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Black Canyon of the Gunnison National Park and Curecanti National Recreation Area

Variance and Power-for-trend Assessment of 2008-2010 Pilot Data

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Abstract

Power analysis provides an a priori understanding of the ability and confidence to estimate the condition (i.e., status) of a resource and detect trends in that resource over time. This report describes the power analysis conducted by the Northern Colorado Plateau Network to identify an "affordable" sample size that optimizes tradeoffs between trend and status estimation and overall operational reality for its integrated upland monitoring protocol at Black Canyon of the Gunnison National Park (NP) and Curecanti National Recreation Area (NRA). Fifty-one plots were monitored at Black Canyon NP and Curecanti NRA for three consecutive years. Key response measurements for (1) detecting shifts in vegetation and (2) understanding the susceptibility of soil to wind and water erosion were used in this analysis. For each key response in sagebrush, pinyon-juniper, and oak vegetation types, we estimated the variance using linear mixed-effects models. We also examined power and precision of standard error of status for four alternative revisit designs and five sample sizes, as well as for the ability to detect different amounts of annual trend. The recommended revisit design for Black Canyon NP and Curecanti NRA samples sagebrush, pinyon-juniper, and oak plots for one or two years in a row and rests plots for 3-4 years. A total of 42 plots are sampled each year, with a different numbers of plots sampled in the priority vegetation types. Graphs of power for trend are presented in Appendix A.

1 Introduction

The Northern Colorado Plateau Inventory and Monitoring Network (NCPN) implemented upland monitoring at Black Canyon of the Gunnison National Park (BLCA) and Curecanti National Recreation Area (CURE) during the 2008 field season. Although the NCPN usually creates separate monitoring designs for each park unit, we decided to use a single monitoring design for BLCA and CURE since they are adjacent, are managed jointly, and have similar upland vegetation. Upland monitoring was initiated as a three-year pilot study to estimate the variance for responses used to monitor vital signs. The power analysis described in this report used variance from the pilot study to evaluate the appropriateness of proposed split-panel revisit designs for detecting a trend and estimating the precision (or standard error) of status for long-term monitoring.

Power analysis provides an *a priori* understanding of the ability and confidence with which one can estimate the condition (i.e., status) of an extensive and variable resource and detect trends in that resource over time (Gerrodette 1987). Statistical power is the ability to detect an effect, given that the effect actually exists (i.e., the probability of *not* making a Type-II error of failing to detect a real trend). This report describes the power analysis conducted by the NCPN to identify an 'affordable' sample size that optimizes tradeoffs between trend and status estimation and overall operational reality by allocating the sample size into alternative revisit designs and determining the maximum number of vegetation types that this sample can be divided.

2 Survey design

2.1 Sampling frame

Survey designs use explicitly mapped areas as the sampling frame. Ecological sites provide an effective way to stratify upland ecosystems by taking into consideration soil geomorphology, landform, and climate, in addition to vegetation characteristics. However, ecological sites for all target monitoring areas in BLCA and CURE have not been developed, and a recent soil survey was not available for the entire extent of the park units. Therefore, ecological sites were used whenever possible and a more general "vegetation type" stratification was used when appropriate ecological sites were not available.

A sampling frame was created using the vegetation map to predict the location of target ecological sites and vegetation types. Changes were made to specific polygons based on field assessments. The sampling frame delineated accessible sagebrush, pinyon-juniper (PJ), oak scrub (oak), and aspen vegetation types in BLCA and CURE (Figures 2-1 and 2-2; Table 2-1). For sagebrush and pinyon-juniper, two target ecological sites were included in the vegetation type but were not mapped separately. Sagebrush was additionally divided into grazed and ungrazed areas.

2.2 Site Selection

A membership design specifies how sites in a survey design are chosen across space (McDonald 2003). For BLCA and CURE, Reversed Randomized Quadrat-Recursive Raster (RRQRR) (Theobald et al. 2007) was used to select spatially-balanced random samples stratified by each target vegetation type. In probability-based surveys, such as RRQRR, the site-selection process allows unbiased estimation of both status and, with repeated visits, trend (Larsen et al. 1995).

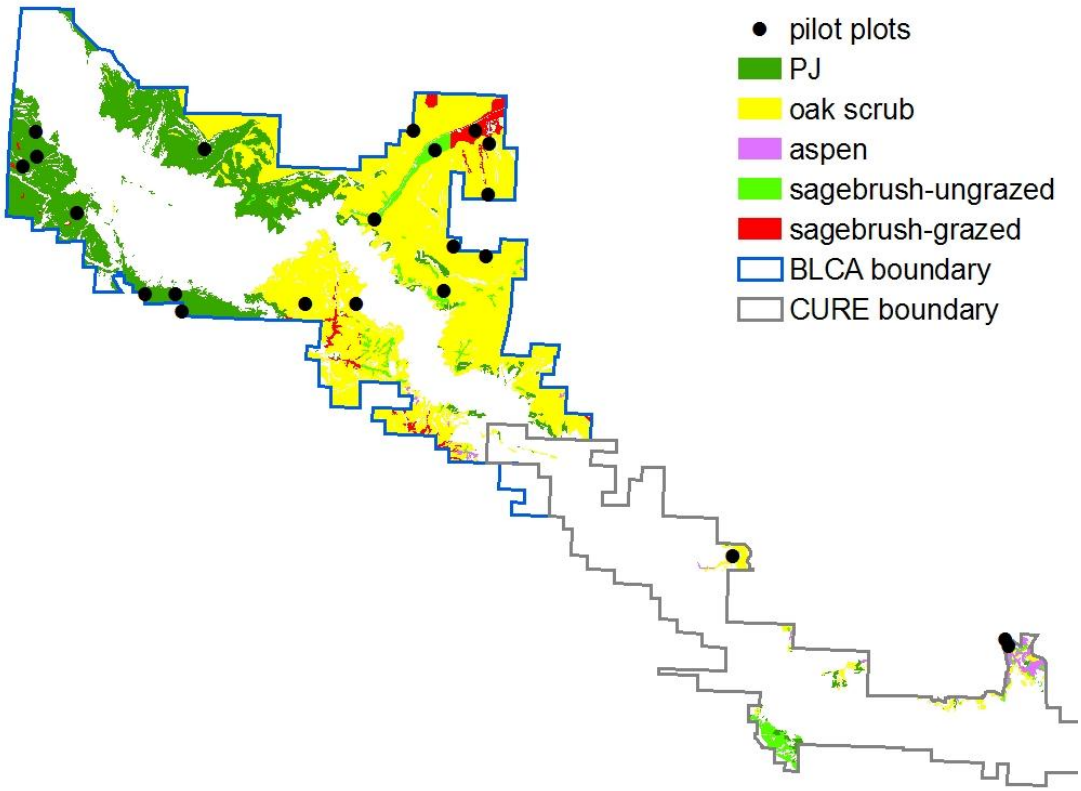

Figure 2-1. Location of vegetation types and pilot monitoring plots in the sampling frame for Black Canyon of the Gunnison NP and the west side of Curecanti NRA.

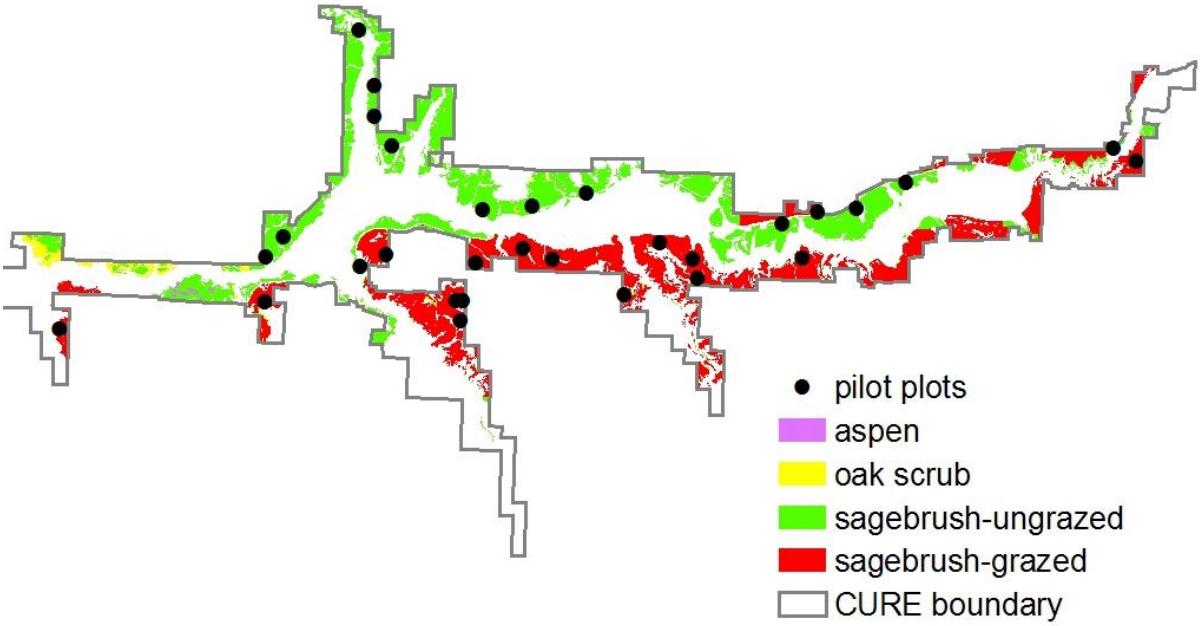

Figure 2-2. Location of vegetation types and pilot monitoring plots in the sampling frame for the east side of Curecanti NRA.

Table 2-1. Vegetation types and ecological sites in Black Canyon of the Gunnison NP and Curecanti NRA pilot upland monitoring.

Vegetation type	Ecological site	Additional strata	Total area* (ha)	
			BLCA	CURE
Sagebrush	Dry Mountain Loam	Grazed	195	2061
	Mountain Loam			
	Dry Mountain Loam	Ungrazed	205	2407
	Mountain Loam			
Pinyon-juniper	Upland Shallow Loam (Pinyon - Utah juniper)		2260	0
	Upland Stony Loam (Pinyon - Utah juniper)			
Oak	Brushy Loam		4425	0
Aspen	none		0	122

*Total accessible area of each vegetation type.

2.3 Pilot study

Using the ordered lists of points produced by RRQRR, fifty-two plots were established in four vegetation types for BLCA and CURE pilot monitoring: 32 sagebrush, 8 PJ, 8 oak, and 4 aspen plots. Sagebrush was further stratified by grazing and ecosite so that there were 8 grazed Dry Mountain Loam, 8 ungrazed Dry Mountain Loam, 8 grazed Mountain Loam, and 8 ungrazed Mountain Loam plots. Thirty-seven plots (31 sagebrush, 1 PJ, 4 oak, and 1 aspen) were established in 2008, and sampled for 3 consecutive years. The remaining 15 plots were established in 2009, and sampled for 2 consecutive years. Plots were sampled between July and September each year. A broad sampling window was used to capture potential variation during the growing season. In addition, field-crew members visited different plots each year, when possible, to include the maximum amount of variation between observers. Plots were sampled according to the Integrated Upland Monitoring Protocol for Park Units in the Northern Colorado Plateau Network (Witwicki et al. draft).

The 4 aspen plots were not included in this variance assessment and power analysis since the area of aspen in the park is very small, and this vegetation type will be monitored using the 4 plots established in 2008 and 2009. In addition, only 7 ungrazed Mountain Loam sagebrush plots, instead of the 8 original plots, are included in this report. One of the plots established in 2008 was partially underwater at the edge of the Blue Mesa Reservoir when revisited in 2009. Due the unpredictable riparian influence on this plot, rebar was removed in 2010, and it will not be included in the long-term data set.

Although 3 years of pilot data from 47 plots is a limited data set, it provides a starting point for creating a defensible long-term sampling design. Variance and power-for-trend assessments will be performed every 5-7 years in order to analyze the operational sampling design, ensure that monitoring goals are being met, and make changes to the design as needed.

2.4 Response variables

Response variables examined in this analysis were those with potentially important thresholds in the target vegetation types. Although threshold values have not been defined for the ecological sites used in this survey design, it is well understood, through conceptual models, that biological soil crusts (BSCs) are a critical component of many sagebrush systems, responsible for holding the soil in place and preventing erosion by wind or water. In addition, the cover of major plant functional groups can in many cases define ecological states.

Important response measurements for detecting shifts in vegetation include percent cover of (1) trees, (2) shrubs, and (3) perennial grasses. Shrub and perennial grass cover were analyzed for all 3 vegetation types, while tree cover was only considered important for pinyon-juniper. Key response measurements for understanding the susceptibility of soil to wind and water erosion include (4) basal gap size, (5) canopy gap size, and (6) soil stability. All three of these measures were analyzed for sagebrush and soil stability was included for pinyon-juniper. Percent cover of BSCs and bare soil are also important measures, but they were not used in this analysis due to changes in data collection methods after the 2008 field season that made the first year of data not comparable to the other two years.

2.5 Linear models and variance components

Using the six response variables described above, we developed linear models to estimate variance following Larsen et al. (1995, 2001) and Urquhart and Kincaid (1999). Residual plots, histograms, and normal QQ (quantile quantile) plots were reviewed for each response to determine the need for data transformation. Natural-log transformation was used to improve model assumptions of normality and constant variance for all responses. Variance components in the model are shown in Table 2-2.

Analyses were performed in SAS 9.2 using Proc Mixed models. Year and site covariates were treated as random effects (Urquhart et al. 1998). To account for our unbalanced design (e.g., different numbers of revisit years for some plots), the restricted maximum likelihood (REML) approach was used to estimate variance and the Kenward-Roger method was used to calculate degrees of freedom (Spilke et al. 2005).

Because the sample size was relatively small, data from all sagebrush sites were combined for this analysis (Table 2-3). This should provide a conservative estimate of power and standard error of status since we would expect variance within each ecological site to be smaller than the variance for all sagebrush plots combined. For the two responses that had a year variance of 0 (see Table 2-3), year variance was substituted from other similar measures in order to give a more realistic estimate. It is more likely that SAS produced a year variance of 0 due to the unbalanced design and low sample size than actually having a year variance of 0. Thus, it is more conservative to use year variance from a similar response than to use the 0 generated by SAS. The year variance for canopy gaps was substituted for the 0 year variance for basal gaps, and the year variance for sagebrush shrub cover was substituted for the 0 year variance for oak shrub cover. Variances were also examined after data were detrended, however, this altered the variances little and increased the number of responses with year variances of 0. Therefore, the original model was used to estimate variance.

Annual precipitation data from the CURE Coop weather station were examined to see if estimated variances from the 2008-2010 pilot study needed to be further inflated to be comparable with historic variability in annual precipitation. Variance of annual precipitation was calculated for (1) the three years of the pilot study (2008-2010), and (2) the history of the weather station (1968-2010). Although variance of yearly precipitation for the history of the

weather stations was 2.4 times higher than the variance from 2008-2010, no additional corrections to variances were made; however, this was considered in selecting a revisit design.

Table 2-2. Variance components used in power analysis.

Component	Description
σ^2_{Site}	Variation among sites that is consistent across years (e.g., variation in vegetation cover or soil stability due to soil component)
σ^2_{Year}	Variation among years that affects all sites in the population (e.g., region-wide climatic variation)
$\sigma^2_{Residual}$	Variation specific to a site during a particular year, including measurement error (e.g., erosion occurs at a single site due to heavy cattle trampling of BSCs).

2.6 Affordable sample size

The NCPN has determined that the affordable annual sample size for upland monitoring is 36-48 plots per park for all large parks in the network (BLCA and CURE, Canyonlands National Park, Capitol Reef National Park, Dinosaur National Monument, and Zion National Park), 18-24 plots per park for medium-size parks (Arch and Bryce Canyon national parks) and 3-8 plots for our smaller parks (Cedar Breaks and Timpanogos national monuments). This is based on an estimate of six field-crew members monitoring uplands full-time for 13 pay periods.

We estimated that the total annual sample size for BLCA and CURE is approximately 42 plots, since there is more travel time needed to monitor these park units due to both distance from the NCPN office in Moab, UT and distance between areas of the park units. We used an affordable sampling size of 12 plots per year per vegetation type for the purpose of evaluating alternative split panel designs (see Figure 3-1). One of the designs was used to evaluate the effect of using different sample sizes (see Figure 3-2).

Table 2-3. Site, year, and residual variance estimates for responses in sagebrush, pinyon-juniper, and oak pilot plots at Black Canyon of the Gunnison NP and Curecanti NRA.

		Variance		
Vegetation type	**Response**	**site**	**year**	**residual**
Sagebrush	Shrub cover	0.06763	0.01785	0.00928
	Perennial grass cover	0.30170	0.02956	0.04245
	Basal gap	0.09770	0	0.02129
	Canopy gap	0.04458	0.00016	0.01074
	Soil stability	0.01721	0.05561	0.02065
Pinyon-juniper	Tree cover	0.22230	0.00318	0.02218
	Shrub cover	0.46410	0.00605	0.02393
	Perennial grass cover	0.64960	0.00371	0.06772
	Soil stability	0.02645	0.00189	0.01190

Oak	Shrub cover	0.01543	0	0.00618
	Perennial grass cover	0.09847	0.03056	0.09633

3 Panel Designs

A serious concern of sampling semiarid upland vegetation and soils is that sites may become fatigued if sampled too often. The most likely scenario of site fatigue at BLCA and CURE is increased soil loss caused by repeated trampling of BSCs in sagebrush monitoring plots. Our goal is to disturb plots as little as possible and to avoid monitoring the effects of our presence at plots as much as possible. As such, designs that revisit the same sites each year were not considered at semiarid sites for upland monitoring. Instead, we investigated split-panel designs that rest plots for 3 to 7 years between revisits.

In order to understand year-to-year variation of shrub and perennial grass cover, we needed a design that sampled some sites two years in a row. A preliminary analysis determined that split-panel designs, like those in Figure 3-1, provided better precision of status and higher power to detect trend in early years by allocating more plots to panels that were visited for only 1 consecutive year (e.g., panels 6 through 10 in Design 1) than to panels where plots were visited for two consecutive years (e.g., panels 1 through 5 in Design 1). Therefore, all four designs analyzed in this power analysis are structured in this way. Design 1 was used to examine the effect of different sample sizes (Figure 3-2) and annual trends.

As per MacDonald (2003), the numerical notation of a panel design indicates the number of consecutive years of sampling followed by the number of consecutive years of rest for plots in each type of panel. For example, Design 1, notated as (2-3),(1-4), calls for 2 consecutive years of sampling followed by 3 consecutive years of rest for plots in panels 1–5, and 1 year of sampling followed by 4 years of rest for plots in panels 6–10.

Design 1 (2-3),(1-4) 45 unique plots, 12 plots per vegetation type per year

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	3	3				3	3			
2		3	3				3	3		
3			3	3				3	3	
4				3	3				3	3
5	3				3	3				3
6	6					6				
7		6					6			
8			6					6		
9				6					6	
10					6					6

Design 2 (2-5),(1-6) 63 unique plots, 12 plots per vegetation type per year

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	3	3						3	3	
2		3	3						3	3
3			3	3						3
4				3	3					
5					3	3				
6						3	3			
7	3						3	3		
8	6							6		
9		6							6	
10			6							6
11				6						
12					6					
13						6				
14							6			

Design 3 (2-7),(1-8) 81 unique plots, 12 plots per vegetation type per year

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	3	3								3
2		3	3							
3			3	3						
4				3	3					
5					3	3				
6						3	3			
7							3	3		
8								3	3	
9	3								3	3
10	6									6
11		6								
12			6							
13				6						
14					6					
15						6				
16							6			
17								6		
18									6	

Design 4 (2-7),(1-2) 45 unique plots, 12 plots per vegetation type per year

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	3	3								3
2		3	3							
3			3	3						
4				3	3					
5					3	3				
6						3	3			
7							3	3		
8								3	3	
9	3								3	3
10	6			6			6			6
11		6			6			6		
12			6			6			6	

Figure 3-1. Split-panel designs tested in power analysis.

Design 1a (2-3),(1-4) 30 unique plots, 8 plots per vegetation type per year

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	2	2				2	2			
2		2	2				2	2		
3			2	2				2	2	
4				2	2				2	2
5	2				2	2				2
6	4					4				
7		4					4			
8			4					4		
9				4					4	
10					4					4

Design 1b (2-3),(1-4) 45 unique plots, 12 plots per vegetation type per year

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	3	3				3	3			
2		3	3				3	3		
3			3	3				3	3	
4				3	3				3	3
5	3				3	3				3
6	6					6				
7		6					6			
8			6					6		
9				6					6	
10					6					6

Design 1c (2-3),(1-4) 70 unique plots, 18 plots per vegetation type per year

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	4	4				4	4			
2		4	4				4	4		
3			4	4				4	4	
4				4	4				4	4
5	4				4	4				4
6	10					10				
7		10					10			
8			10					10		
9				10					10	
10					10					10

Design 1d (2-3),(1-4) 90 unique plots, 24 plots per vegetation type per year

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	6	6				6	6			
2		6	6				6	6		
3			6	6				6	6	
4				6	6				6	6
5	6				6	6				6
6	12					12				
7		12					12			
8			12					12		
9				12					12	
10					12					12

Figure 3-2. Variations of Design 1 used to analyze sample sizes of 8, 12, 18, 24, and 32 plots per vegetation type per year.

Design 1e (2-3),(1-4) 120 unique plots, 32 plots per vegetation type per year

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	8	8				8	8			
2		8	8				8	8		
3			8	8				8	8	
4				8	8				8	8
5	8				8	8				8
6	16					16				
7		16					16			
8			16					16		
9				16					16	
10					16					16

Figure 3-2. Cont.'d

4 Analysis

4.1 Minimum Detectable Difference

The minimum detectable difference (MDD) is the annual rate of change in trend that a design can detect. For log-transformed responses, such as those described here, this equates to a proportional change or annual percent increase or decrease. A 5% annual decrease equates to a 39% total decrease over 10 years, or a decrease in shrub cover from 44.4% in 2008 to 27.1% in 2018. The annual rate is equivalent to the slope of the regression line in a linear model.

The minimum detectable difference for a trend should be ecologically relevant and can be determined using thresholds of ecological sites, if known. Because no threshold values have been determined for target ecological sites in BLCA or CURE, we attempted to determine ecologically meaningful annual increases or decreases for each response variable based on the pilot plot means and extremes, change over a 10-year period, and professional judgment (Table 4-1). Cover of vegetation types required at least 5% change per year for meaningful ecological changes to occur. Changes in all other soil-related variables were meaningful at a 2-5% annual rate of change.

Table 4-1. Summary of proposed minimum detectable differences (MDD) for each response in each vegetation type.

Vegetation type	Response	MDD (annual trend)	Mean (min – max)		Possible range
			Current status*	After 10 years**	
Sagebrush	Shrub cover	5-10% decrease	27.3% (11.3-52.0%)	16.7% (6.9-31.7%)	0-100%
	Perennial grass cover	5-10% decrease	18.7% (4.0-61.0%)	11.4% (2.4-37.2%)	0-100%
	Basal gap size	2-5% increase	90 cm (43-235 cm)	110 cm (52-287 cm)	0-5000 cm
	Canopy gap size	2-5% increase	59 cm (36-101 cm)	72 cm (44-123 cm)	0-5000 cm
	Soil stability	2-5% decrease	2.4 (1.0-5.1)	2.0 (1.0-4.2)	1-6
Pinyon-juniper	Tree cover	5-10% decrease	22.5% (5.7-39.0%)	13.7% (3.5-23.8%)	0-100%
	Shrub cover	5-10% decrease	3.8% (0.3-10.0%)	2.3% (0-6.1%)	0-100%
	Perennial grass cover	5-10% decrease	1.9% (0-8.0%)	1.2% (0-4.9%)	0-100%
	Soil stability	2-5% decrease	3.6 (1.7-4.7)	3.0 (1.4-3.9)	1-6
Oak	Shrub cover	5-10% decrease	44.4% (33.3-59.6%)	27.1% (20.3-36.4%)	0-100%
	Perennial grass cover	5-10% decrease	22.3% (7.9-41.7%)	13.6% (4.8-25.4%)	0-100%

*Status for first 3 years of data (2008-2010)
**Calculation uses lowest value for each row in the MDD (annual trend) column

4.2 Estimating power for trend and precision of status

Power to detect a specified trend and precision of status were estimated using an unpublished function written by Tom Kincaid (US EPA, Corvallis, Oregon) for R. This function uses MDD, variance components, desired Type 1 error (alpha), the selected panel design, and two additional correlation values (site.rho = 1; year.rho = 0) set to these default values based on Urquhart et al. (1993). We set alpha = 0.10 and examined power for trend and standard error of status over a 20-year time frame. We used a less conservative alpha because we do not want to risk missing trends that may be important to park managers.

4.3 Effect of panel design

In Designs 1-4 (Figure 3-1), each response in each vegetation type was compared using an annual sample size of 12 and the appropriate MDD (Figures A1, A2, and A3 in Appendix A). All four split-panel designs performed similarly for all vegetation cover and soil stability responses. The only responses where power for trend varied by design were basal and canopy gaps, which had very low year variance. For these responses, Design 1 had 80% power to detect a trend 3 years earlier than Design 3. Design 2 and 4 were intermediate of Designs 1 and 3, with Design 4 providing more power in early sampling years.

4.4 Effect of sampling size

Sample sizes of 8, 12, 18, 24, and 32 plots per year were compared for each response using Design 1 (see Figure 3-2) and the appropriate MDD. For most responses, all five sample sizes performed similarly and adding plots did not improve power for trend or standard error of status (Figures A4, A5, and A6 in Appendix A). One of the few differences was a slightly lower power for trend in sample sizes of 8 for basal and canopy gaps in sagebrush, perennial grass cover and soil stability in pinyon-juniper, and perennial grass cover in oak. Standard error of status was also slightly higher for shrub and perennial grass cover in pinyon-juniper with sample sizes of 8 and 12.

4.5 Effect of annual trend

A range of annual trends (2%, 5%, 10%, and 20%) was compared for each response using Design 1 and an annual sample size of 12 (Figures A7, A8, and A9 in Appendix A). Varying MDD did not affect the standard error of status, so these results are not presented. For most responses, 80% power was reached in 5 years for a 10% annual change, in 10 years for 5% annual change, and in 20 years for a 2% annual change. The exceptions were soil stability in sagebrush plots and perennial grass cover in oak plots, which lagged behind by a few years.

4.6 Effect of response type

The variance of each response type, especially year variance, had the strongest influence on power for trend and standard error of status. For all responses except soil stability at sagebrush plots, the low estimate of MDD could be detected within 10 years at 80% power.

4.7 Discussion

The differences between the split-panel designs tested were relatively minor, which was not surprising, given the similarity between the designs. Where year variance was less than 0.01, Design 4 had the highest power for trend in years 3 and 4 and Design 1 had the highest power for trend in years 5, 6, and 7. Both designs performed similarly in subsequent years. Either of these designs would be appropriate for upland monitoring at BLCA and CURE.

A more unexpected result was the similarity between the different annual sample sizes analyzed, ranging from 8 to 32. We expect to gain power for trend and decrease standard error of status by increasing annual sample size, however, variance of each response, especially year variance, seemed to have an overriding influence for most sample sizes. In around half of the responses, a sample size of 8 had slightly lower power for trend or higher standard error of status (or both) compared to the larger sample sizes. A couple of the responses showed a similar improvement by increasing the sample size from 12 to 18. For all responses, a sample size greater than 18 did not substantially improve power for trend or standard error of status.

Precipitation during the pilot study was less variable than for the historic record at the Curecanti Coop weather station. This means that we may see more variability in vegetation cover over long-term monitoring than we detected in this pilot study, and that we should consider a more conservative revisit design to maximize our ability to detect trends with even more variable precipitation in future monitoring years.

Biological soil crust and bare soil cover were not included in this analysis due to differences in measurement techniques between 2008 and the subsequent years. The high amount of variance produced in this situation is not conducive to detecting long-term change. Methods of estimating bare soil and crust cover were clarified after the first year of pilot sampling, and we are optimistic that these changes will result in greater repeatability between observers and decrease variance.

High variance in the responses can also be caused by sampling at different times of the year. NCPN minimizes seasonal variability in plant phenology between sampling dates by sampling parks units at approximately the same time each year. BLCA and CURE uplands will be sampled between mid-August and mid-September each year for long-term operational monitoring. This is a smaller window than we used for the pilot study, and this should help reduce year variance and improve the power to detect trends.

We feel that the (2-3),(1-4) design (Design 1 in Figure 3-1) is the best option for sampling uplands at BLCA and CURE, and this design has been implemented in other NCPN park units for upland monitoring. This design ensures the best power for trend after year 4 and has a similar standard error of status to other designs.

When we are able to expand these analyses to include simulations and numerous additional years of data, we may see meaningful changes and need to alter the revisit design. While we do not expect this to happen, a key advantage of a RRQRR design is the ability to recast the panel membership of existing plots into new structures.

5 Proposed revisit design

The proposed revisit design for integrated upland monitoring at BLCA and CURE is based on Design 1 (see Figure 3-1), but modified to accommodate monitoring goals of the different vegetation types (Figure 5-1).

Twelve plots will be monitored each year in both oak and pinyon-juniper, following the original sample size and structure of Design 1.

A total of 4 aspen plots will be monitored in CURE. The NCPN recommends monitoring one of these plots every year so that we can account for annual variation in climate in this vegetation type. All four plots will be monitored for 2 years in a row and then 3 of these plots will be rested for 3 years.

Fourteen or 17 plots will be monitored each year in sagebrush to allow for the 4 aspen plots to be monitored in some years (Figure 5-1). The larger sample size of sagebrush plots should also allow for comparisons between grazed and ungrazed areas of the park units in future analyses, which is a high priority of park managers.

Plots will be accepted from anywhere within the sampling frame for the vegetation type, unlike the pilot analysis, where an even number of plots were included for sagebrush from each of the two target ecological sites and grazed and ungrazed areas. This will give us a different number of plots in each ecological site and in grazed and ungrazed areas, but these numbers should represent the area of each ecological site and grazing use across the landscape. The main reason that the NCPN would like to set up the sampling design this way is that sagebrush ecological sites seemed to be more of a continuum than two distinct groups. In addition, grazing allotments in the park units may change over time, and some areas do not have fencelines separating grazed and ungrazed areas. When soil and ecological site information are updated for BLCA and CURE, this information can be incorporated in more in-depth analyses.

The overall proposed design calls for the following:

- Sampling 42 upland monitoring plots per year using a rotating split-panel design.
- Establishing 153 plots over a five-year period.
- Allowing 3-4 years of rest at all sagebrush, pinyon-juniper, and oak plots to minimize the effects of repeated visits.
- Preferentially placing plots used in the three-year pilot study (2008-2010) in panels 4 and 10 for sagebrush, pinyon-juniper, and oak, to allow the maximum amount of rest after the initial three years of monitoring.

Park managers will be given an outline of the design and an opportunity to provide feedback in July 2011. Full operational monitoring of uplands in BLCA and CURE will begin in August 2011.

a) Sagebrush (2-3),(1-4) 59 unique plots, 14 or 17 plots per year

Panel↓/Year→	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	4	4				4	4			
2		4	4				4	4		
3			4	4				4	4	
4				4	4				4	4
5	4				4	4				4
6	9					9				
7		9					9			
8			9					9		
9				6					6	
10					6					6

b) Aspen (1-0),(2-3) 4 unique plots, 1 or 4 plots per year

Panel↓/Year→	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1	1	1	1	1	1	1	1	1	1
2				3	3				3	3

c) Pinyon-juniper & **Oak** (2-3),(1-4) 45 unique plots per vegetation type,
12 plots per year per vegetation type

Panel↓/Year→	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	***10***
1	3	3				3	3			
2		3	3				3	3		
3			3	3				3	3	
4				3	3				3	*3*
5	3				3	3				*3*
6	6					6				
7		6					6			
8			6					6		
9				6					6	
10					6					*6*

Figure 5-1. Proposed revisit design for upland monitoring of each vegetation type at Black Canyon of the Gunnison NP and Curecanti NRA.

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Appendix A
Power for Trend Figures

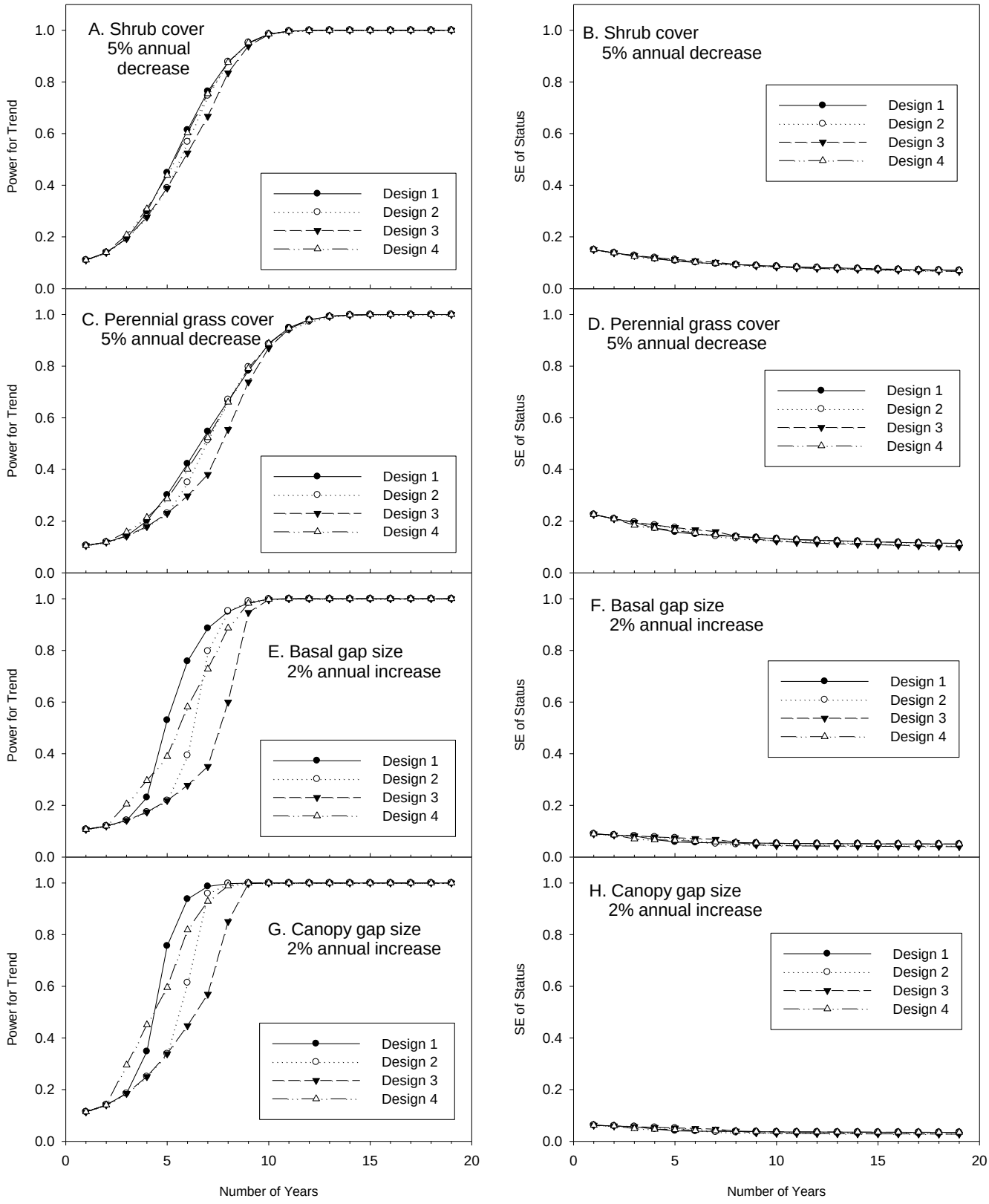

Figure A1. Power for trend and standard error (SE) of status for each sampling design (Figure 3-1) at all sagebrush sites (annual sample size = 12). Responses include percent cover of shrubs and perennial grass, basal and canopy gap size, and soil stability.

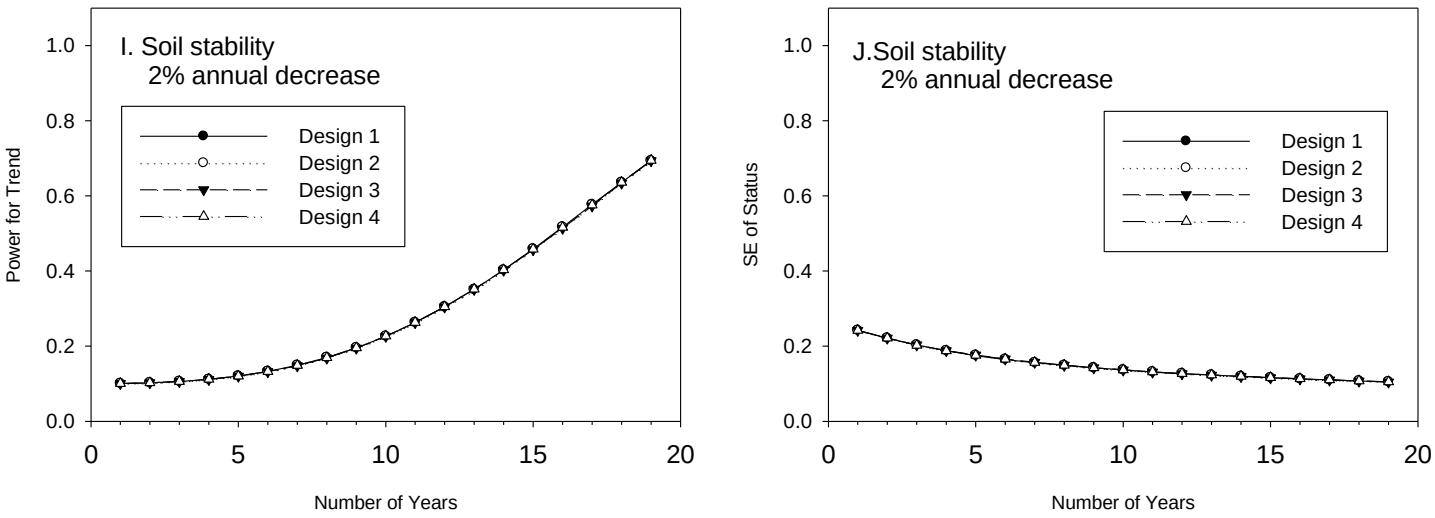

Figure A1. cont'd.

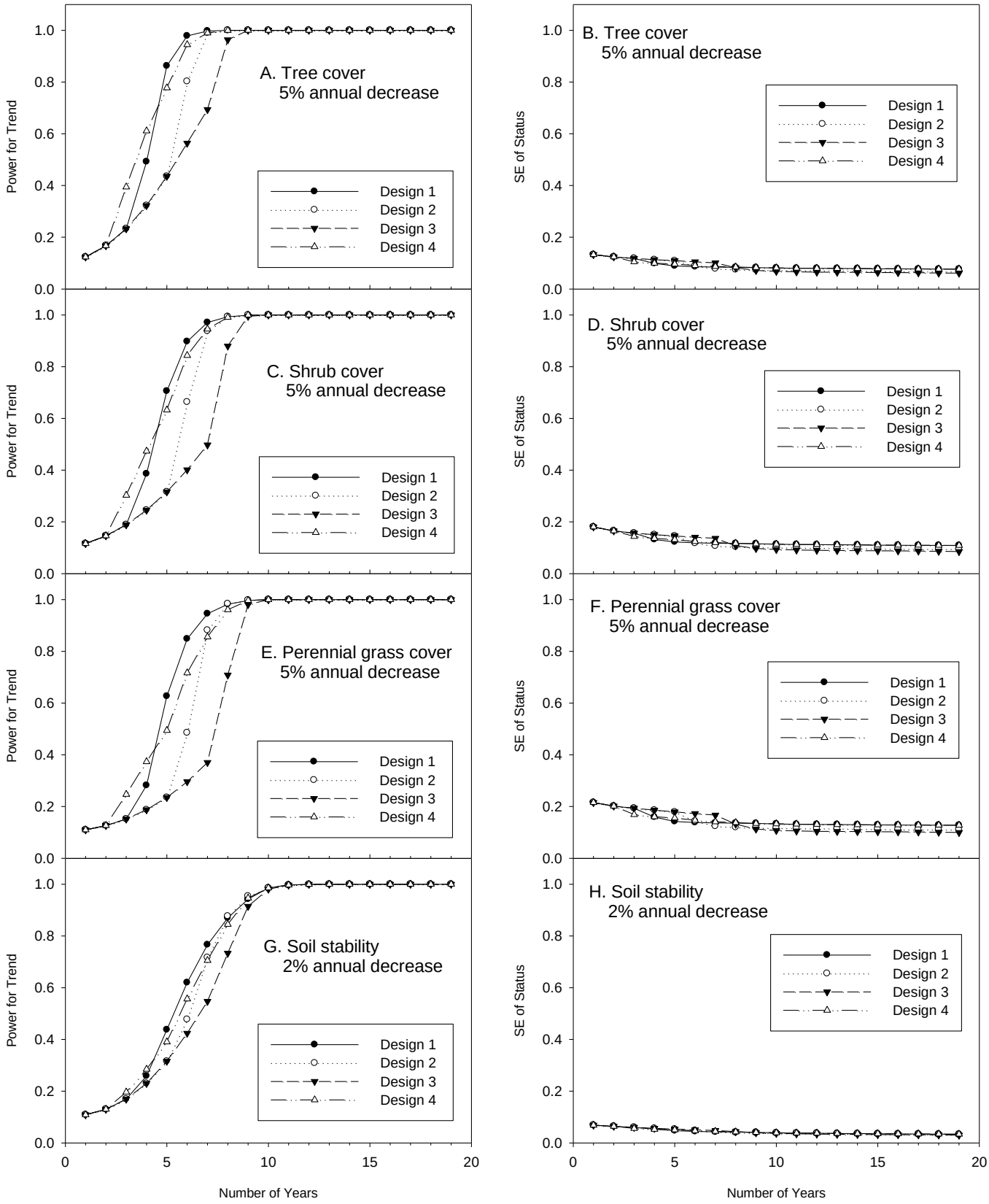

Figure A2. Power for trend and standard error of status for each sampling design (Figure 3-1) at all pinyon-juniper sites (annual sample size = 12). Responses include percent cover of trees, shrubs, and perennial grass, and soil stability.

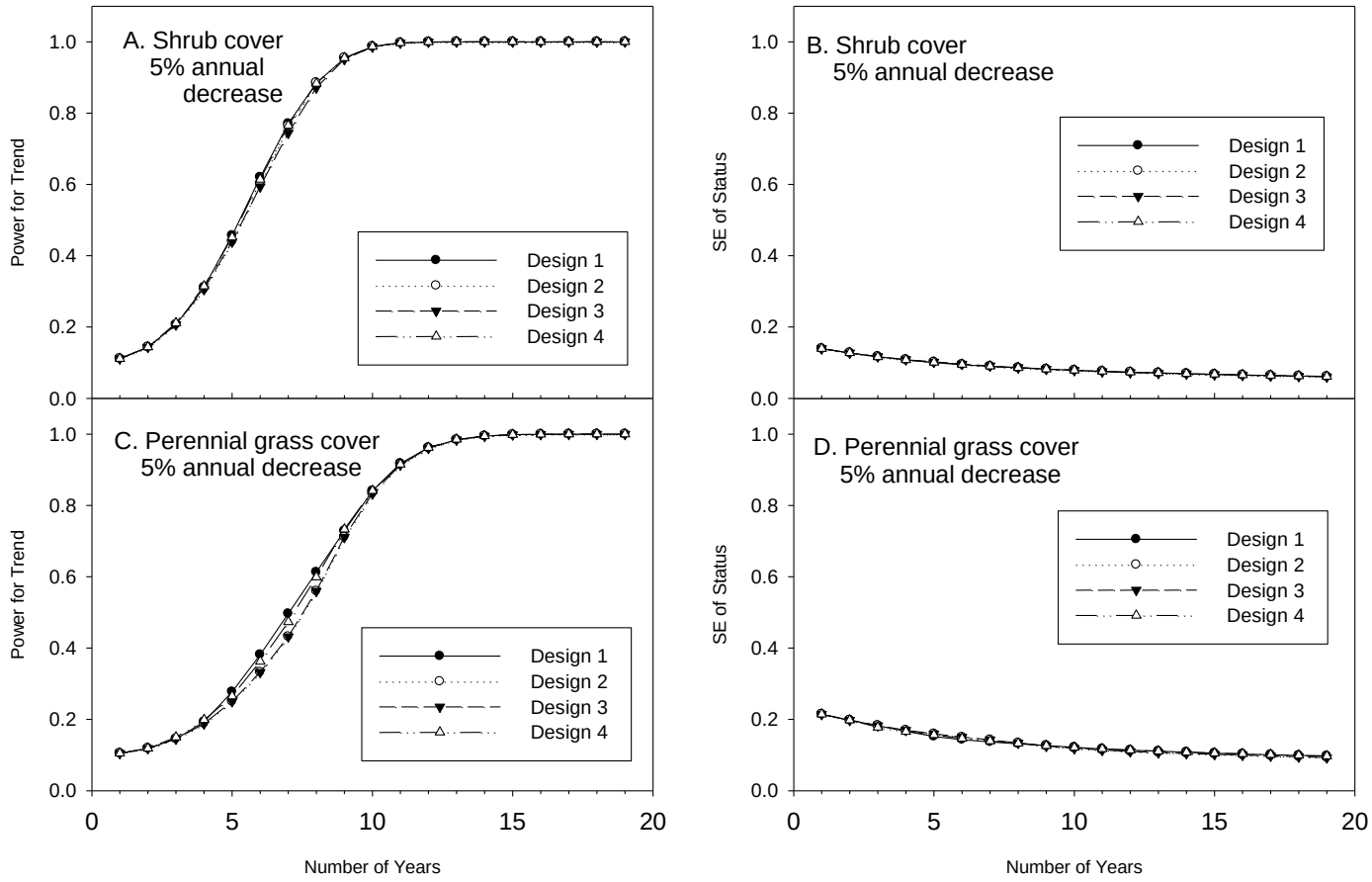

Figure A3. Power for trend and standard error of status for each sampling design (Figure 3-1) at all oak sites (annual sample size = 12). Responses include percent cover of shrubs and perennial grass.

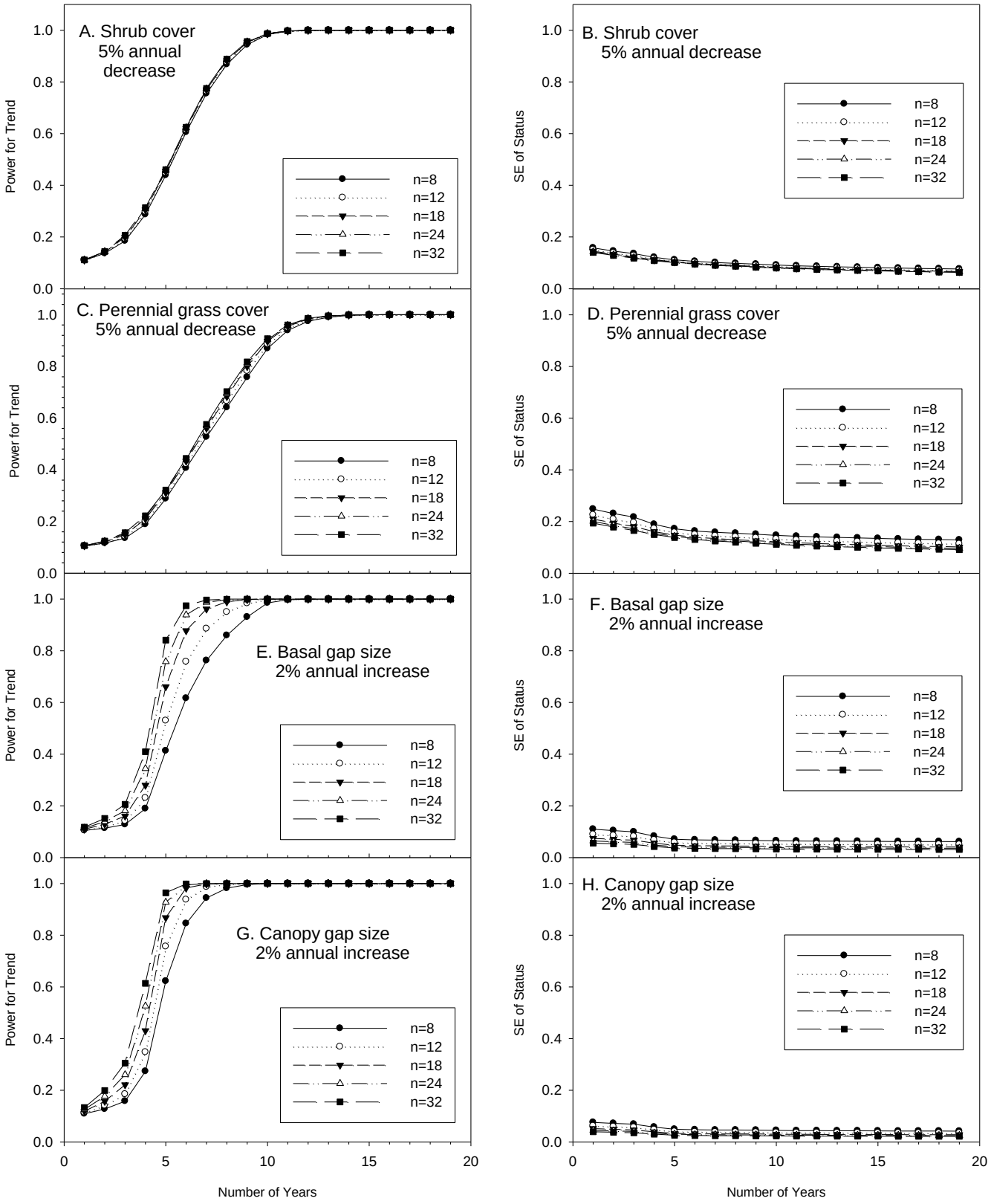

Figure A4. Power for trend and standard error of status for each response variable at all sagebrush sites comparing annual sample sizes of 8, 12, 18, 24, and 32 plots per year using Design 1 (Figure 3-2). Responses include percent cover of shrubs and perennial grass, basal and canopy gap size, and soil stability.

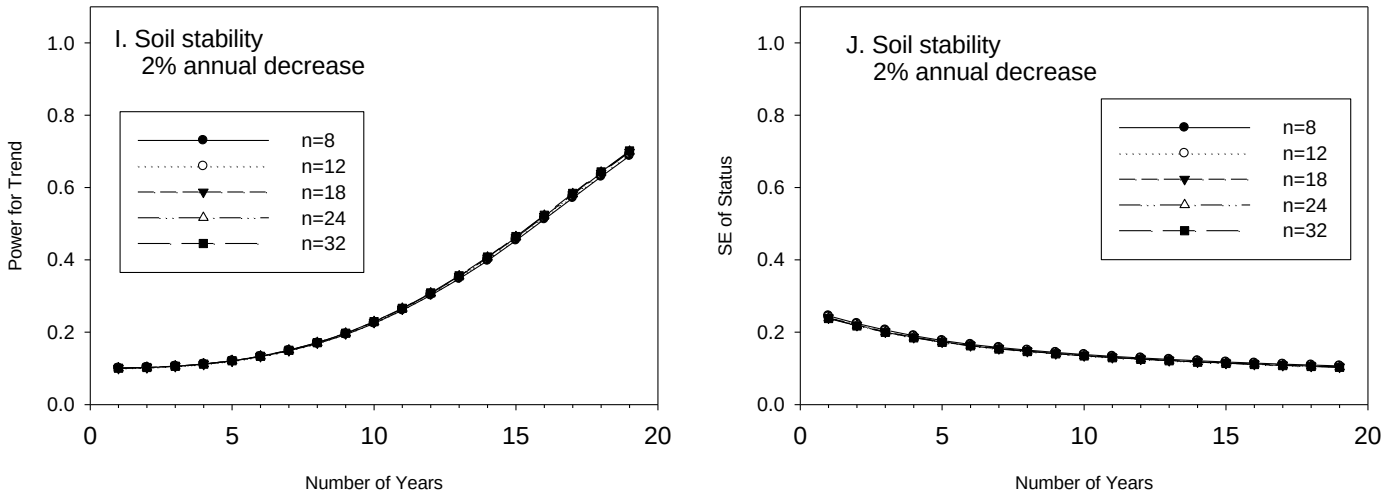

Figure A4. cont'd.

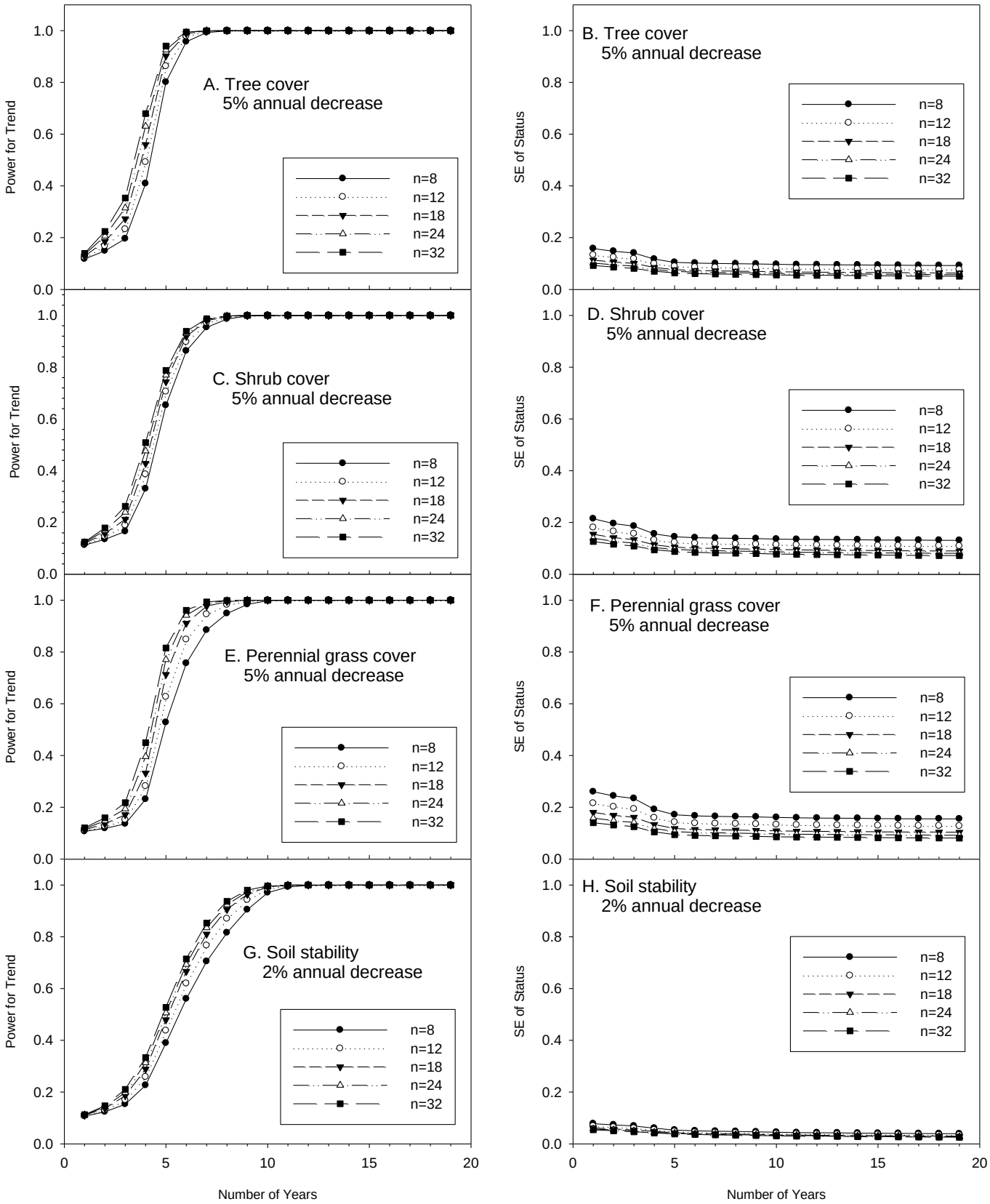

Figure A5. Power for trend and standard error of status for each response variable at all pinyon-juniper sites comparing annual sample sizes of 8, 12, 18, 24, and 32 plots per year using Design 1 (Figure 3-2). Responses include percent cover of trees, shrubs, and perennial grass, and soil stability.

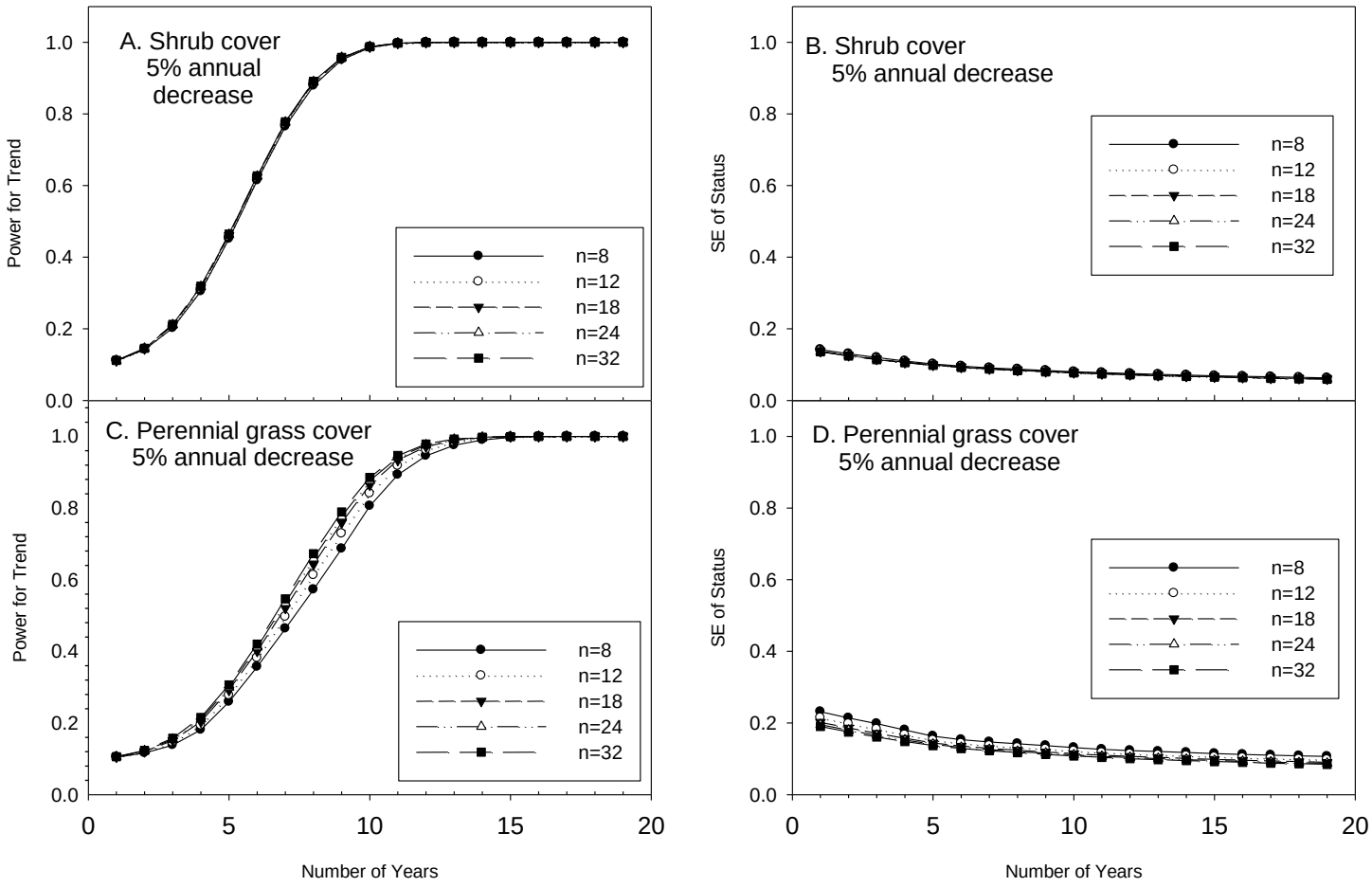

Figure A6. Power for trend and standard error of status for each response variable at all oak sites comparing annual sample sizes of 8, 12, 18, 24, and 32 plots per year using Design 1 (Figure 3-2). Responses include percent cover of shrubs and perennial grass.

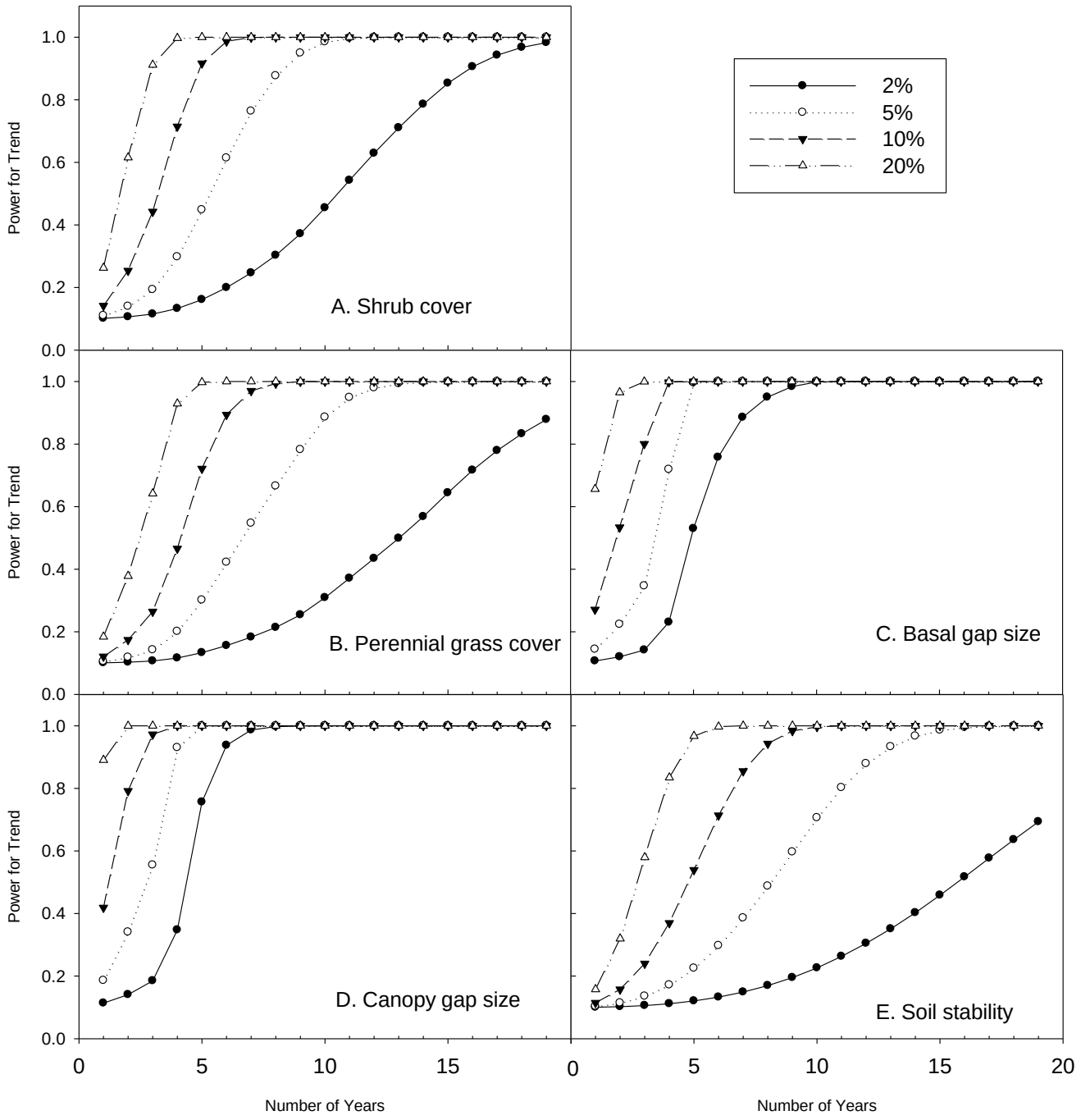

Figure A7. Power for trend for a range of annual increases or decreases in response variables at sagebrush sites using Design 1 (Figure 3-1) and an annual sample size of 12. Responses include percent cover of shrubs and perennial grass, basal and canopy gap size, and soil stability.

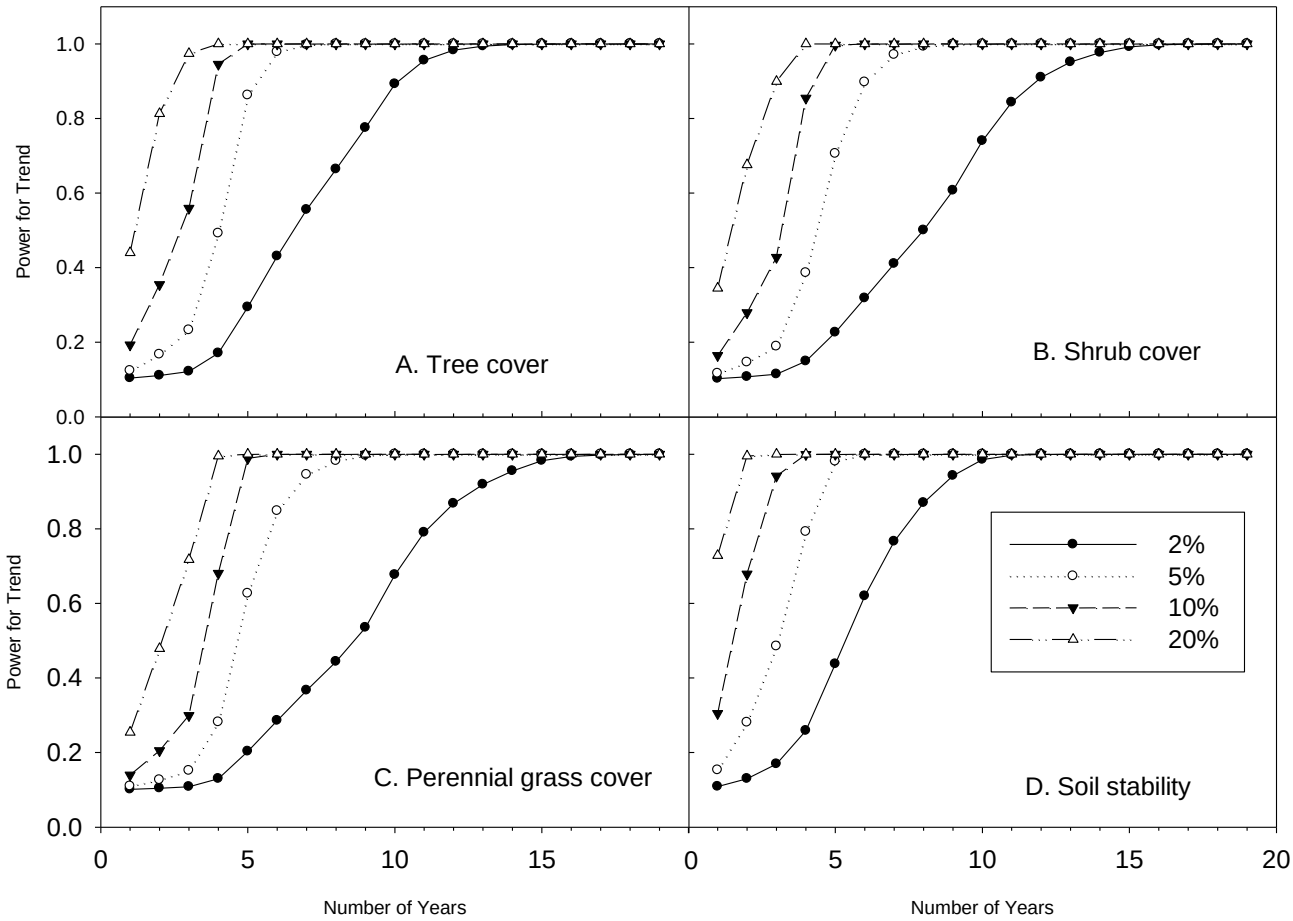

Figure A8. Power for trend for a range of annual decreases in response variables at pinyon-juniper sites using Design 1 (Figure 3-1) and an annual sample size of 12. Responses include percent cover of trees, shrubs, and perennial grass, and soil stability.

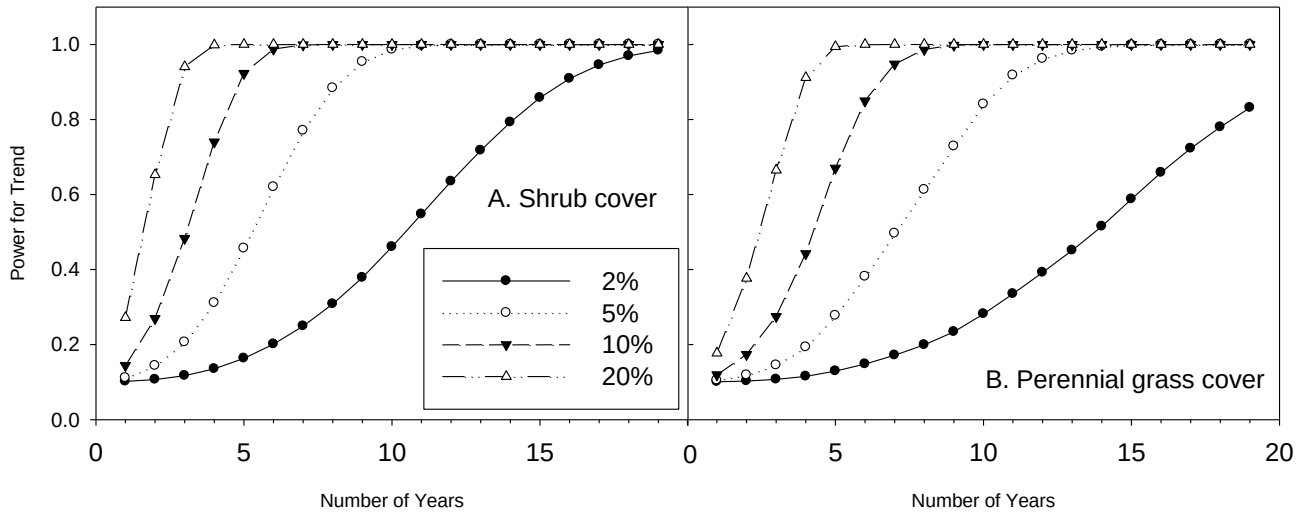

Figure A9. Power for trend for a range of annual decreases in response variables at oak sites using Design 1 (Figure 3-1) and an annual sample size of 12. Responses include percent cover of shrubs and perennial grass.