distributions on power curves for a decrease in basal cover from 12% to 10% (solid lines) and 8% (dashed lines) of simulated shortgrass steppe. α ≈0.05 (the exact error could not be specified for a discrete population).

The decrease in random error at the extremes is expected, given that the power of the test follows a logistic function (Tanke and Bonham 1985). As a result, all power curves closely parallel each other as the possibility of detecting a population change converges on 0% and 100%.

Conclusions

Power analysis can demonstrate to resource managers how well a monitoring system can detect a pre-established change in ecosystem state. For a monitoring design to be useful, however, it must be robust across an unknown number of ecosystem variables. The point-line method, regardless of other shortcomings, is a robust estimator of basal cover with respect to population distribution, average plant size, and the non-randomness of a disturbance.

Outside the limits of this particular sampling method, we conclude that a graphical modeling approach has excellent utility for evaluating the overall effectiveness of any vegetation inventory procedure. It allows an investigator the opportunity to set plant community parameters, compare sampling methods, and determine sample adequacy.

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