EXTENSION AGRICULTURE

On Farm Research

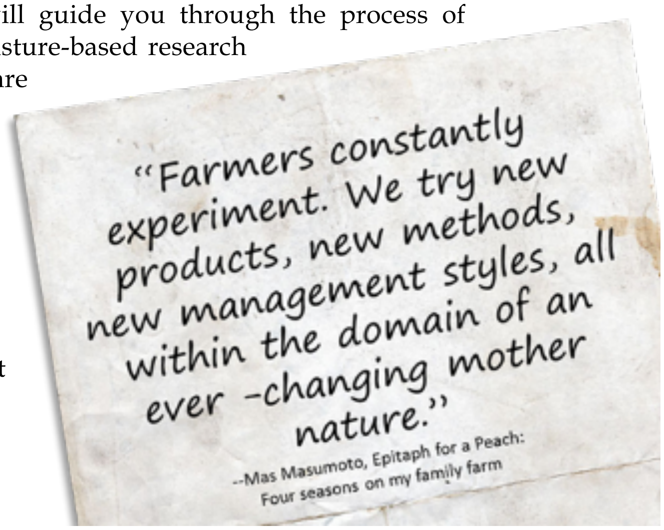
A Practical Guide to On-Farm Pasture Research

Farmer implemented, farmer managed research projects can provide fact-based answers to a farmer's challenging questions. On-farm trials have the potential to improve production efficiency, farm profitability and environmental stewardship. By conducting the research in a controlled way, the results also offer other farmers and researchers valuable information.

PASTURE BASED RESEARCH

Conducting research in a pasture poses unique complications. Pastures are incredibly diverse and fluctuating ecosystems; their growth rate and quality is a function of the time of the year, weather conditions, prior grazing events, and plant communities.

Unlike crop and animal based studies, researchers cannot simply define the success of their treatment using a single measurement of yield or growth at the end of one year. To accurately quantify the worth of a pasture, one needs to know both the productivity and quality of a wide variety of grasses multiple times throughout the year. As plants and soil within pastures tends to be highly variable, these measurements can be difficult to collect. To compensate for these obstacles, there are special sampling protocols specific to pasture research. The following information will guide you through the process of setting up an on-farm pasture-based research project. Although there are many different ways to conduct this type of research, this guide will present a simple methodology that can answer most questions on most farms. The guide is, by no means, the only way to conduct pasture research.



Published by University of Vermont Plant and Soil Science Department.

Funded by the Sustainable Agriculture Research and Education (SARE) program.

ON-FARM RESEARCH

STEPS TO SUCCESS

These four questions provide the foundation for your project. The two steps following them are the actual project. Your answers to the questions will help you develop your research project.

• WHAT ARE YOU INTERESTED IN KNOWING?

Develop a clear simple question with a definite, quantifiable answer.

• WHAT SINGLE PRACTICE ARE YOU INTERESTED IN TESTING?

Define what the “treatment” will be; this novel practice will be compared against an untreated “control” group.

• WHERE AND HOW WILL YOU CONDUCT THE EXPERIMENTS?

Select four to seven paddocks to conduct the experiment on. Then establish replicates[1] and randomize the treatments within each experimental unit.

• WHAT PARAMETERS / VARIABLES WILL YOU MEASURE?

Choose two to four variables to measure. You will be able to determine the impact of your treatment by measuring how these parameters respond differently in the “treatment” and “control” groups.

• COLLECT RESEARCH DATA FOR EACH RESEARCH VARIABLE.

Measure how the treatment affected all of the parameters you selected; in most cases you’ll have to collect many samples from each experimental unit and calculate an average value.

• DESIMINATE YOU FINDINGS!

Congratulations! You’ve finished and are ready share your exciting results.

[1] See “Replication” on page 4 for more information

STEP ONE: Define the Study Question

> **Key Vocabulary**
>
> **Treatment:** Something that researchers administer to experimental units.
>
> *Example: A pasture divided into three sections; each part is 'treated' with a different fertilizer to see which produces the most forage*
>
> **Experimental units:** The area or subject getting the treatment.
>
> *Example: In the pasture above, each of the three sections is an experimental unit.*
>
> **Variable:** What you measure or observe to determine the treatment impacts;
>
> *Example: Common variables a researcher measures include soil pH, forage protein content, forage production rate, etc.*

We recommend choosing a research question can be definitively answered in less than two years. In addition, the question should clearly state both what treatments will be examined and what variables will be monitored over the course of the study. (For more information on choosing your treatments and variables, see below.) Here are some general questions written by farmers and a corresponding research question.

General Question:	Research Question:
Should I inject liquid manure into my pasture?	Will injecting liquid manure into pasture result in a greater forage production and higher soil nutrient availability than one would expect by spreading a similar amount of manure.
Should I plant brassicas to extend my grazing season?	What is the effect of hand seeded forage radish (at 10lbs/A) on forage quality and production during the fall months?

Notice how each general question was amended to be much more specific. The research question now includes information regarding exactly what the treatment will be, what you will measure to determine how effective the treatment is, as well as other useful details like the time-frame of the study. Having a well-defined research question will help you stay focused.

STEP TWO: Choose Treatments (2)

If you designed your research question well, the treatment should be clearly laid out in the research question. Common examples of treatments include, a certain fertilizer applied at a certain rate, a new plant species seeded into the pasture, and an innovative plowing technique.

It is important to include a "control" group to contrast against the "treated" group. The control plots will not receive the treatment under investigation. Below are examples for treatment/control combinations for the examples listed in step 1.

General Question:	Treatment:	Control:
Should I inject liquid manure into my pasture?	Liquid Manure Injection (5-tons per Acre)	Manure Spread Over Surface (5 tons per Acre)
Should I plant brassicas to extend my grazing season?	Pasture with forage radish hand seeded (at 20lbs/A)	Standard Pasture

STEP THREE: How and Where Will You Conduct the Study

Selecting the Location

Location is important. When choosing a site, consider previous crop history (fertilizer rates, herbicides, tillage, etc.), drainage, forage species, soil texture, soil depth, topography, pest infestations, and other factors. Choose a field site with the greatest possible uniformity. The goal is to plan and organize the field plot layout to assure that all treatments have an equal opportunity to succeed.

For pasture research, you will want a fairly large tract of land, usually enough for at least 6 paddocks or about 3 acres. The study will be easier if you use established, permanent paddocks, even if they are only permanent for the length of the project.

Plot Layout: Paired Design

The experimental design described below is known as a "Paired Comparison Trial." This classical on-farm design is characterized by having long strips of treated and untreated land side-by-side in the field, replicated at least six times. Each pair of strips should be located in an area that is fairly homogeneous or uniform. (See figure on page 5)

Paired comparison trials are well suited to pasture research. By replicating the treatment within every pasture many factors, such as grazing use, are kept constant. The design is fairly simple to understand and implement; each data pair yields one difference. These differences can be analyzed using a simple, single-sample technique described on page 12. In addition, the results are clear and easy to interpret.

Replication

When using a paired design the treatment/control plots are paired six times, making six replications. This gives you some leeway if one or two plots fail but is not too difficult to complete practice implementation and sampling.

Replication gives you a "second opinion" on your question. With only one pair in the trial, the conclusion is based on only one observation – which may or may not be representative of the result. You would not know if the results you saw were a random fluke or a real treatment effect. By replicating the experiment in multiple places, you can be certain that the effect measured is real.

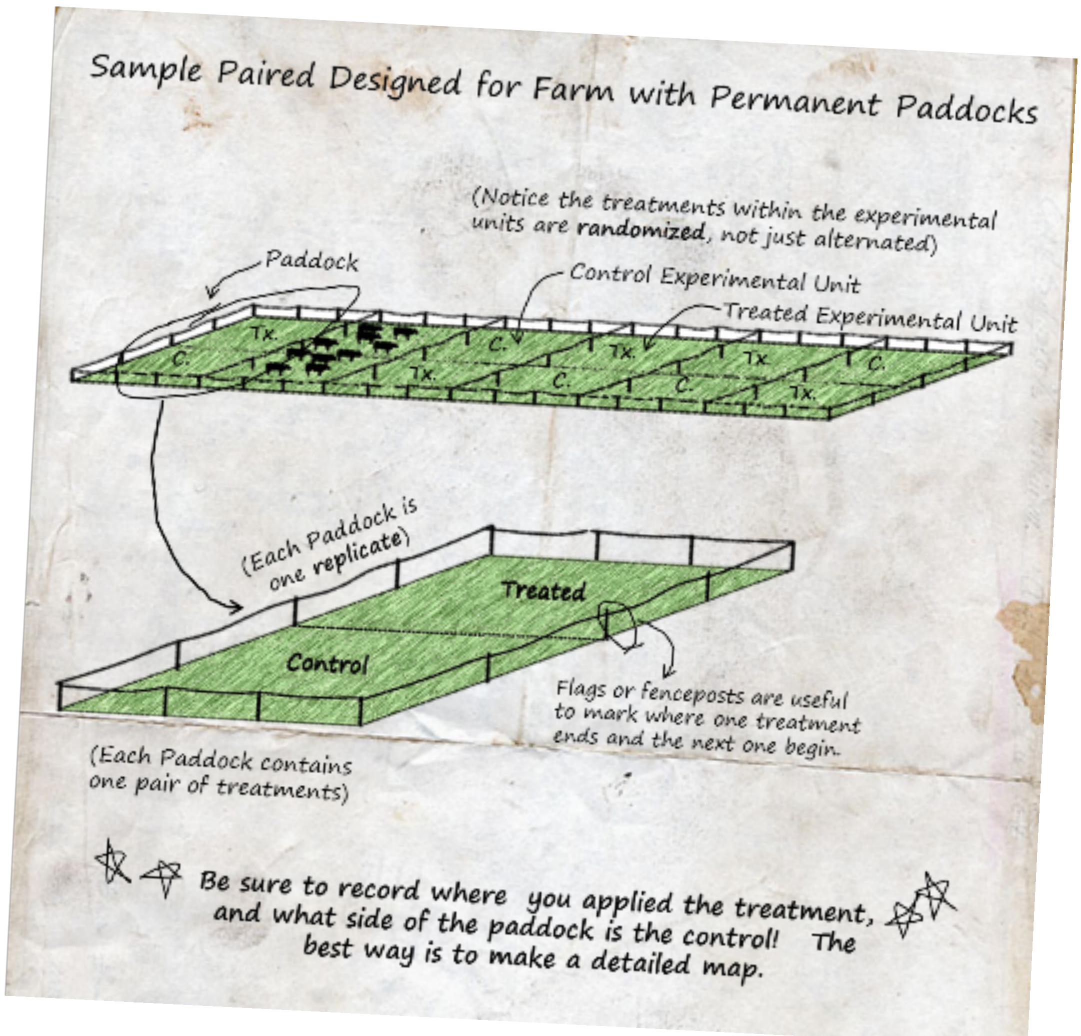
Creating Experimental Units

If conducting the experiment in permanent established paddocks, creating experimental units is easy. Mentally split each paddock roughly in half; each half will be one experimental unit. Each paddock is one replicate and will contain one pair of treatments (treated and control). You will need six paddocks to complete this experimental design. See the sketch below.

If conducting the experiment in an area that is strip grazed, setting up the experimental units will requires a bit more work. You will be applying the treatments in long narrow strips. Each strip will be one experimental unit. Two adjacent strips will be paired. (It is helpful, if you are applying the treatments with a tractor, to make plots that are field length long and one or two tractor passes wide. This makes it easier to apply treatments along the entire strip without having to start or stop in the middle of the field.) Decide what width you would like each strip to be; use flags or markers to mark the chosen interval within the field.

Randomize Treatments within Experimental Units

To prevent unanticipated sources of bias from entering your data measurements, treatments must be randomized. This means that the order of treatments cannot be the same in every replication. Within each pair of experimental units, randomly assign which side will be treated and which side will be the control by flipping a coin.



STEP FOUR: Choose Variables to Measure

Once you have an experiment established in the field, there is no limit to the kinds of data you can measure: soil chemical properties, yield parameters, weed counts, forage protein content, etc. Measurements should be chosen from the list below depending on the outcomes you are looking to measure in the trial you are conducting. Please note there might be measurements specific to your trial that is not included below.

A few of the most common analyses are also described on the next two pages. With a little bit of online research you can also find more information regarding how to properly take each measurement and interpret the results. Also consult your local extension agents; they can help you refine you experimental design and sampling procedures and may even be able to lend you equipment.

Be sure that what you are measuring will be useful in answering your research question. It is easy to overextend yourself by measuring more variables than you have time or money for. We recommend focusing on two to four variables.

Table Key

Cost per Sample
$ = less than $1
$$ = $1 to $5
$$$ = over $5

Time Requirement per Replicate
1 = less than 1 hour
2 = 1 to 2 hours
3 = more than 2 hours

Equipment Requirements
A = no measurement equipment required
B = some low cost, simple measurement equipment required
C = expensive or sophisticated

Measurement	Cost	Time	Equipment
COMMON SOIL MEASUREMENTS			
Soil Organic Matter	$$	3	A
Soil pH	$	2	C
Soil CEC (Cation Exchange Capacity)	$$	3	A
Soil Nutrient Composition	$$$	3	A
Soil Moisture	$	2	C
Soil Temperature	$	2	B
Earthworms	$	3	A
Soil Compaction	$	2	B
Soil Infiltration	$	3	B
COMMON FORAGE MEASUREMENTS			
Percent Desirable Plants*	$	1	B
Plant Cover*	$	1	B
Plant Diversity*	$	1	B
Plant Residue (Standing Dead Matter) *	$	1	B
Percent Legumes*	$	1	B
Forage Quality	$$$	2	A
Forage Production Rate	$	2	C
Brix Content	$	3	B

* Assuming visual assessment with quadrat is conducted

Soil Variables

Soil Nutrient Content

Note: Most soil nutrient tests won't measure nitrogen content. Focus on other

Required equipment: Soil Probe ($20.00)

A standard soil nutrient report can provide a lot of information about your soil. Most will include data regarding the sample organic matter content, pH, cation exchange capacity, percent moisture, and concentration of key macro- and micro-nutrients (excluding nitrogen). This is a great variable to measure when you are testing a new fertilizer or amendment.

Collect composite samples by getting soil from 20-30 random spots in each plot. Pasture should be sampled to a depth of 4 inches using small soil probe. Once you have collected a composite sample from one plot, mixed it up, bagged it, and labeled it, then go on to the next plot. You will end up with the same number of samples as plots.

Select part of the composite sample (approximately 1 cup) for analysis. Samples can be sent (dry or fresh) to your local Land-Grant University Agricultural Testing Lab. You can usually choose to save money by analyzing one parameter (i.e., phosphorous content) rather than all of the parameters included in the analysis package.

Soil Moisture

Required equipment: Soil Moisture Meter* ($30.00-$250.00)

In non-irrigated pastures, soil moisture is often the largest factor determining plant growth. Any physical changes you make to the soil (such as sub-soiling) will affect the way your pasture drains and stores water.

Why do you need to collect so many samples or measurements? *See "Subsample to*

To measure soil moisture content, walk around the experimental unit and measure the soil moisture content in at least 30 random locations following the instructions provided by your specific soil moisture meter. Be sure to collect all of the measurements on the same day, from the same soil depth, at all locations. The soil moisture value for the experimental unit will be an average of all 30 readings from the experimental unit.

Soil Compaction

Required equipment: Compaction Meter or Penetrometer ($150.00-$250.00)

Soil compaction is common in many pastures, particularly when animals are allowed to graze wet soils. Compaction destroys structure, reduces porosity, limits water and air infiltration, and increases resistance to root penetration. If you were planning on physically altering the soil (aerating for examples), you may want to measure the soil compaction.

Walk around the experimental unit and measure the soil compaction in at least 30 random locations following the instructions provided by your penetrometer manufacturer. Take care to collect readings from the sample soil depth at all locations. Use the average of all readings as the soil compaction value for the experimental unit.

Soil pH

Required equipment: pH Meter ($30.00-$250.00)

Soil pH affects plant growth and longevity, particularly among legumes. You may be implementing a practice that has the potential to alter the soil acidity; if so, you will want to measure soil pH.

You can either determine your own soil pH or have a soil testing laboratory determine the pH of the composite soil sample following the procedures outlined above (Soil Nutrient Quality). If you are testing your own soil, you have the option of using a probe (faster but requires expensive equipment) or a soil pH testing kit. If you are using the kit, collect a composite soil sample following the procedure outline in "Soil Nutrient Quality", then follow the manufacturer's instructions. For a probe, simply use the probe to measure soil pH in at least 30 locations throughout the experimental unit. Use the average of all the readings as the soil pH value for the experimental unit.

Forage Variables

MEASUREMENTS OF FORAGE MASS/YIELD

The growth rate of pasture is a function of the soil nutrient availability, moisture, compaction as well as climate and land use history. Any time you are applying a treatment with the aim of achieving greater production, consider monitoring forage mass.

In standard scientific research, forage mass is estimated using hundreds of carefully clipped, dried, and weighed forage samples. This method is very time consuming and requires expensive equipment. However there are other relatively easy and efficient means of indirectly measuring the forage mass within a pasture. Two common produces are outlined below.

Measuring Forage Mass using Falling plate meters

If you want your data to be in standard units (pounds per acre) you will need to calibrate the plate meters using clipped samples. See your local extension agent for more details.

Required equipment: Falling Plate Meter ($30.00-$400.00*)

There are two types of plate meters available; rising plate meter are available commercially for $200 to $400. Falling plate meters are relatively easy to construct for about $30.00 (See http://www.wvu.edu/~agexten/forglvst/fallplate.pdf for construction details.) Falling plate meters measure the compressed height of the pasture canopy. To measure forage availability using a plate meter, select random locations in the pasture, gently place the meter on the forage until the plate is supported by the forage, and then measure the height of the plate's top above the ground. Use the average of all of the height values as the value for experimental unit.

Measuring Forage Mass using Rulers

Why do you need to collect so many samples or measurements? *See "Subsample to Increase Precision" on Page 11*

Required equipment: Yardstick ($5.00)

You may also use a simple ruler to estimate the pasture mass. This method assumes that as the sward height increases forage yield increases. If you choose to use this method, walk around each experimental unit and select 30 random points; use the ruler to estimate the height of the sward disregarding any weed species or outliers. Use the average of all of the height values as the true value for experimental unit. A measurement of pasture density will help calibrate this value. As you know, a more dense pasture will have more forage than a sparser pasture.

Forage Quality

Required equipment: None

Forage quality has a direct effect on animal performance, forage value, and profits. It is strongly influenced by the population of plants in the pasture and timing of grazing. Forage quality analyses are useful whenever you are interested in the impact of a new species of forage or a new system of grazing.

Pasture samples for forage quality should be taken before animals are turned into the pasture. Walk around the experimental unit and collect 30 grab samples with your hand or scissors; remove the forage to the height the animals will graze. Samples must represent what livestock will eat. Once you have collected the subsamples, thoroughly mix them together. Select part of the combined sample for analysis. Samples should be either dried at 140°F or frozen immediately after collection. The samples can be sent to any forage testing lab for analysis. You can chose to measure the entire suite of forage quality parameters (about $16 per sample) or an individual parameter like NDF of crude protein content for less money.

BRIX Content

Required equipment: Refractometer ($30-40)

The brix reading on a plant is an indication of its nutrient content; it refers to the total amount of soluble solids (mostly sugars) along with plant proteins, vitamins, and minerals. Consider measuring BRIX whenever you suspect the treatment influences forage quality.

To determine the average brix content of you pasture, select one dominate plant species to work with. Since brix values fluctuate throughout the day, we also recommend collecting your samples at the same time of day over the duration of the experiment. Collect blades of grass from the same species of roughly the same maturity from at least 30 locations in you pasture. In small batches, roll the leaves between your palms for 15 seconds. Then place the specimen in garlic press to extract the juice. Use a refractometer, also called a brix meter, to measure the solute content.

Step 5: Conducting the Experiment

Develop a Project Timeline

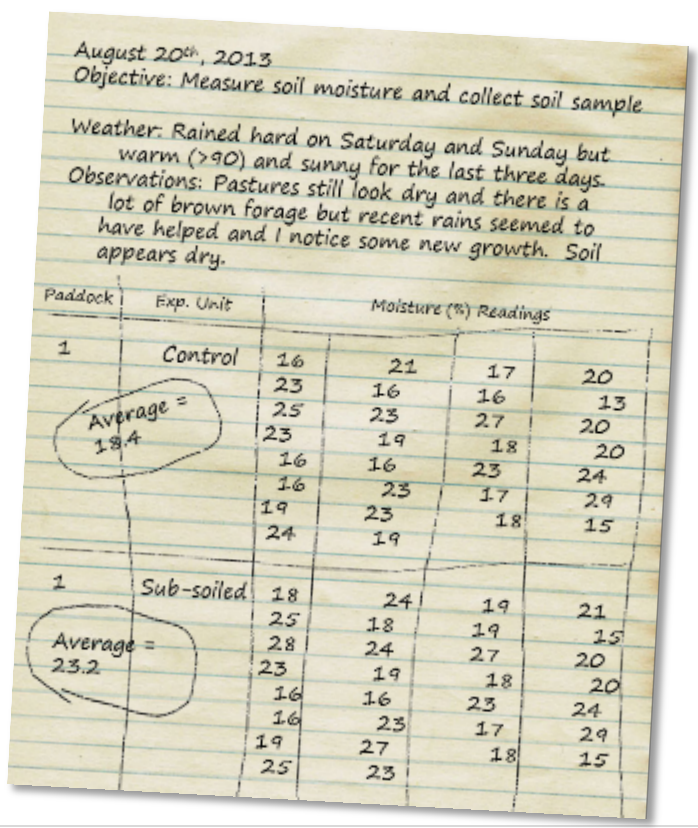
Every trial is different and will require a different timeline. In general, most studies are conducted for at least two years. You will likely collect data regarding the pasture and/or soil quality at multiple times during the years. That said, it is important to not over-commit yourself. Research can be very time consuming and tedious – for instance, expect sampling forage quality in 12 experimental units (6 paddocks) to take at least 4 hours; collecting soil samples will likely take longer.

Take Notes

Recommendation:
"Rite in the Rain" all weather notebooks are expensive but well worth the investment.

Keep detailed written records of everything you do related to the project. Record all field operations in diary format. Take notes on the methods of your field operations, such as the type of equipment, depth of tillage operations and materials applied to either the whole field or to just one treatment. You should also include personal observations about the weather, pests, forage growth and development, etc. These will be essential when you got to interpret the data. The documentation also preserves the detailed of your farm trial so that you can share the information with others.

It is useful to draw out a plot map or plan to help visualize the project and keep track of which treatment has been applied where. Make sure that any changes you make in the field are reflected on your map. Be sure to make at least one copy of the plot map and keep it somewhere safe so that you don't lose all your work if you lose your working copy of the map.



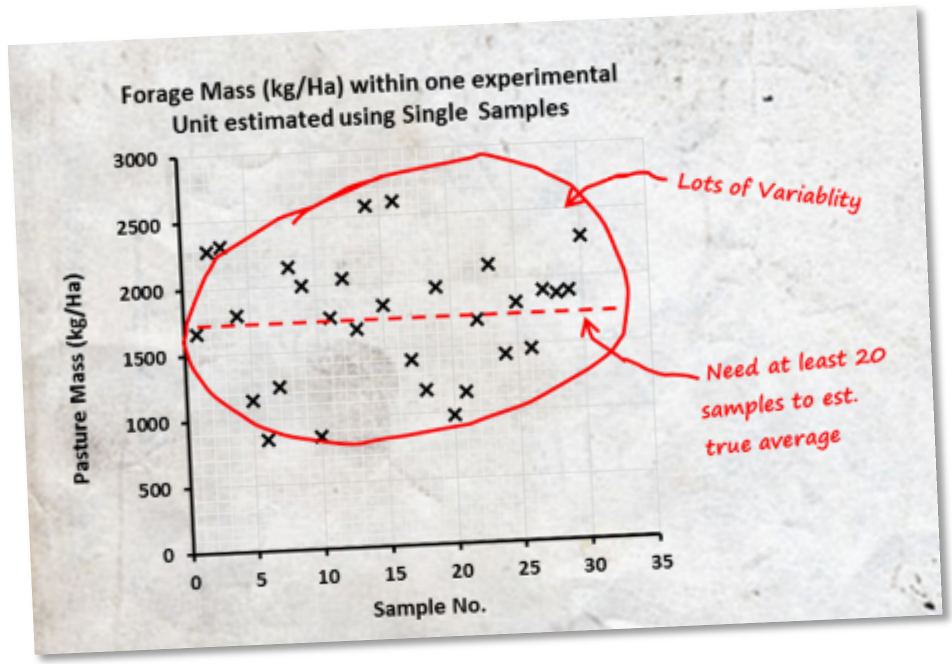
August 20th, 2013
Objective: Measure soil moisture and collect soil sample

Weather: Rained hard on Saturday and Sunday but warm (>90) and sunny for the last three days.
Observations: Pastures still look dry and there is a lot of brown forage but recent rains seemed to have helped and I notice some new growth. Soil appears dry.

Paddock	Exp. Unit	Moisture (%) Readings			
1	Control	16	21	17	20
		23	16	16	13
	Average = 18.4	25	23	27	20
		23	19	18	20
		16	16	23	24
		16	23	17	29
		19	23	18	15
		24	19		
1	Sub-soiled	18	24	19	21
		25	18	19	15
	Average = 23.2	28	24	27	20
		23	19	18	20
		16	16	23	24
		16	23	17	29
		19	27	18	15
		25	23		

Subsample to Increase Precision

When measuring variables like soil nutrient content and forage mass it is important to take a lot of samples. Pastures are "fertilized" and "harvested" by animals; the forage within them is a dynamic, diverse, living community of plants. To overcome the variability, many samples must be taken in order to accurately estimate what the experimental unit is really like. Usually 30 samples are recommended for experimental unit ½ acre or greater in size. For smaller experimental units, you 15-20 subsamples would be adequate.



For samples that are shipped to laboratories for professional analysis, thoroughly mix together at least 20 (30 is best) samples collected from one experimental unit. Then select a portion of aggregated sample to send out for analysis.

For variables that you are measuring on your farm (soil moisture, forage height, etc.) take at least 20 (30 is best) measurements in each experimental unit. Calculate the average of all of the measurements. This new value will be the best estimate of the soil/forage parameter in each experimental unit.

STEP 5: Analyzing the Results

Statistically Significant
In statistics, a result is called statistically significant if it is unlikely to have occurred by chance.

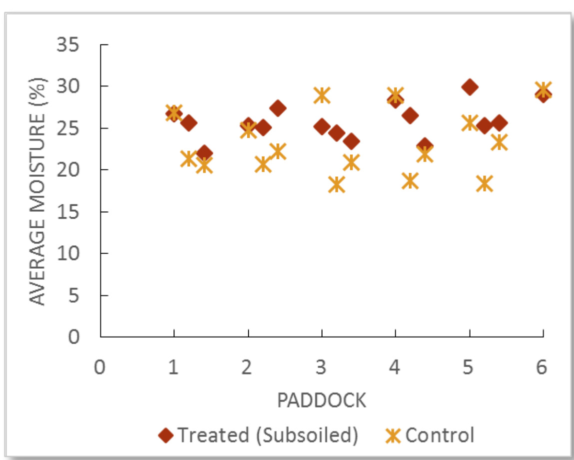
Once you've collected all the data, you will need to analyze it in order to determine if the treatment has a "statistically significant" effect on the treatment. This important step brings together all of the data, from all of the paddocks, and summarizes it into one simple statement.

To analyze a paired data set, enter the data into a spreadsheet. Organize the data the same manner as pictured in the image below. You will have one column containing all of the data from the "treated" experimental units and one column with all the data from control experimental units. (Mostly likely these values will be the average from all of you subsamples.) Each row will contain data from a single paddock/pair collected on a single date.

Paddock	Date	Treated (Subsoiled)	Control
1	23-Jun	26.8	26.9
2	23-Jun	25.3	24.8
3	23-Jun	25.2	28.9
4	23-Jun	28.4	28.9
5	23-Jun	29.9	25.7
6	23-Jun	29.1	29.6
1	4-Aug	25.6	21.4
2	4-Aug	25.1	20.7
3	4-Aug	24.4	18.3
4	4-Aug	26.5	18.7
5	4-Aug	25.3	18.4
6	4-Aug	23.8	22.5
1	15-Sep	22	20.6
2	15-Sep	27.4	22.2
3	15-Sep	23.5	20.9
4	15-Sep	22.9	21.9
5	15-Sep	25.6	23.3
6	15-Sep	25.2	22.5

Averages from Each Experimental Unit on Each Date t

When this data is plotted, as show below, it is difficult to tell if there is a real difference between the treatment and control; the data it so variable it looks like a jumble of random points. Simple statistics will make it easier to interpret the data.

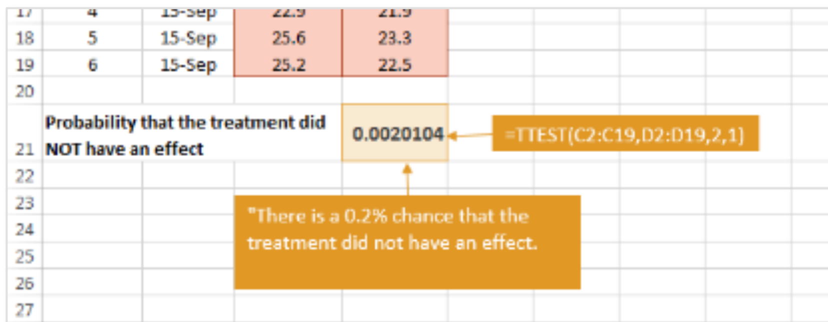


To determine if there is a statistically significant different between the control and treated plots, use Microsoft Excell or other spreadsheet software to run a two-sided, paired t-test. In an empty cell, type:

```
=TTEST(C2:C19,D2:D19,2,1)
```

Notice how "C2:C19" is an array encompassing all the celled from C2 down to C19. You will want to change this to encompass all of the call cells from in your treatment column. Similarly, you will need to adjust "D2:D19" to encompass all of the cells in your control column.

When finished, click Enter.



The number displayed is the probability that the treatment did not have an effect. In the case of out example, there was a 0.201% change that the treatment and the control were the same. Any time this value is less 5% (0.05), most agricultural researchers will assume that that the treatment and the control are different. Therefore, we can conclude from our example that the treatment (in this case subsoiling) had a significant effect on soil moisture.

You will want to "play" around with the data to draw more conclusions. Use the spreadsheet software to determine what the average difference was between the control and treated plot. You can also make graphs and charts to summarize the data.

Analyzing paired data from a pasture can be relatively simple. Nonetheless, it is very normal for questions to arise, and it can be difficult to find immediate answers. Your local extension agent should be able to help you answer them.

What does the formula mean?

TTEST
Run a T-test

C2:C19
An array containing all of the data from treated experimental units.

D2:D19
An array containing all of the data from control experimental units.

2
Two Side T-test

1
Paired Data

STEP SIX: Share your Results

After you've completed your research and analyzed the results, put aside some time to share your results with other researchers and farmers. It doesn't matter if your results were positive or negative – other farmers and researchers will want to learn from all your hard work.

Try to target your research toward the stakeholders that will be most interested in the results. Extend your outreach campaign beyond the merely local farmer in order find the widest possible appropriate audience.

There are many different ways to spread your message. Below are some common examples. Don't be afraid to get creative and branch out!

- Host an field day, on-farm demonstration, or workshop
  Contact your local extension agency. They may be able to help you plan and advertise for the event.
- Present at a conferences
  Contact the event organizers and ask to present a presentation on your research. There are a many grazing and NOFA conferences being conducted all over the country.
- Put together a factsheet or brochure
  Contact your local extension agency. There is a good chance they will post your factsheet online or display it upcoming field days and workshops.
- Write an article for local newsletter
  There are many newsletters oriented toward farmers. Consider contacting the editor and submitting a short article.

Contributors

Bridgett Hilshey
Graduate Student
University of Vermont, Plant and Soil Science Department

Sidney Boswoth
Extension Associate Professor
University of Vermont, Plant and Soil Science Department

Rachel Gilker
Pasture Program Coordinator
University of Vermont Center for Sustainable Agriculture