INTEGRATED TRAINING AREA MANAGEMENT
ITAM Learning Module
LCTA Scenario

Power Analysis: Estimating Minimum Detectable Change

Recommended Reading

ITAM Technical Reference Manual:
 Chapter 3: *Introduction to Sampling*
 Chapter 8: *Structured Query Language (SQL)*
 Chapter 11: *Data Analysis and Interpretation*

Anderson, A.B., Guertin, P., and Price, D. *Land Condition Trend Analysis Data: Power Analysis*. USACERL Technical Report 97/05 October 1996.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. *Measuring and Monitoring Plant Populations*. BLM Technical Reference 1730-1, USDI Bureau of Land Management, National Applied Resource Sciences Center, Denver, CO.

Background

Commonly during statistical analysis of data a test of significance is performed. Testing a null hypothesis (Ho) against an alternative hypothesis (Ha) does this. The null hypothesis for many monitoring programs is that no change has occurred. The alternative hypothesis is that a change has occurred.

An appropriate analysis of LCTA data is a paired plot comparison (t-test) between 2 years of data. The null hypothesis is that no change has occurred between the two years. The alternative hypothesis states that a change has occurred. If the null hypothesis is rejected then one can state that a change has occurred. However, two types of errors are associated with any statistical test, Type-I and Type-II errors. A Type-I error (α) is the probability of rejecting the null hypothesis when it is true. This is also called a false-change error. If a false-change error is made, a resource manager may implement remedial actions that are not required. A Type-II error (β), or missed-change error, is the probability of failing to reject the null hypothesis when it is false. In the case of a missed-change error actions may be delayed causing more expensive or less effective actions in the future.

Statistical power ($1-\beta$) is the probability that a test will reject the null hypothesis at a given level (α) when it is false. For monitoring programs, this is the probability that a change will be detected when a change has really occurred. If a monitoring program has a low power and a change has not been detected, one cannot conclude that a change has or has not occurred.

In this scenario the *a posteriori*, or *post hoc*, power analysis is reviewed for LCTA data. Here we will determine minimum detectable change (MDC) for some common variables, which can indicate if the monitoring program is sufficiently fulfilling management objectives.

Problem Statement

Is the current LCTA monitoring program at Fort USA meeting management objectives? That is to say, is the monitoring program strong enough to detect critical changes? The three variables of interest for this question are military disturbance, bare ground, and canopy cover.

Acquire data

Any data available in the LCTA database that are used in paired comparisons can be tested. Here we are only interested in three variables, listed above. The mean disturbance, bare ground, and canopy cover for each plot from 1997 and 1999 were extracted from the database and placed in a spreadsheet. The same plots were measured in both years. First, the MDC is determined for each of the three variables for the installation as a whole. Then we will look at data for open woodland plots only.

Perform Procedures

The first step for each group of data (disturbance, bare ground, and canopy cover) is to determine the absolute difference between measurements (delta) for each of the plots. The means from 1997 for each of the 110 plots were compared to the means of 1999 data. The table below shows a partial table containing the changes for disturbance. Notice we are using absolute change. The Excel function ABS() is used here.

Plotid	Mean 1997	Mean 1999	Delta
1	0	0	0
2	2	3	1
3	27	39	12
4	27	4	23
5	27	7	20
6	37	62	25
7	42	38	4
8	0	66	66
…	…	…	…

The next step is to calculate the variance of the differences between measurements. The Excel variance function, VAR(), was used on the column of differences (delta) in the table above.

Two remaining values are needed for calculating the MDC, the student t values for both α and β. These can be found in a Student's t distribution table or the Microsoft TINV() function can be used. Here we have decided to use relatively conservative Type-I and Type-II error rates of 0.1 (α=β=0.1). We will use the Student t value for a two-tailed test for α and a one-tailed test for β. Infinity is used as the degrees of freedom. The TINV() function in Excel returns the Student t value from a two-tailed distribution. The following function was used to return the value for α.

=TINV(0.1, 10000000)

where

10000000 represents infinity

Because the TINV function returns the Student t value from a two-tailed distribution, we must multiply the probability by two to return the value for a one-tailed distribution. Thus, the following function was used for β.

=TINV(0.2, 10000000)

The following equation was used to estimate the MDC (*a posteriori*):

$$\Delta = \sqrt{\frac{(t_a + t_b)^2 S^2}{n}}$$

where

- Δ = detectable change
- n = sample size (110)
- α = Type-I error level
- β = Type-II error level
- t_α = Student t value associated with α
- t_β = Student t value associated with β
- S^2 = variance of the differences between measurements

The values for each factor of the MDC equation, as well as the absolute and relative MDC, are shown below for the disturbance data. The relative MDC is calculated by dividing the absolute MDC by the mean of the first year (1997) and multiplying by 100. Absolute detectable change is the absolute change that can be detected regardless of the abundance of the variable being measured. In other words, an absolute change of 5.12 is detectable regardless of the mean. The relative detectable change implies that the change size will depend on the mean value of the variable. Here, a change of 37.05 is detectable when the mean is 13.81 and 20.48 when the mean is 25. Relative minimum detectable change is the more common format found in literature.

MDC values and factors for disturbance

variance of the differences	336.751043
t (alpha) two-tailed 0.1	1.644853
t (beta) one-tailed 0.1	1.28155079
n	110
mean of 1997 data	13.82
Absolute MDC	5.12026435
Relative MDC	37.0545446

The results of the MDC calculations are shown below for bare ground and canopy cover.

MDC values and factors for bare ground

Variance of the differences	164.0997498
t (alpha) two-tailed 0.1	1.644853
t (beta) one-tailed 0.1	1.281550794
n	110
mean of 1997 data	21.74
absolute MDC	3.574307136
relative MDC	16.44390569

MDC values and factors for canopy cover

variance of the differences	214.6529608
t (alpha) two-tailed 0.1	1.644853
t (beta) one-tailed 0.1	1.281550794
n	110
mean of 1997 data	64.95
absolute MDC	4.087957296
relative MDC	6.293566166

The calculations above were done for the entire installation, which included 110 plots. Next we would like to examine the MDC for just one vegetation type found on Fort USA. For this, the 30 plots that are found in open woodlands were used. The mean canopy cover for each of the 30 plots from 1997 and 1999 were extracted from the database. Again, the MDC was calculated, shown below.

MDC values and factors for canopy cover
(open woodlands)

variance of the differences	31.63678161
t (alpha) two-tailed 0.1	1.644853
t (beta) one-tailed 0.1	1.281550794
n	30
mean of 1997 data	85.07
absolute MDC	3.005175034
relative MDC	3.532729272

From a management point of view, the MDC presented above is probably more meaningful than the previous ones. Often it is more desirable to analyze the data based on vegetation type, training area, or other grouping rather than the installation as a whole. The same procedure can be done based on any valid grouping. The means for each plot found in the group for two years of data is all that is required.

Conclusions

Of the first three variables examined (disturbance, bare ground, and canopy cover) canopy cover had the lowest relative MDC of 6.29. The second lowest relative MDC was found for bare ground. To assess the strength or weakness of the monitoring design, the biological significance level must be determined for each variable. Biological or ecological significance is based on management considerations of the installation. When evaluating a study design the MDC should be compared to the biological significance to see if management objectives are met by the study. If the MDC is larger than the detectable change that would be considered biologically significant, the design is considered weak. Weak study designs fail to detect small, but biologically significant, changes in the resource. A strong study design will have a MDC smaller then the biologically significant detectable change size. Here, biologically significant changes should be detected. An understanding of the system biology and the economic and implementation constraints associated with a survey should be considered when determining the desired detectable change.

If detecting a change in canopy cover is a goal of the LCTA program at Fort USA we should closely examine the MDC for this data. We found the relative MDC for canopy cover on the installation as a whole to be 6.29 given 110 plots with a mean of 64.95 during 1997. We will detect a change if the mean for 1999 is 69.04, or a change of 4.09 (absolute MDC). If we conclude that the relative MDC of 6.29 is higher than the biological significant change size we must lower the MDC. This can be done by;

1. Reducing standard deviation (altering the sampling design)
2. Increasing the number of plots
3. Increasing the acceptable level of false-change errors (α)

4. Increasing the MDC

The first two of these are related to changing the sampling design while the remaining two are related to making changes in the monitoring objectives.

How many plots do we need to detect a change of four percent? The equation below will estimate the sample size for a given absolute change.

$$n = \frac{(t_a + t_b)^2 S^2}{\Delta^2}$$

where

Δ = detectable change
n = sample size
α = Type-I error level
β = Type-II error level
t_α = Student t value associated with α
t_β = Student t value associated with β
S^2 = variance of the differences between measurements

Note that this equation uses absolute MDC. If our desired relative MDC is four percent and our first year's mean is 64.95, we have a desired absolute MDC of (.04 * 64.95) = 2.60. Using the equation above we find that approximately 273 plots are needed. Obviously time and funding constraints may limit the addition of plots.

Recall that our last example examined canopy cover for only those plots found in open woodlands. The relative MDC for these plots was 3.53 with a sample size of 30 and a mean of 85 percent canopy cover for 1997. We find that the relative MDC for this sample is less than our desired detectable change (four percent) from above. Here we conclude that our ability to detect a change in canopy cover on open woodland plots rather that the installation as a whole, will meet our requirements and is fairly strong.

References

Anderson, A.B., Guertin, P., and Price, D. *Land Condition Trend Analysis Data: Power Analysis*. USACERL Technical Report 97/05 October 1996.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. *Measuring and Monitoring Plant Populations*. BLM Technical Reference 1730-1, USDI Bureau of Land Management, National Applied Resource Sciences Center, Denver, CO.