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Adaptive Management for Invasive Annual Grasses

A Step-By-Step User's Guide

AREA-WIDE

EBIPM

SCIENCE-BASED SOLUTIONS
FOR INVASIVE ANNUAL GRASSES

Adaptive Management for Invasive Annual Grasses

A Step-By-Step User's Guide for Implementing EBIPM

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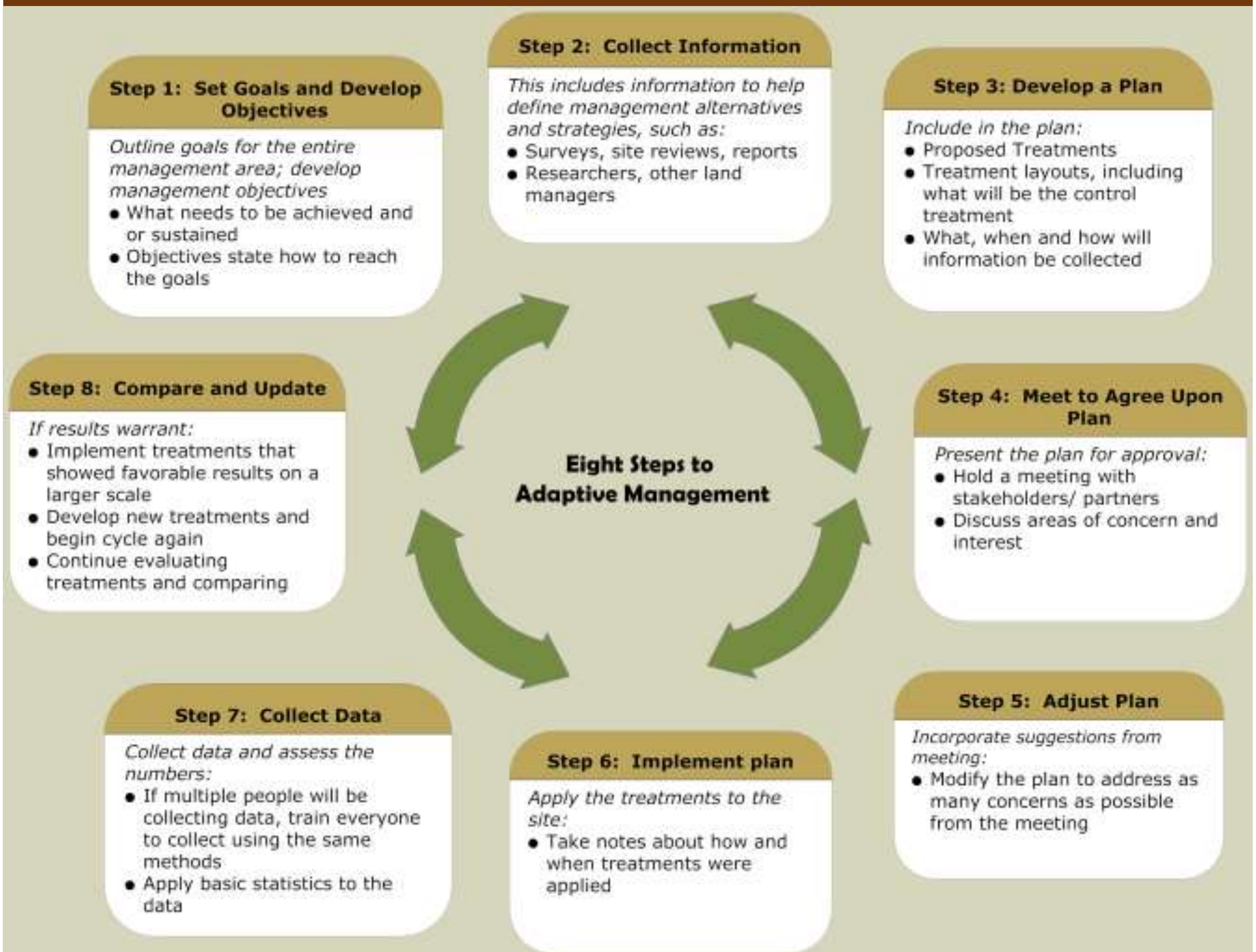
Eight Steps To Adaptive Management



Contents

Benefits of Adopting Adaptive Management:

Managers have been seeking solutions to invasion of western rangelands by annual grasses for decades. But annual grasses continue to invade and destroy once productive rangeland at an alarming rate. It is becoming increasingly clear that effective land management is complicated and no one treatment or technique works across all areas. In many situations, an effective solution for annual grass infestations has not been developed or only partially developed.

The magnitude and complexity of invasive annual grasses calls for land managers to implement thoughtful programs based on the most up to date science combined with practical experience. Managers need a framework to implement good ideas for managing annual grasses in a way to determine how well the ideas actually worked. This bulletin provides a concise step-by-step method for testing current practices, comparing management strategies to develop locally applicable "Best Management Practices (BMP's)" while encouraging continued management improvements over time.

Implementing adaptive management can directly benefit you and your land resources by:

- Increasing the ability to document and support management decisions to ensure they have the highest chance for protecting and conserving our natural resource base for future generations.
- Empowering managers to proceed with management, instead of waiting for solutions to be developed.
- Gaining information on specific areas being managed and knowing if strategies will 'work' for your site.
- Continually building on the knowledge about how to manage specific sites for invasive annual grasses.
- Having management techniques supported with credible data that could be valuable if management choices are challenged in court.
- Promoting the most efficient use of funds.

Adaptive Management at the Circle Bar Ranch in Mitchell, Oregon has reduced invasive annual grass infestation and increased growth of desirable species.

What is Adaptive Management

Managers frequently think of better ways to meet their land objectives and periodically try new strategies to improve their success. In many cases, the vegetation response to new strategies is not known prior to implementation. Even after implementation, it may be difficult for managers to know if the new strategies are better than the old ones or if some strategy that seems a little risky is the best. Adaptive management is a "learn by doing" approach. The learning occurs by using actual management to test different alternatives.

What sets adaptive management apart from a traditional management or monitoring program is that alternatives are planned and conducted as an experiment. These alternatives are tested and compared using the scientific process to determine which practices work best. Managers are then able to test, compare and gain knowledge on ideas for managing annual grasses on a landscape scale.

How to Use this Guide

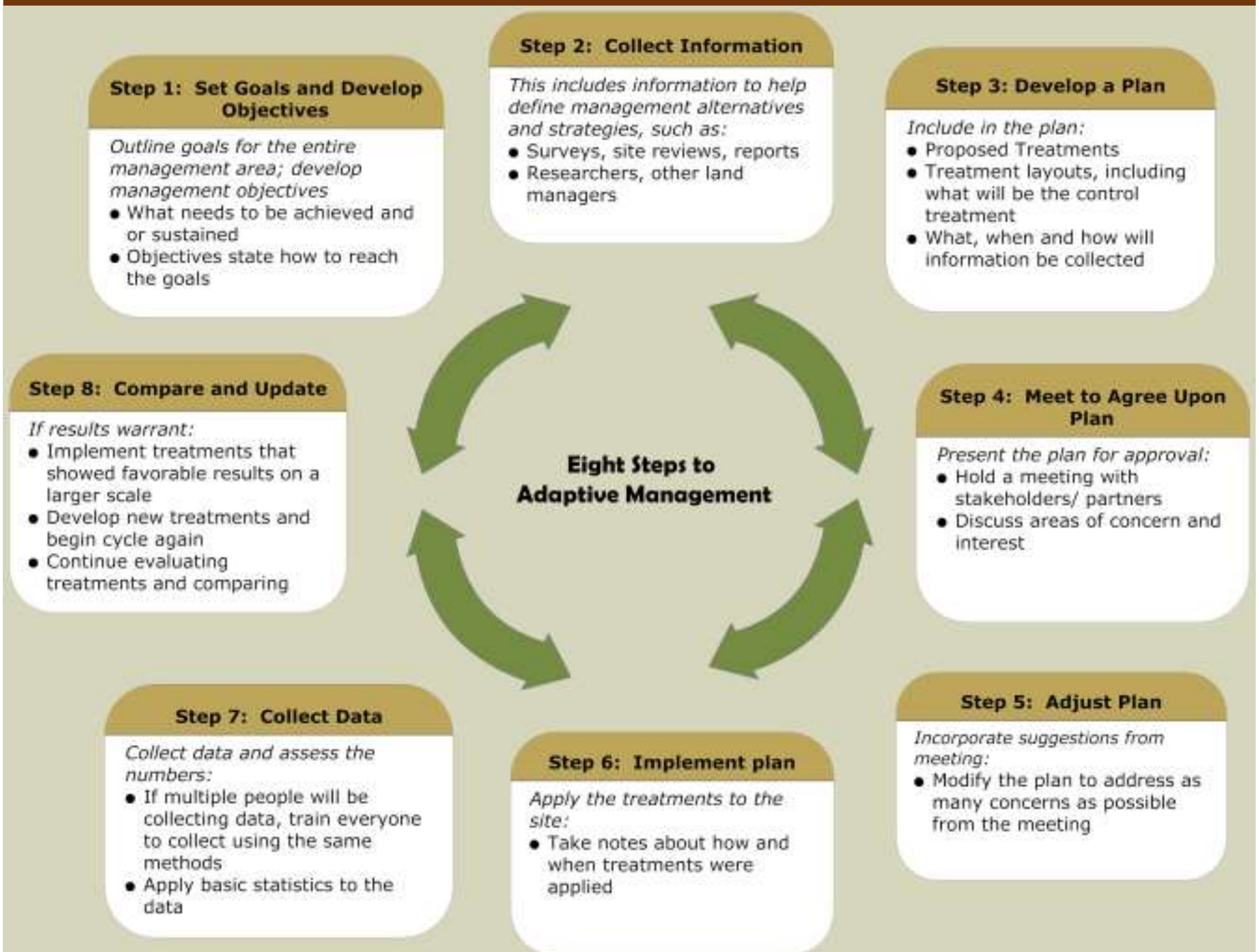
This guide breaks down how to effectively implement adaptive management into eight convenient steps. The eight steps are designed for ease of use to encourage the adoption of adaptive management. Managing plant communities under pressure from invasive grasses demands innovative management ideas. By using adaptive management, a variety of alternative management strategies can be tested to ultimately find what works best for your situation. Adaptive management is cyclical and the steps are repeated as you learn and refine your management. You will be able to assess management strategies and adapt accordingly.

These eight steps are:

Eight Steps To Adaptive Management

- Step 1: Set Goals and Develop Objectives
- Step 2: Collect Information
- Step 3: Develop A Plan
- Step 4: Meet To Agree Upon the Plan
- Step 5: Adjust the Plan
- Step 6: Implement the Plan
- Step 7: Collect Data
- Step 8: Compare and Update, Repeat

Eight Steps To Adaptive Management



Step 1: Set Goals and Develop Objectives

Developing goals and objectives is a critical step in any management plan. There is often a sense of urgency to get out and start doing something about invasive grasses. However, the complex nature of invasive annual grass infestations requires spending time setting goals and developing objectives before an effective management plan can be put into action. Clear goals and well-defined objectives will improve chances for success and will help guide the collection of information and targeting of partners for the adaptive management process.

> Having lost sight of our goals, we redouble our efforts.
>
> -Mark Twain

The difference between goals and objectives can be subtle but having both is helpful. **Simply put, goals are where we want the land to be, objectives are the steps needed to get it there.** Generally, goals are broad and abstract while objectives are narrow and measurable.

In the context of land management, goals would be stated as what you want to see for the land; what you want to achieve. Objectives are the steps you need to take in order to accomplish what you want to see for the land.

It is counterproductive to state goals or objectives as 'what you **don't** want to see'. Goals and objectives are most effective when made as positive statements.

Objectives can state species composition, desired density and biomass and a timeline for seeing the system on the trajectory toward meeting the objectives. These targets will be used to compare against the effectiveness of the management alternatives tested in adaptive management.

Seeking input from people with a stake in the management will augment effective planning. A basic principle of adaptive management is that management actions are determined by goals. Progress is measured toward reaching those goals.

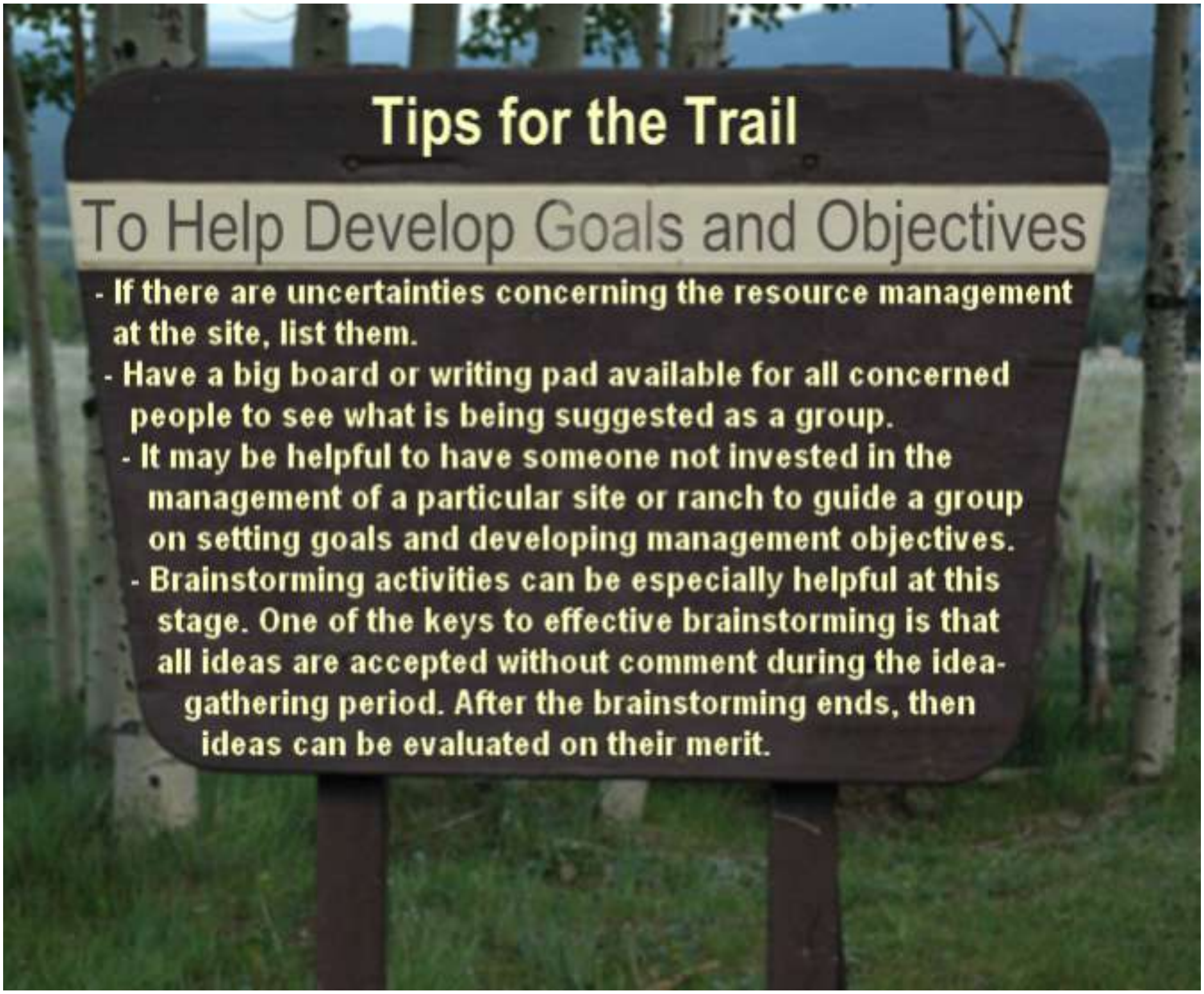
Goals and Objectives in Land Management

Goals: where we want the land to be or what we want to achieve for the land.

An example of a goal would be 'we want to increase forage production for livestock and wildlife'.

Objectives: the *steps needed* to achieve what we want for the land.

An example of an objective would be, 'we want to see perennial grasses increase 30% within 2 years.'



Step 2: Collect Information

The second step of adaptive management is to collect information to assist in developing strategies relevant to the site. Base information is helpful as alternative management strategies and treatments are formulated. Knowing the soils, ecosystem and climate data for the land is a great start. A survey of the area where adaptive management is proposed will be helpful. The survey can simply be taking note of the plant community present, erosion or potential for erosion, slope, soils; general information that can be collected visually.

Once there is a base of information collected, it can be utilized to generate a series of alternative management strategies for the site directed at meeting goals and objectives developed in Step 1.

More on Collecting Information

- More in-depth information can be retrieved through internet databases (e.g. the NRCS websites such as: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm.

- Knowing growing zones, rainfall and temperature data generally is useful. The National Oceanic and Atmospheric Administration (NOAA) has that information accessible on their site: http://www.nws.noaa.gov/climate/.

- On-line searches are important as there is a wealth of information to be gathered in a short amount of time. Maps or more visual information of the land can be obtained by accessing:

  http://www.terraserver.com

  or: http://www.earth.google.com

- All of this information about soils, the ecosystem and climate can help determine which tools may be incorporated into management options.

- Simply talking to others familiar with the area or people facing similar management challenges, is a good way to gather general information. Extension offices, NRCS and other federal agencies, as well as state agricultural departments within counties will have staff that can assist in finding information. The more you can search out and review scientifically sound data from people and publications, you will find more decision tools and choices available. Surveys of past management choices can be extremely helpful in knowing how to proceed. Find out what has worked and failed at the site. If you are working with landowners or managers, ask them what they are interested in trying. You may already have management ideas that you would like to test.

Step 3: Develop A Plan

At this step, management **alternatives** are developed. Avoid creating too much complexity or too many treatments. Complex plans and treatments are easily derailed in the time crunch of daily tasks. To be enthusiastic about a plan and garner support for it, develop **basic treatments** that will address management objectives as straightforward as possible. Determine whether they will be feasible to implement at the chosen site.

Once alternatives are decided upon, the draft management plan can be developed. Work with all the involved parties to make the adoption of the plan and implementation of the management options much smoother. Write clear explanations of how the treatments under consideration for implementation will address the **meeting goals and objectives** developed in step 1.

A strength of adaptive management is the incorporation of non-treated controls into larger treated areas. Thus, one can test the effectiveness of treatments while continuing resource management. Plots need to be created and treatments assigned using basic experimental design principles. There are several components of experimental design. Designing an experiment does not need to complicate management. The few extra steps in setting up the experiment will pay off in the ability to make valid inferences about what you are seeing and learning on the land.

Treatment Alternatives: ____________________

How will the treatment address your goals? ____________________

Control: ____________________

How will the treatment address your objectives? ____________________

Definitions

Experimental Design– the design of all information-gathering exercises where variation is present. Using scientific principles to plan your experiment so it will produce accurate results.

Plots– an area of predetermined size that has a treatment applied to it. The smaller areas within the site that will be used to test treatment plans.

Sampling- The process of selecting observations intended to yield some knowledge about the process being tested.

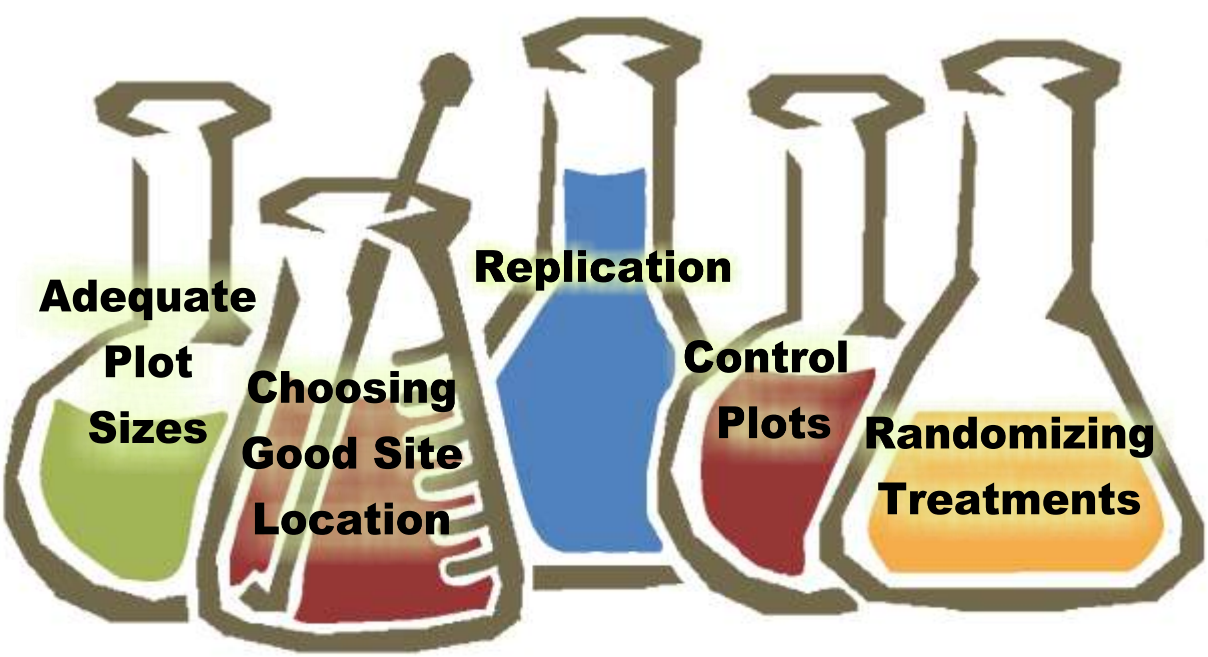
Replication- Repeating an experiment in different places (sites) and in different years to reduce the chance of drawing incorrect conclusions.

Control plot- a standard of comparison. The control plot is set up the same as the other plots but no treatment is applied in order to observe what changes are occurring naturally.

Statistics- a mathematical science pertaining to the collection, analysis, interpretation or explanation, and presentation of data. Using the information gathered to learn what happened in the experiment.

In order to design an experiment, it is important to understand the basic elements of an adaptive management experiment. These elements are choosing good site locations, adequate plot sizes, having replications and control plots, and randomizing treatments.

What Are The Basic Elements of Designing An Experiment?



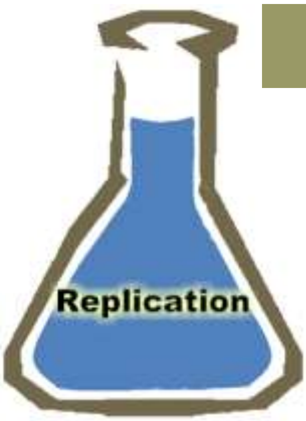
Site Location

Study sites should represent the area of interest and should be as uniform as possible. At a good study location, different treatments are applied across an area that is as unvarying as possible. The more natural the variability of the landscape is minimized, the easier it will be to make valid comparisons from the treatments applied. The area should be uniform and similar in densities of invasive grasses, desirable plants, soil types and aspects. The goal is to factor out landscape variation and make sound comparisons of treatment differences, which at times can be subtle.

Plot Size

Once you have decided upon the ‘site’ where the adaptive management treatments will be applied, ‘plots’ need to be determined. A plot is an area of predetermined size that has a treatment applied to it. The size of the plots depends on the size of the site, the number of treatments, and how many times you will replicate (see below) the treatments at a specific site. While it is desirable to have plots of the same size, it is not crucial. Nor do plots have to be in straight lines. They can follow land contours as you establish the boundaries.

Choosing a good site location is crucial in making valid comparisons of the treatments applied.



Replication

If you try a management strategy in one area and the plant community and annual grass response is exactly as hoped, how sure can you be that you will see the same response in different years or in other areas? It is valuable to know if the treatment response was more than a one-time event. Year-to-year variation in precipitation and site-to-site variation in important characteristics (e.g. soil type) can make it difficult to make this determination. You want to be able to evaluate if a positive response will occur most of the time when managing in a similar way.

This is why adaptive management requires using replications in designing a plan. Replication is repeating an experiment in different places (sites) and in different years to reduce the chance of drawing incorrect conclusions. To gain confidence in management, replicate treatments in as many areas as reasonable.

Why Replication?

- If treatments are not replicated, you cannot tell effects from pre-treatment differences among sites.
  For example, if there is only one comparison, let's say we fertilize one plot and not another. If the fertilized plot is more productive, we may incorrectly conclude that fertilizer is a good investment. If there are three or four different pairs of plots to compare, we will have more confidence if the fertilized plot is always more productive.
- Replication allows you to test whether treatment effects are real or a result of site differences, if the treatment occurs on several replicates and they all respond the same way to the treatment, then you know you are seeing a true treatment response.

Notes:

Control Plots

It is fairly standard practice for land managers to incorporate monitoring into their management. However, monitoring alone is not adequate because it only allows an assessment of whether you are achieving the desired plant community. It does not allow for testing the effectiveness of competing management alternatives. Monitoring alone without a control does not allow you to determine whether changes are occurring due to management or the changes are just happening naturally or are weather-related. Dry areas are known for their huge year-to-year variation in weather, which can influence vegetation trends.

What sets adaptive management apart from a monitoring program is the management alternatives you implement are compared against control areas.

Controls can be non-managed areas or areas that are receiving current management methods (as long as they are different than the methods being tested). Control plots are replicated just as with the treatments.

Randomization of Treatments

Once the number of alternatives and replications are determined and the sites, locations, and plots are chosen, randomly assign the management treatments and controls to the plots. Randomization removes the potential for bias in an experiment and is important when data is collected. Randomized treatments are necessary to use some basic statistics to help draw conclusions from the treatments.

Control plots are set up in the same way as the treated plots but no treatment is applied in order to observe what changes are occurring naturally.

Examples for Designing an Effective Adaptive Management Experiment:

The following examples may be helpful in providing ideas for setting up a study that allows for the comparison of different management strategies. In resource management, these techniques can include **herbicide applications, grazing applications, carefully-timed mowing, prescribed burns, reseeding with competitive plants**, or **any combination of these methods**.

The methods chosen as treatments will depend on which methods have been effective in managing the problem at similar sites and are based on information collected in Step 2. The following two examples are offered as ideas for a straightforward adaptive management experiment.

Example 1

You have a grazing management plan with the objective of improving fair condition rangeland to good condition and lowering the amount of annual grasses. Is it working? You can test whether your grazing is creating positive changes in vegetation composition and abundance by designing an adaptive management experiment.

Q. What will be the control?
A. Non-grazed exclosures within the pasture.

Q. How many replications will you have?
A. 3 (In this case, each pasture is a replication and data will be collected for each of 3 years).

Setting up and carrying out an experiment is an essential step in knowing what management practices will improve the condition of the managed land.

Q. What should you do?
A. Choose 3 similar pastures that you can graze at the desired intensity, frequency and season. If the pastures are similar, they should have about the same plant species composition and abundance. Randomly locate at least 2 - 6 ft x 6 ft exclusion cages in the pasture (you could need more than this depending on the size of your plots). Allow the animals to graze under the new management plan throughout the whole pasture and collect plant community response data annually for 3 years.

Example 2

You have an idea of using herbicide in conjunction with a different grazing regime that you think will keep desired species strong and healthy, control weeds more effectively, and produce more forage. You would like to test this strategy compared to your current one.

1) current management, which is grazing alone
2) proposed new management, which will be spraying an herbicide and spring grazing for 2 months

Treatments will be:

Let's say you own a section (640 acres) of rangeland divided into several pastures that range from 40 to 100 acre's. In this case, there are exactly nine pastures.

Q. What will be the control?
A. No grazing or herbicide

Q. How many replications will you have?
A. 3 for each treatment (randomly assigned).

If you assign treatments to plots, then you can have three replications per treatment (3 treatments x 3 replications = 9 plots). Below, for example, treatment 1 is applied to plots 1, 4 & 8 (these are replications), treatment 2 is applied to plots 3, 5, 7, and treatment 3 is applied to plots 2, 6 & 9. The three remaining plots are used as controls.

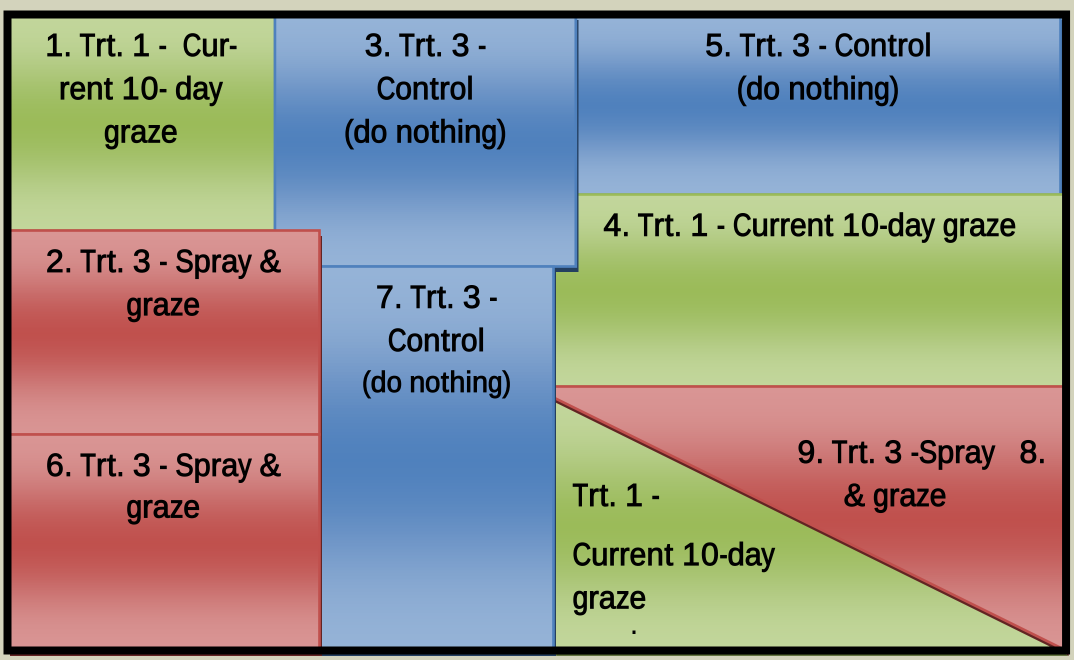


Fig. 3. Sample experimental design for example 2, randomized with 3 treatments

Eight Steps to Adaptive Management Worksheet

STEP 1: Set Goals and Objectives

Describe goals and objectives for the entire management area (these will be broad in scope)

- Include people involved in the operation: ________________________________
  ____
- What do you want to achieve for this land?________________________________
  ____
- What do you want to sustain? ____
  ____

STEP 2: Collect Information

This includes information to help define management alternatives and strategies, such as:

- Surveys, site reviews, reports
- Dominant Vegetation: ____
  Soils:____
- Approximate Precipitation: ____
- Slope/Aspect: ____
- Management Issues: ____
  ____
  ____
- Past History:____

STEP 3: Develop A Plan

Include in your plan:

- Use goals and objectives with collected information to design your experiment.
- Proposed treatments: ____
  ____
  ____
  ____
  ____
  ____

-What is your control? ____
____

-How many replications will you have? ____________________________________

-What will be the dimensions of your plots?________________________________
____

-How many samples will be taken from each site/location/plot?_____________

-Randomize your treatments including your control

STEP 4: Meeting to Agree Upon Plan

Present the plan for approval:

- Hold a meeting with stakeholders/partners
  - When? ____________________ Where? _______________________________
  - Who should be there? ____
    ____
    ____
- Discuss areas of concern and interest:____________________________________
  ____
  ____
- Acquire input of stakeholders: ____
  ____
  ____

STEP 5: Adjust Plan

Incorporate suggestions from the meeting

- Modify the plan to address as many concerns as possible from the meeting.
- Adopted treatment (s) ____
  ____
  ____
  ____
  ____
  ____
  ____
  ____

STEP 6: Implement Plan

Apply the treatments to the site

- Take detailed notes about how and where the treatments were applied:_________
  - Temperature:____
  - General weather conditions: ____
  - Soil condition: ____
  - Stages of plant growth:____
  - Other notes:____
    ____
    ____
    ____
    ____
    ____
    ____
    ____
    ____

STEP 7: Collect Data

Collect data and assess the numbers

- If multiple people will be collecting data, train everyone to collect using the same methods:

  ____
  ____
  ____
  ____

- When will sites/locations/plots be sampled? __________________________________

  ____
  ____

- What data will be sampled?

  Density? _____ Biomass? _____ Both? _____ Other? _____

- Will the data collected be compared using T-test?______________

  If not, describe, in detail, the analysis that will be conducted: _____________

  ____
  ____
  ____

- Apply basic statistics to the data

STEP 8: Compare and Update

If results warrant:

- Compare the means of the data to:

  -Control: ____

  ____

  -Between management alternatives: ________________________________

  ____

  - Management objectives: ____

  ____

- Which alternative most closely matches stated objectives? ___________________

  ____

- Is this alternative statistically significant from the others? ____________________

  If not, what will you do? ____

  ____

- Develop new treatments and begin the cycle again
- Continue evaluating and comparing treatments
- Record updates and logic for changes___________________________________

  ____
  ____
  ____

Step 4: Meet to Agree Upon the Plan

Once a plan is drafted, the next step is to meet with people who have a stake in the management plan. The primary aim is to let stakeholders involved provide suggestions or contributions, thereby gaining "ownership or buy-in" for the adaptive management plan. It is helpful to begin with a plan as a basis for discussion, but it is just as critical to allow the group to incorporate their ideas into it. This increases the likelihood of people supporting the program and plan.

Getting diverse groups (even if it is family) to come together around the plan could be enhanced by stressing points that represent the shared visions or common goals between the groups. These meetings can take the form of facilitated meetings to make sure that everyone's voices are heard.

For private land, this step in adaptive management generally will be the landowner and family members.

For public land this will include public interest groups, users of the site or services from the site, environmental groups, and groups interested in resources (e.g. water, forage, or weeds). When public land is being considered for adaptive management, it is vital to establish and maintain public support. Encourage feedback and address concerns that diverse groups have about the project.

Some examples of public concerns may be that the management plan favors one use of the site over others (such as forage production over wildlife needs), or that treatments at the site may have negative side-effects (such as an herbicide application on a weed patch may negatively impact desired plant species). It is important to complete this step to obtain the best possible outcome for the project.

Meeting to agree upon a plan can initiate new ideas, improve existing ideas and can cultivate support from stakeholders which will all lead to a better outcome.

Step 5: Adjust the Plan

During this step, the adaptive management plan should be adjusted to accommodate as many of the concerns generated in Step 4 as possible. When peoples' concerns are addressed by incorporating their suggestions, there is greater likelihood of them continuing to be supportive of the project. It is also important to include as many of the suggestions as possible to ensure they feel a greater level of ownership.

For private land, adjustments may not be extensive, depending on the number of cooperators.

For public lands, however, there may be many stakeholder concerns to consider and the challenge will be addressing as many of these concerns as possible while still maintaining a plan that addresses the main management questions. You may need to adjust experimental designs or add response variables in order to satisfy all groups and get approval for the plan.

Adjustments to the Plan

In implementing the plan you've developed, it's important to take good notes on everything that could be important in determining results.

Step 6: Implement the Plan

Finally, the adaptive management plan is ready to be implemented and the treatments applied. As treatments are initiated, good notes should be taken about how the treatments were actually applied. This information may be beneficial when evaluating different treatments. For example, herbicide successes or failures can hinge on conditions at application or shortly after.

Recording temperatures, general weather and soil conditions and stages of plant growth when applications are made can be extremely helpful when evaluating the effectiveness of any treatment, even if it does not involve the use of an herbicide. Other types of notes to take are how herbicides were mixed and the type of sprayer used. If a grazing treatment is applied, make notes of the number of cattle in a plot, the size of the cattle, if they are cow/calf pairs or stockers. All types of pre-treatment notes may be valuable when evaluating what occurred on the landscape.

Applying treatments should not be looked at as a point-in-time event. For example, it may take several years to test alternatives and find the most effective management strategies on a site where annual invasive grasses are problematic. Each set of management alternatives should be continued for at least two growing seasons because treatments that work well in a wet year may not work as well in a dry year and vice-versa.

Testing a management alternative for multiple years provides a better understanding of which treatments give consistent results despite climate variation. The best long-term management may not be attained by using the same management treatments every year, instead there may be two or three treatments that can be alternated – one that works best for high rainfall years, one for dry years, and one for normal rainfall years.

Step 7: Collect Data

The seventh step in adaptive management is data collection and analysis. Data collection is ideally conducted at the end of each growing season, though in some situations the treatments may be run for a couple of years before collecting data. Yearly data collection gives a better understanding of how the treatment will work in different years, while longer periods between data collection give an average (over time) response of the site to the treatment.

The type of data to collect, such as plant biomass or density, should be amenable to answering the question of whether the management strategy is driving the plant community in a desired direction. If the objectives stated at the beginning of the process have measurable outcomes, then sampling should tell if you are making progress toward achieving those objectives.

Collecting data should give an idea if progress is being made toward the chosen outcomes.

Data: How to collect it?

Data collection involves a base level of knowledge regarding field procedures. When a person collecting the data has little experience, be sure to give them training in the methods they will use to ensure that the data is valid. Better data can be obtained by spending time training personnel on data collection techniques. Results will be more uniform. It is helpful to develop standardized data collection protocols to refer to when collecting data. A goal is to collect data in a way that it will be of sufficient quality to answer the key management questions developed in the adaptive management plan (see a sample sheet for data collection on page 24).

As you initiate data collection, let's revisit the idea of reducing bias once again. An example of biased data collection is an experiment with two treatments and two people collecting data. Say one person collects all the data for the plots assigned treatment A, and the other person collects all the data for the plots assigned treatment B. The two people might differ in their data collection procedures just enough to make it appear that the treatments are significantly different when they actually are not. On the other hand, the differences in data collection may mask a treatment effect that would have been seen if data collection procedures were identical in both treatments.

An example is where the harvesting of biomass can be subjective if one person leaves behind the crowns of bunch-grasses while the other harvests the plot completely down to the soil.

To reduce bias, divide plots up between personnel so that no one person is responsible for collecting all the data in a treatment or plot or alternatively have only one person collecting all the data. If at any point you find collection or interpretation of data is more involved than anticipated, or if you have questions about how to interpret it, state or county extension specialists, NRCS, ARS and education professionals often can provide assistance for a project of this kind.

Data: When and What To Collect

Ideally, sampling should be done each year after the treatments have been applied for a reasonable amount of time (usually a few months). More accurate results are obtained when vegetation is mature and no grazing has yet occurred. If you have grazing treatments, it may be necessary to sample prior to turn-out. Grasses must be mature to provide a total forage production or cover values but grazing is largely irrelevant if the response variable is plant density.

In collecting data, it is essential that all involved are trained to use the same sampling methods so that data is collected without bias.

Using a hoop that is 4.8 ft² simplifies the process of conversion to pounds per acre.

What data should be collected to provide an appropriate level of information to determine what management strategies are viable for the conditions? There are all kinds of data to be collected; the following are a few good choices in rangeland situations:

- Density or frequency of occurrence usually takes the least amount of time to collect. When time is limited, it is important to collect basic, accurate data and not get too in-depth. Remember the purpose of implementing adaptive management is to ‘help’ in making land management decisions. In some cases estimating plant density will provide valuable information. Plants per unit area (per ft²) can provide a reading of plant density. Plant density is valuable sample data in many situations, but cannot be used to quantify forage production.

- If the time and labor are available, biomass provides an estimate of productivity.

A procedure to collect biomass is as follows:

Randomly place a 4.8 ft²hoop (these hoops can be obtained or made) on the ground inside and near the outside of each enclosure. The purpose of a 4.8 ft² hoop is that when the biomass collected in this area is weighed in grams and multiplied by 20, the conversion is now in pounds per acre, a familiar unit to make evaluations. It may be useful to count each plant in the hoop by species and to clip and weigh each species.

Keeping notes of species and quantity while collecting your data can be very helpful.

Another technique is to sample by lumping groups of species that are important as a group together. For example, counting perennial grasses as a group as compared to individual species of perennial grasses might be sufficient for the purposes of your management plan. Place forage clippings in bags and weigh with a gram scale. Weights should be marked on each bag. For more information on collecting biomass data, the AUM Analyzer provides helpful techniques at: http://www.dowagro.com/range/land/aum.htm.

- Forage production is based on dry weights of the plant material, somewhat like hay. In many cases, drying the material is not convenient. One way to get around this is to put the bags of forage in a pickup with the windows closed for a few days or place them in the sun with good airflow, then re-weigh. Always use paper bags for holding forage. Plastic bags do not work well because they are airtight and moisture does not evaporate. This causes molding and distorts the data.

Air drying is the optimum method for getting the most accurate data in weighing samples.

Another way to determine dry weights is to use the table below to help figure out what the dry weights are likely to be. This table allows you to estimate the actual dry weight based on the growth stage and type of grasses. This information does not exist for forbs and weeds.

Estimating dry weight based on growth state and type of grasses

	Before Heading Initial Growth to Boot Stage	Headed out Boot Stage to flowering	Seed ripe Leaf tips drying	Leaves dry Stems partly dry	Apparent dormancy
Cool Season Wheatgrass Perennial bromes Bluegrasses Prairie junegrass Fescues	35%	45%	60%	85%	95%
Warm Season Tall grasses: bluestems Indiangrass switchgrass	30%	45%	60%	85%	95%
Midgrasses: side-oats grama	40%	55%	65%	90%	95%
Short grasses: blue grama buffalograss short 3-awns	45%	60%	80%	90%	95%

Source: National Range Handbook

Year:		Site:		Date Collected:				
Treatment	Rep	Sample #	Clipping Weight	Species 1	Species 2	Species 3	Species 4	Species 5

***For additional data sheets (including a printable sheet), please visit EBIPM.org

What Do I Do After the Data is Collected?

Once the data from each treatment has been collected, it is time to determine which treatment provided the best responses. Understanding what the numbers are telling you is a critical juncture in deciding which treatment(s) are having the desired effect. You want to be able to assess how well the best treatment compares to the predetermined land management objectives. In a straightforward comparison of treatments, you can calculate averages from the data collected.

To determine how reliably the averages actually reflect what is happening on the land, basic statistics are employed. The statistical analysis is how you will be able to draw satisfactory conclusions from the data collected.

Treatments can be compared with one another statistically using a simple T-Test (see following pages for an example). This test is used for comparing only two treatments or one treatment to a control, such as grazing vs. herbicide application, or herbicide application vs. untreated pasture. By using this method you will make an individual T-Test for each comparison. In some cases these statistics can be calculated by hand. With a computer we suggest using Microsoft Excel.

If you are interested in a comparison of more than 2 treatments, a T-Test is not adequate for analyzing your data and you may need the assistance of a statistical consultant. Finding a statistical consultant may sound difficult but usually isn't difficult. Your local cooperative extension agent may be able to assist with analyzing the data or be able to direct you to someone on the campus of the university that would be able to assist in analyzing the data.

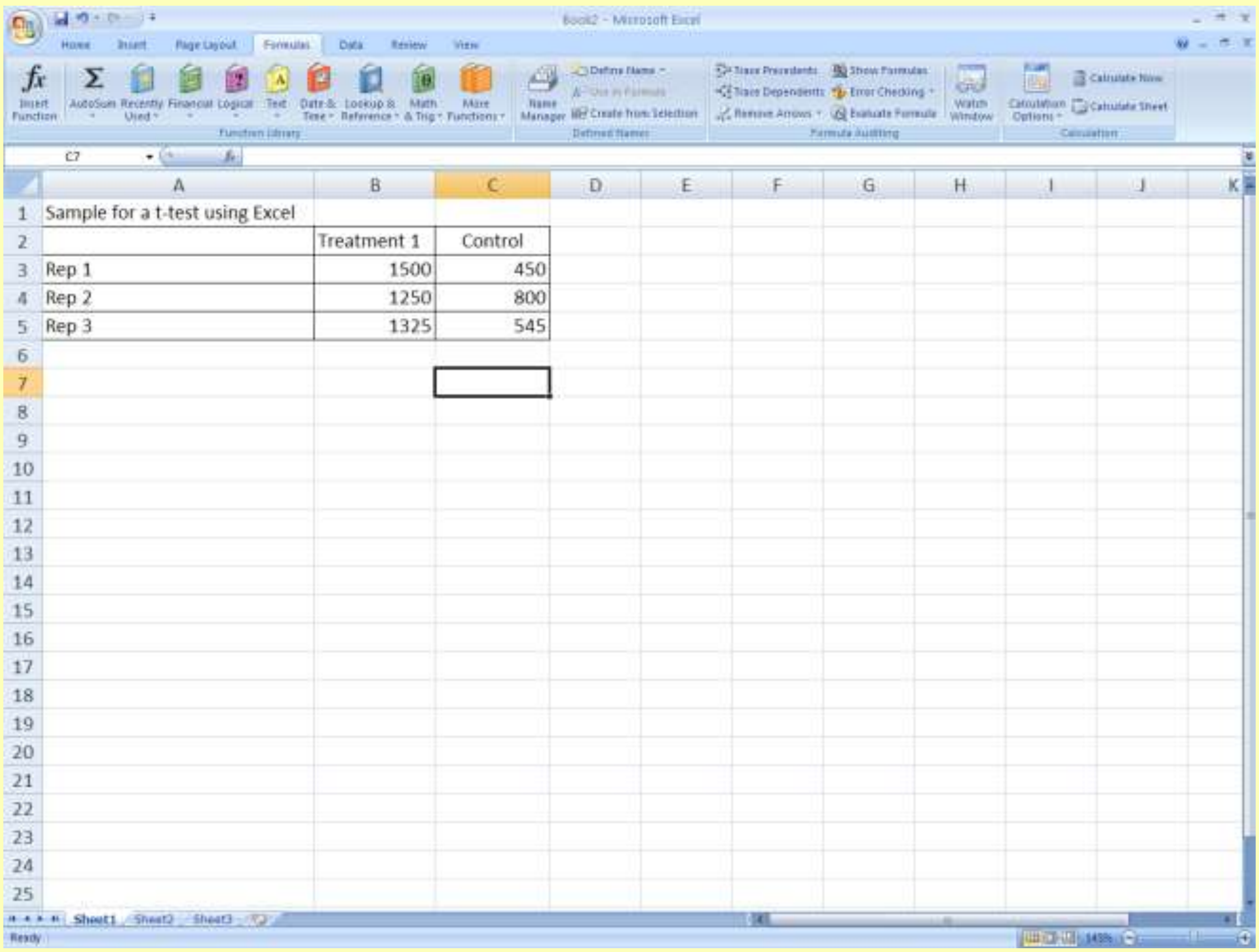
Don't let this be a limiting step. Work with extension agents, ARS specialists or university scientists who are accustomed to doing this kind of analysis but may not be able to do the field work.

Understanding the data you collect is critical in deciding which treatments produce the desired results.

Here's An Example of How to Do a T-Test Using Microsoft Excel's T-TEST Function:

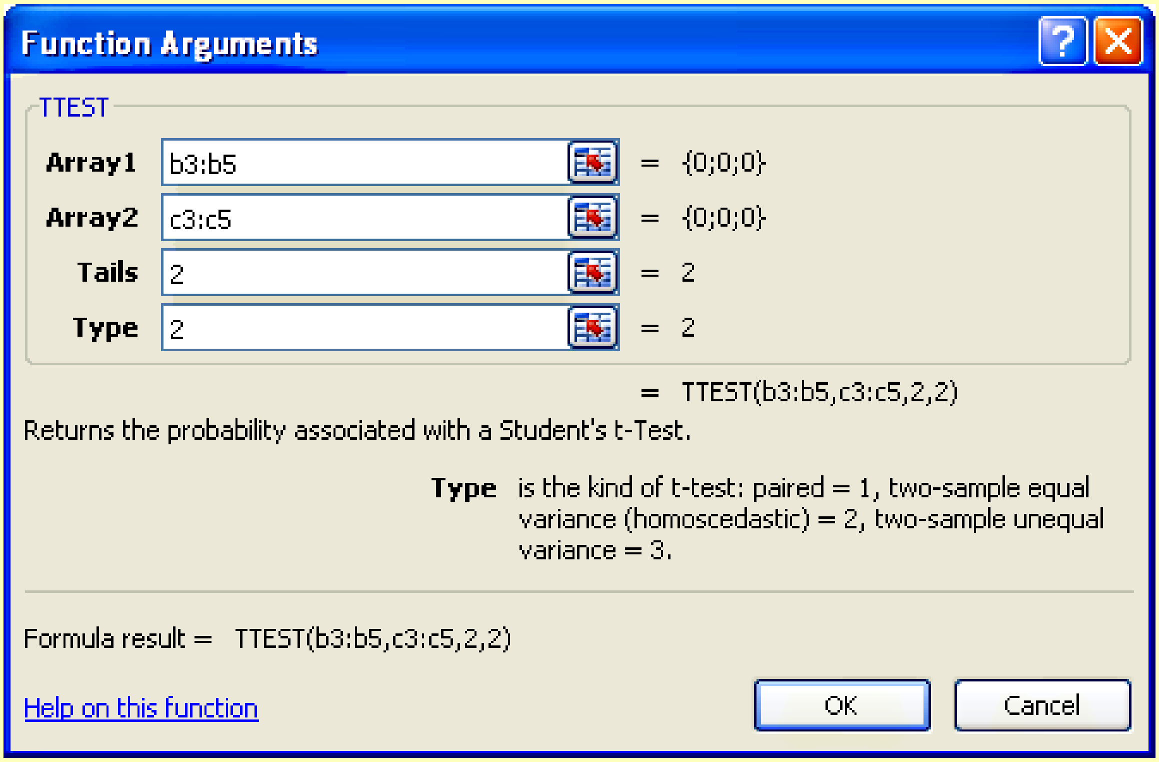
1. Open a spread sheet, and create a data column for each treatment.
2. Enter the numbers for each replication. Let's go through a demonstration with Example 1.

   The area grazed had 1500 lbs of grass in pasture 1, 1250, lbs in pasture 2, and 1325 lbs in pasture 3. The control plots had 450, 800, and 545 lbs of grass in pastures 1, 2, and 3, respectively. In Excel create columns of the data (called Arrays) (see sample screen).



3. In Excel, under Formulas, click on 'more functions, then 'statistical' and you will scroll through a drop down menu to click on 'T-TEST'. Array 1 is column B – insert b3:b5 and Array 2 is column C – insert c3:c5. For tails[1] enter=2; for type[2] enter=2.

The screen below is the screen you will insert this information in based on the spreadsheet that was developed for this data.

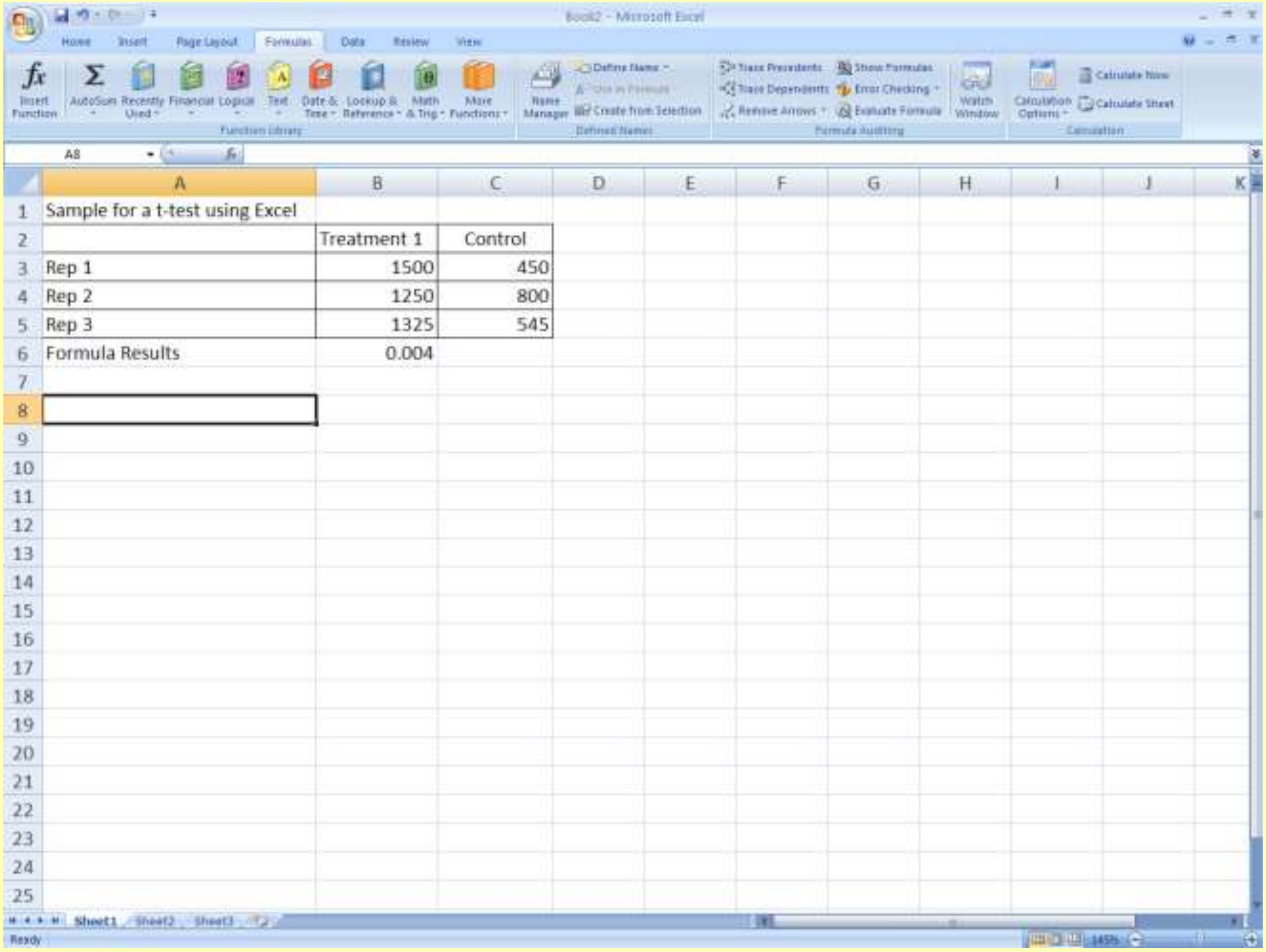


[1]“”Tails” describes whether you want to test if one treatment will always be larger than the other (one-tailed) or whether the mean for one treatment is larger or smaller than the other (two-tailed); generally a two-tailed test is used.

[2] For T-Test type, you will most commonly use the two-sample test.

How To Interpret the Results

The Following is a sample screen after running the T-Test function in Excel.



Sample for a t-test using Excel

	Treatment 1	Control
Rep 1	1500	450
Rep 2	1250	800
Rep 3	1325	545
Formula Results	0.004	

The resulting number from the T-Test in Excel is the 'Formula results'. This number is the probability the data collected from the grazing portion of the experiment are the same as the control. In this example, shown above the 'Formula result' is 0.004. This number indicates there is a .04% chance that the means are not different. In other words, there is a high likelihood that they are different; indicating that plots where the grazing treatment was applied provided more grass than the control plots.

After completing this process for the forage data collected, conduct the same analysis on other vegetation groups or data collected. Then these numbers should be compared with those identified as target numbers for your management objectives.

What Makes Treatments Significantly Different From Others?

What is significance? In scientific papers, you will often see a P-value written as a test of statistical confidence in the results. Generally, the results are considered statistically significant if the P-value is less than 0.05 ($P < 0.05$). The P-value is commonly thought of as the probability of getting a particular result by chance. There are no hard and fast rules about what constitutes a significant difference. It comes down to the level of statistical probability you are willing to accept and this value should be determined before conducting adaptive management.

For example, you might be interested in comparing the biomass of weeds on plots randomly assigned an herbicide treatment to the mean weed biomass of the control as a way to assess the value of the treatment. The mean weed biomass for the control plots was 850g with a large amount of variation, and the mean weed biomass for the herbicide-treated plots was 800g with a large amount of variation. Because the difference between the means is only 50g and the variation is very high, a T-Test on this data gave a P-value of 0.75 (T-test, $P = 0.75$). Thus, based on this data, there is a fairly high probability of seeing a 50g difference between means due to chance alone.

If, on the other hand, the mean weed biomass for the control plots is 1250g with little variation between plots and the mean biomass for the herbicide treated plots is 800g with little variation between plots, a very different conclusion is drawn. If the means and variation are used to run a T-Test on this data, the result is a very low P-value (e.g. $p < 0.0001$). In this case there is very small probability (less than 0.01%) of seeing a 450g difference between the control plots and the herbicide-treated plots due to chance alone. Thus, there is a very high probability that the observed difference in mean biomass between the herbicide treated plots and the control is real and did not happen by chance alone.

It is important to understand the difference between what changes occurred because of the treatments and what changed naturally.

There is some debate about exactly what P-values level constitutes statistical significance. The above descriptions are generally the most accepted. While it is common in carefully controlled science experiments to say that there is no treatment effect unless the P-value is less than or equal to 0.05, in management it may not be realistic to expect such low P-values due to the inherent variability between treatments implemented on a larger scale. As a compromise, you may want to use a P-value that is higher to make decisions on whether a treatment had an effect (such as P = 0.20). When data are highly variable, such as was seen in the first example, a much larger number of replicates will be required to detect a difference between two means.

The worksheet on page 16 may be helpful in sorting out data and determining how to make conclusions based on the data collected.

Step 8: Update the Adaptive Management Plan

The eighth step is the final step before initiating the adaptive management cycle again. Steps six through eight should be continued until all feasible alternative treatments have been evaluated and you are comfortable in understanding which management alternatives are most effective under a variety of climatic conditions. You are not finished now, only ready to adapt in an ongoing process of applying management strategies and evaluating what is working.

With this step, the goal is to apply what was learned from the data analysis by incorporating treatments that worked into the management plan. If a treatment successfully shifts the system in a positive

Updating the adaptive management plan helps to decide what works well and what doesn't; what treatments should be continued and what shouldn't.

direction, it may be continued for additional seasons to test how yearly climatic variation affects the treatment response.

The final assessment requires a comparison of the economics, logistical complications, and political considerations among the management alternatives tested. The management alternative that optimizes these factors and most closely meets the stated management objectives should be considered the BMP for implementing on a larger scale for managing invasive annual grasses in your system. This does not mean it will be the best choice for all situations and this is why you want to continue managing using the adaptive management guidelines.

For public land sites, it is important to keep stakeholders informed and engaged in the process, so planning to hold tours, informational meetings, and progress reports as adaptive management is implemented is encouraged.

Conclusion

Congratulations, you are now practicing adaptive management. As you become more familiar with using this step-by-step method, the benefits of knowing how different management treatments affect your land and resources will continue to grow. You also now have verifiable data if your management practices are called into question. Adaptive management is a long-term commitment to managing resources and making progress toward reducing infestations of invasive annual grasses.

Additional Resources in our EBIPM Series:

DVD Video: A Working Ranch with an Effective Medusahead Management Program

Weed Wheel - Knowing, Preventing and Managing the Dispersal of Seeds

DVD Video: Implementing EBIPM: In the Field tackling invasive plants with science-based solutions

The above products are available to request or download at www.ebipm.org and more resources are in development; check www.EBIPM.org for the most up-to-date listings.

Revegetation Guidelines for The Great Basin: Considering Invasive Weeds

Ecological Principles for Invasive Plant Management

Applying Ecologically -Based Invasive Plant Management

Establishing a Weed Prevention Area A Step-by-step User's Guide

The Area-wide project is a USDA-ARS funded program to encourage and support enduring invasive annual grass management throughout the Great Basin.