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# A Grower's Guide to Successful On-Farm Research


**Olga S. Walsh**
Systems Agronomist
University of Idaho Extension

**Kathleen Painter**
Agriculture, Assistant Professor
University of Idaho Extension

**Kelli M. Belmont**
Cropping Systems Research Technician
University of Idaho Extension


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## Reasons to consider on-farm research

EXPERIMENTATION IS AT THE HEART of agricultural practice. Growers have many ideas for improving their farming operations, such as changing management, trying a new product, or updating equipment. Some of these ideas can be implemented quickly and easily, while others take major investments of time and money. There is always a certain amount of risk involved in implementing any change. A great way to minimize this risk is to test changes on a smaller scale by carrying out on-farm experiments. For example, many newly developed products are marketed to growers are claimed to be beneficial to farming operations. Conducting an on-farm experiment can help support or reject these claims, helping growers make sound management decisions based on their own specific farming practices, crops grown, soil, and environmental conditions.

A successful research project is one that provides a grower with a clear and accurate answer to the question being asked. For growers to draw proper conclusions from on-farm research, experiments must be set up appropriately, following the scientific method. Because variability exists between different fields on a farm and between growing seasons, it is important for on-farm research to include data collected from multiple fields and growing seasons. This approach can help growers better understand how the management practices, products, and growing conditions being tested affect yield and profitability.

This publication provides suggestions on potential opportunities for funding this type of research and gives basic information on how to conduct a successful on-farm research project, including both agronomic and economic assessment. This publication is aimed at helping growers interested in testing agricultural products or methods on their farms and provides a resource for agricultural consultants, university Extension educators, and other specialists working with growers to make management recommendations.

## Potential funding sources

Growers may be able to access funding to help them conduct on-farm research. Two possible funding sources are described below.

Western Sustainable Agriculture Research & Education (SARE) (http://www.westernsare.org/) is a program of the United States Department of Agriculture (USDA) that supports on-farm research initiated by growers. Western SARE has an annual competitive grant process with proposals submitted by farmers, ranchers, researchers, and agricultural professionals. Its focus is on-farm (or on-ranch) research that promotes sustainable agricultural practices. Western SARE has several different grants programs available that can help fund on-farm research projects. The following two grant programs can be applied for by agricultural producers with support and guidance from a technical advisor for a period of one to three years:

- A Farmer/Rancher Research & Education project is driven and coordinated by a farmer or rancher.
- A Professional & Producer project is coordinated by an agricultural professional (Extension specialist or educator) working with a producer.

The USDA Natural Resources Conservation Service (NRCS) in Idaho (https://www.nrcs.usda.gov/wps/portal/nrcs/main/id/programs/financial/) offers annual Conservation Innovation Grants and other programs to help growers manage natural resources in a sustainable manner. These funds are awarded through a statewide competitive process.

## Let's do science!

A common approach for on-farm experiments involves a comparison of two products or practices (e.g., conventional tillage vs. strip-till, dry granular vs. liquid fertilizer, one-time vs. split application of fertilizer). The most common approach is to do a "side-by-side" experiment. For this type of experiment, a grower divides the field into two parts, applies contrasting treatments to each part of the field, and compares the results (e.g., crop yield or quality, or economic viability).

Although these types of comparisons can be successfully used as field demonstrations, they lack the necessary requirements for drawing scientifically sound conclusions. Thus, management decisions based on these comparisons are not scientifically validated. This is primarily because side-by-side comparisons are not replicated and do not allow for the assessment of within-field variability and "noise." (For more information, see Designing the Experiment.)

The scientific method is the process by which scientists, collectively and over time, endeavor to construct an accurate (i.e., reliable, consistent, and non-arbitrary) representation of the world. When conducting an on-farm experiment, growers should follow the scientific method (Figure 1).

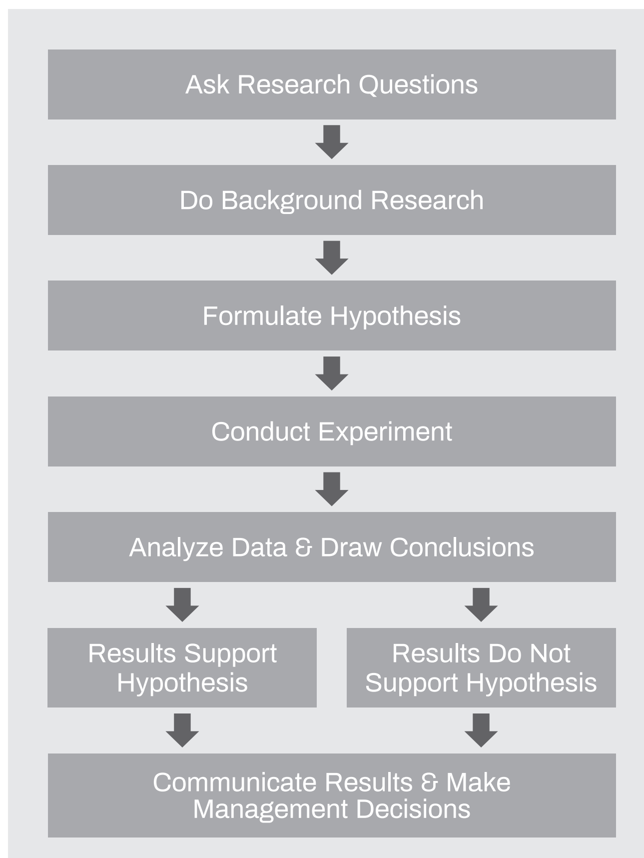


**Figure 1.** Scientific method process.

**Table 1.** Examples of research questions and associated hypotheses.

| Example | Research Question | Hypothesis |
|---|---|---|
| A grower is interested in investigating the impact of different levels of irrigation on wheat yield. | Will decreasing levels of irrigation lower wheat yield? | Decreasing water application by 25% will not decrease wheat yield. |
| A grower is interested in comparing the efficacy of two types of fertilizer. | Is liquid nitrogen fertilizer more effective than dry granular nitrogen fertilizer? | Liquid fertilizer will result in higher grain yield and better quality. |

The scientific method is used to ask a research question, then prove or reject a hypothesis based on data that are gathered and then analyzed (Table 1). Both the research question and the hypothesis refer to potential outcomes of the project. The research question is the question that we set out to answer and is used to focus analysis and investigation of a particular topic. In contrast, the hypothesis is a predictive statement. It is formulated to predict the project outcome: "If [I do this], then [this] will happen." A well-formulated hypothesis contains a prediction that is easily measured, which allows sound conclusions to be drawn upon collection and analysis of data.

It's important to conduct background research in the beginning stages of the project. Doing an online search to thoroughly educate about the topic of the on-farm research will help with formulating your research question and choosing the most appropriate materials and methods to answer them.

# Designing the experiment

After the research question has been determined, some preliminary background research has been conducted, and a hypothesis has been formulated, it is time to establish an on-farm research experiment.

## Site selection

The most common mistake in designing on-farm experiments, is to ignore the fact that the inherent variation in a field can mask or obscure treatment differences. Choosing a site that is as uniform as possible helps to ensure that each treatment has an equal opportunity to perform. Factors such as topography, soil characteristics, previous crop, fertilizer and chemical application history, and tillage must be considered when selecting a site.

## Experimental units

The objective of a typical on-farm experiment is to quantitatively compare treatments assigned to experimental units (e.g., plots or strips) by determining if there are significant differences resulting from these treatments. Replicating treatments, randomizing how treatments are applied, and using a control allows certainty that any differences observed are truly due to the applied treatments, rather than background variation that is naturally present in a field.

## Control

A control (or check) refers to experimental units to which all other units will be compared to determine if there are statistically significant differences among treatments. For example, if a grower is testing effects of a particular input (e.g., fertilizer or herbicide), the control will be the check plots to which no input is applied. If a grower is testing a new equipment or practice, the typical equipment or practice used would be the control.

## Replication

Physical replication of experimental units across a field is necessary to quantify the variability among experimental units that receive the same treatment. The variability from these plots is essentially "noise," resulting from within-field variability, measurement errors, environment, equipment or software issues, and human error. Each treatment should be replicated at least four times.

## Randomization

Randomly assigning treatments to experimental units eliminates bias and helps to counteract the impacts of spatial variability. For an experiment containing only two or three treatments, an easy way to randomize is to do a "coin flip" or "hat draw." Randomization is also important for statistical data analysis.

## Experiment layout

There are two layouts commonly recommended for on-farm experiments. The Completely Randomized Design is suited for more uniform sites with less in-field variability. In this design, treatments are assigned at random throughout the entire experiment (Figure 2). The second type of layout is the Randomized Complete Block Design, which is suited for less uniform sites and sites with gradients. In this type of design, each block contains a complete set of treatments (Figure 3). It is important to make sure that each block represents all gradient levels. Figures 4 and 5 show examples of incorrect and correct blocking layout.

## Requesting assistance

Requesting assistance from those who do research for a living is a great idea. A poorly planned and designed on-farm research project has a high risk of not being successful. University researchers, Extension specialists and educators, industry researchers, and crop consultants are available to assist growers.

## Multisite and multiyear replication

The more site-years of data that are collected, the more certain we can be about the results of the study, which will improve the management decisions made based on the results. Because environmental conditions have such a significant impact on plant and soil systems, on-farm trials should be repeated for at least two years. Caution must be taken when establishing the study in the second year to ensure that the previous year's treatments do not affect the second-year results. Moving the study to a different part of the field, or to a different nearby field, is highly recommended. Detailed recordkeeping is critical to ensure that the experiment can be replicated using identical methods and materials.

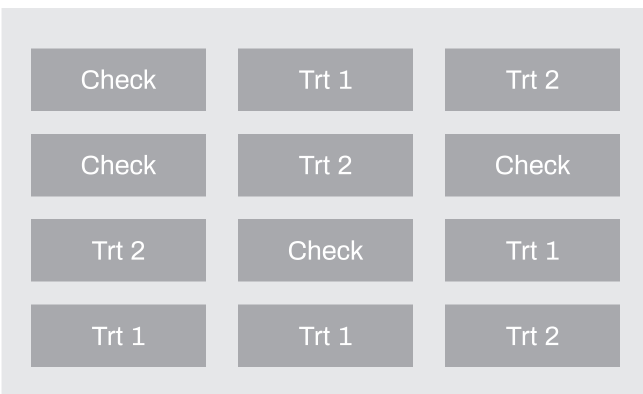


**Figure 2.** Completely Randomized Design plot layout with three treatments (check, trt 1 and trt 2) replicated four times.

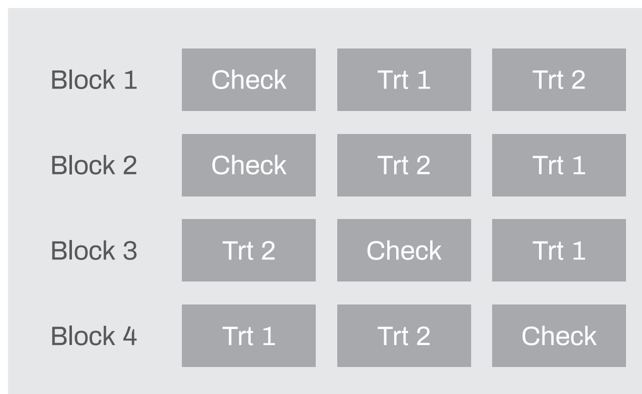


**Figure 3.** Randomized Complete Block Design plot layout with three treatments (check, trt 1 and trt 2) replicated four times, and grouped into four blocks.

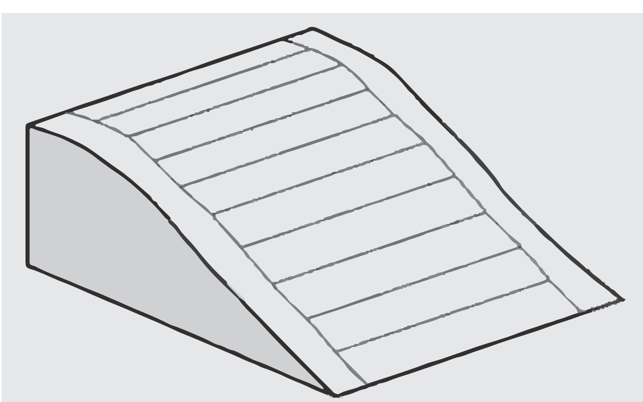

**Figure 4.** Incorrect blocking layout—each block represents only one level of gradient.

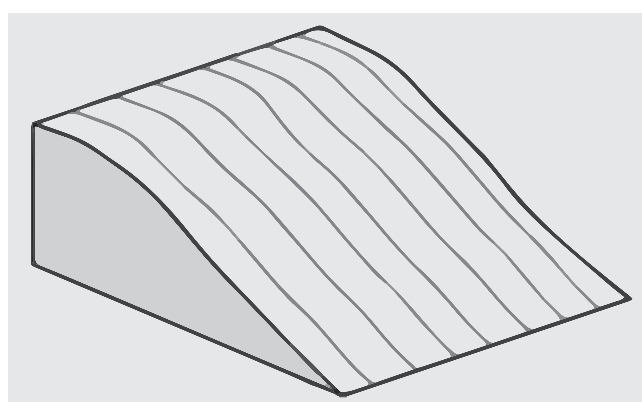

**Figure 5.** Correct blocking layout—each block represents each level of gradient.

# Recordkeeping and data collection

## Recordkeeping

It is important to keep detailed written records for on-farm experiments. Well-kept records are critical for interpreting data and understanding research results. In addition to clearly-stated objectives, treatments, experimental design, and plot layout, records should include field history, soil test results, fertility program, tillage operations, chemicals applied, and any other potentially relevant information.

## In-Season observations

Records should include observations of plant growth and development, climatic information such as rainfall and temperature, and any abnormal conditions (e.g., extreme heat or drought) that might be important in explaining final study results. Any visual difference among treatments must be recorded. Finally, it is also important to record when no differences are observed.

## Data collection

It is important to identify what parameters will be measured and plan when and how to take measurements. The measurements required will be directly related to the project's objectives. For example: If the project's objective is to increase soil water retention, soil moisture measurements must be taken. If the purpose is to increase net profit of the farming operation, detailed measurements of all input costs and returns (including yield) must be recorded. For most on-farm experiments, yield serves as the ultimate measurement of treatment success or failure. Best results are achieved with an accurately calibrated yield monitor. In addition, one should try to harvest the entire experiment on the same day (to minimize environmental effects), using the same combine (to avoid calibration differences). Finally, quality parameters such as protein levels may need to be carefully measured and recorded as well.

# Data analysis

The type of data analysis needed, generally, depends upon project design and implementation. It can be difficult to tell just by looking at the data whether differences are truly due to treatment effects, or simply due to random variation. Furthermore, it is difficult to say if differences are truly significant without carrying out statistical procedures.

The differences between treatments are commonly determined using the Least Significant Difference (LSD)–a parameter designed to minimize the risk of making an incorrect conclusion about treatment differences. If two treatment means (averages) differ by more than the LSD value, we can conclude that the difference is due to treatment effects and that similar results can be expected if the experiment is repeated (Figure 6). If two treatment means differ by less than the LSD value, it is likely that the difference is due to random variation or error, and the same results are not likely to be observed in the future (Figure 7).

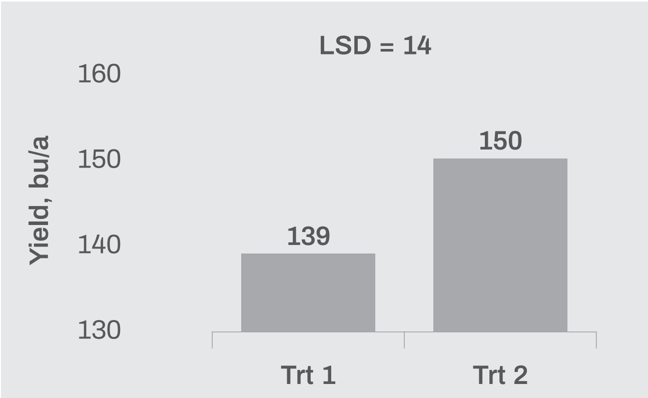


**Figure 6.** Numerically higher yield was achieved with treatment 2, but statistically speaking treatment 1 and treatment 2 are equal (150 - 139 = 11 < 14).

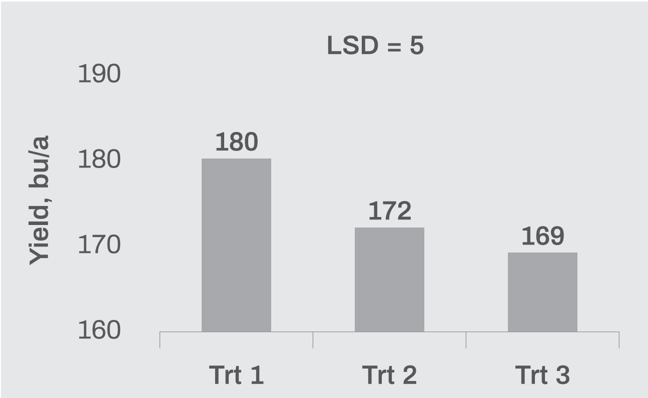


**Figure 7.** Numerically, yields decreased as treatment 1 > treatment 2 > treatment 3; statistically, treatment 1 > treatment 2 and treatment 1 > treatment 3, but treatment 2 = treatment 3 (180 - 172 = 8 > 5; 180 - 169 = 11 > 5; 172 - 169 = 4 < 5).

Statistical analysis is conducted to estimate the probability that the differences observed were caused by the applied treatments. The results of data analysis can then be used for drawing conclusions on the effects of the treatments. Typically, a 95% confidence level is used, which means that there is a 95% chance that measured differences are due to the treatments rather than random variation or error. Additional information on data analysis from on-farm experiments can be found in Chaney (2017), Iowa Soybean Association (n.d.), and Sooby (n.d.).

For data analysis and interpretation of their results, growers are encouraged to work closely with university researchers who have access to statistical specialists and resources. University of Idaho Extension specialists and educators represent a great resource for growers conducting on-farm research. Contact information for University of Idaho Extension county offices can be found at http://www.extension.uidaho.edu/find.aspx.

## Making management decisions

Although many on-farm research projects are focused on agronomics, there are many other factors to be considered when making management decisions regarding the adoption of new products or practices. Even though the agronomics of a new practice may make sense, it is also important to also consider intangible benefits (e.g., improvements in soil quality, enhancement of the environment) resulting from changes in farming practices. Furthermore, it is important to focus on the economics of a new practice. Measuring costs and benefits will help a producer determine whether the assessed practice will be worthwhile from a farm enterprise perspective. As an example, fertilizer A may produce significantly higher yields compared to fertilizer B, yet may be cost-prohibitive and, therefore, not make sense from an economic perspective.

## Economic assessment

### Economic evaluation

An economic evaluation of on-farm research trials will help growers identify potential weaknesses or shortcomings from an economic perspective and, thus, determine whether a proposed change is worthwhile. A detailed economic analysis may also help garner support from potential funding sources or others involved in making farm decisions.

Economic analysis is often undertaken at the end of an on-farm trial. However, it is important to consider economics at the beginning of the project for two reasons: 1) so that all relevant data for the analysis are collected in an efficient manner, and 2) to make sure that the trial has been set up in such a way that all the economic questions of interest will be answered. Economic comparisons typically involve a comparison of “with” and “without” treatments. Even when measuring the impact of two different levels of an input (e.g., fertilizer), it may be necessary to have a control plot without any fertilizer to get a complete picture of how the fertilizer is affecting crop yields.

Recordkeeping for economic analysis can occur simultaneously with recordkeeping for agronomic data. However, careful planning is necessary to ensure that the required data are collected. For example, differences in labor hours or management time are often ignored, particularly if these are not cash expenses to the operation.

### Budgeting

There are many types of budgets that can be used to evaluate an on-farm experiment. Enterprise budgets itemize expenses, income, and net profit from a specific enterprise, typically over a one-year period. Budgets can help supply input costs and crop prices for particular enterprises as well as costs for machinery usage. Many land grant universities provide current enterprise budgets for typical crop and livestock production systems in their region. If it’s possible to find a good template for a similar enterprise, adapting this budget for the situation may save time and give better results. However, creating an enterprise budget from scratch may be the best approach if there are no appropriate examples available. There are many resources available for this purpose (Harper 2013; Smathers 1992). In this publication, simple approaches for analyzing the economic results of an on-farm trial are discussed, including partial budgeting, sensitivity analysis, and break-even analysis.

#### *Partial budgeting*

Partial budgeting is a systematic method of comparing positive and negative outcomes from a proposed change over a specific time period, usually one year or one production cycle. In partial budgeting, the analysis is simplified; only the costs and returns that differ are considered.

While a partial budget analysis can be undertaken on its own, it is helpful to refer to a complete enterprise budget. Typical examples of partial budget problems include substituting one crop for another, adopting a new production practice, or expanding production.

In order to compare two alternatives using partial budgeting, it is important to collect data showing the value of negative impacts (additional costs and reduced revenue) and positive impacts (additional revenue and reduced costs), on an annual basis. These items are typically arranged as shown in Figure 8.

A partial budget analysis focuses on average annual performance, that is, what happens in a typical year. Two tools are used to annualize, or calculate yearly costs, for a multiyear expense. The first tool, a simple economic depreciation calculation, is used to allocate this expense over the length of its useful life. For example, a large farm truck purchase would be annualized by estimating the following:

- purchase price or market value at the time of purchase;
- length of time that this purchase will be used; and
- salvage price at the end of this time.

These values are then used to estimate an annual value for this expense (Figure 9).

The second tool calculates a value that represents interest, also referred to as the time value of money or cost of capital. This interest cost can be considered an opportunity cost. In other words, money is tied up in this expense that could have been used elsewhere, so any gain the money would have realized in an alternative use is lost. For example, this money could have been earning interest in an interest-bearing account or it could have been used to fund an alternative investment. The interest cost could also simply represent the cost of borrowing funds. In either case, the annual interest rate should represent a value that reflects the cost of capital.

To calculate an annual cost of interest, use the purchase price and salvage price from the depreciation calculation above to determine the average value of the investment over the life of the investment. This is a simple average of the purchase and salvage prices for the investment (Figure 10).

Then, multiply this average value by the annual interest rate chosen for this investment (Figure 10). This estimates the annual cost of capital for the life of the investment.

| Problem: | |
|---|---|
| Additional Costs: | Additional Revenue: |
| Reduced Revenue: | Reduced Costs: |
| A. Total additional costs and reduced revenue: $ ______ | B. Total additional revenue and reduced costs: $ ______ |

$ (B) - $ (A) = $ (Net Change in Profit)

**Figure 8.** A partial budget analysis is typically arranged in two columns, with negative impacts in one column and positive impacts in a second column, much like a benefit-cost comparison.

Simple Economic Depreciation:

$$\frac{\text{Purchase Price - Salvage Value}}{\text{Years of Life}} = \text{Cost/year}$$

Example:

$$\frac{\$40{,}000 - \$10{,}000}{10 \text{ years}} = \$3{,}000\text{/year}$$

**Figure 9.** A simple economic depreciation formula is used to calculate an annual cost for a multiyear purchase with a purchase price of $40,000, a salvage value of $10,000, and an estimated 10 years of life.

Annual Cost of Capital:

(Purchase Price + Salvage Value) ÷ 2
= Average Value of Investment

Average Value of Investment × Annual Interest Rate
= Annual Cost of Capital

Example:

($40,000 + $10,000) ÷ 2 = $25,000
$25,000 × 8% = $2,000/year

**Figure 10.** Annual cost of capital formula.

The following example illustrates how to compare the costs and benefits of a multiyear investment. Using the values for the large farm truck in Figures 8 and 9, it is possible to compare the expense of paying for freight when selling grain locally to the expense of purchasing a large farm truck for this purpose (Figure 11). First, it's necessary to identify the costs that vary. These may fall into several categories, such as inputs, labor, equipment rental, or hauling expenses. Which costs and returns will vary under the proposed plan to purchase a large farm truck?

- Increased costs and reduced revenue
- truck purchase (This is a multiyear expense, so use the annualized depreciation and interest values from Figures 9 and 10.)
- truck operating costs (e.g., fuel and repair costs)
- labor costs
- loss in revenue associated with this change, if applicable
- Additional revenue and reduced costs
- any additional crop revenue you might receive if you hauled it yourself
- reduced costs would include the hauling charges that would be avoided

Let's assume that freight cost savings are $1.45 per bushel. On a yearly basis, 15,000 bushels of wheat are shipped, so the cost reduction would be $21,750 per year. Operating costs for the truck would be based on 15 semi-truck loads hauled to a river port. The round trip takes nine hours. Fuel and repair costs per year for 135 hours of operating time would be $10,800. Labor costs would be based on a $20 per hour wage for a truck driver, which would be $2,800 for 140 hours. In addition, an unknown amount would be saved on handling fees charged by the hauling company. But, let's just add up the known costs at this point. The net change in profit from this example is $3,150 per year. Thus, this purchase of a grain truck would result in a more profitable operation.

The following example uses a partial budget analysis to assess the profitability of reseeding a field with spring wheat after a field of winter wheat had poor stand survival. The winter wheat that survived is estimated to yield 30 bushels per acre and would sell for $5.25 per bushel. The spring wheat crop would yield about 50 bushels per acre and sell for $6.25 per bushel. The additional costs of cultivating, fertilizing, and seeding are estimated at $70.93 per acre. The additional operating interest for these expenses would be $2.84. The net change is $81.23 per acre (Figure 12).

**Partial Budget**

Alternative: Purchase a used semi truck for hauling your own grain.

| | | | |
|---|---|---|---|
| **Additional Costs:** | | **Additional Revenue** | **$0** |
| *Fixed costs* | | | |
| Interest on truck purchase | $2,000 | | |
| Economic depreciation on truck | $3,000 | | |
| *Variable costs:* | | | |
| Labor | $2,800 | | |
| Fuel and repair | $10,800 | | |
| **Reduced Revenue** | **$0** | **Reduced Revenue:** | |
| | | Hauling: $1.45 bu x 15,000bu | $21,750 |
| | | Handling fees | |
| **A. Total additional costs and reduced revenue:** | **$18,600** | **B. Total additional revenue and reduced costs:** | **$21,750** |
| | | Less additional costs and reduced revenue: | **$18,600** |
| | | **Net Change in Profit (B-A)** | **$3,150** |

**Figure 11.** A partial budget analysis of a grain truck purchase.

| | Partial Budget Template | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Reseeding problem** | | | | | | | |
| | **Section 1** | | | | **Section 3** | | | |
| | **Additional returns from proposed change** | **Price/ unit** | **Quantity** | **Amount of Change** | **Additional cost of proposed change** | **Price/unit** | **Quantity** | **Amount of Change** |
| **1** | sell spring wheet | $ 6.25 | 50 | $312.50 | Cultivation | $ 8.32 | 1 | $8.32 |
| **2** | | | | $0.00 | Fertilization | $ 5.66 | 1 | $5.66 |
| **3** | | | | $0.00 | Drill | $ 11.05 | 1 | $11.05 |
| **4** | | | | $0.00 | Seed | $ 80.00 | 0.28 | $22.40 |
| **5** | | | | $0.00 | Nitrogen | $ 0.94 | 25 | $23.50 |
| **6** | | | | $0.00 | SUBTOTAL | | | $70.93 |
| **7** | | | | $0.00 | Interest on operating capital (6 months at 8% = 4%) | $ 0.04 | $70.93 | $2.84 |
| **8** | | | | $0.00 | | | | |
| **9** | | | | $0.00 | | | | |
| **10** | **Sub-total additional returns** | | | **$312.50** | **Sub-total additional cost** | | | **$73.77** |
| | **Section 2** | | | | **Section 4** | | | |
| | **Reduced costs from proposed change** | **Price/ unit** | **Quantity** | **Amount of Change** | **Reduced returns from proposed change** | **Price/unit** | **Quantity** | **Amount of Change** |
| **11** | | | | | Loss of winter wheat | $ 5.25 | 30 | $157.50 |
| **12** | | | | | | | | |
| **13** | | | | | | | | |
| **14** | | | | | | | | |
| **15** | | | | | | | | |
| **16** | | | | | | | | |
| **17** | | | | | | | | |
| **18** | | | | | | | | |
| **19** | | | | | | | | |
| **20** | | | | | | | | |
| **21** | **Sub-total reduced costs** | | | **$0.00** | **Sub-total reduced returns** | | | **$157.50** |
| | **Summary Section** | | | | | | | |
| **22** | **Total Change in Benefits (Section 1 + Section 2)** | | | **$312.50** | **Total Change in Costs (Section 3 + Section 4)** | | | **$231.27** |
| **23** | **Net Change in Income (Change in Benefits - Change in Costs)** | | | **$81.23** | | | | |
| | Adapted from University of Missouri's template written by Dr. Vern Pierce by Kathleen Painter, University of Idaho Ag Extension Educator | | | | | | | |

**Figure 12.** A partial budget analysis of the reseeding problem.

The partial budget template shown in Figure 12 is available at http://tinyurl.com/partialbudgettemplate. This same approach could be used to compare different scenarios, including: crop alternatives, hiring custom machinery versus using your own machinery, direct seed versus conventional tillage, and pesticide usage.

## *Sensitivity analysis*

Sensitivity analysis answers questions about how sensitive the analysis results are to the underlying assumptions. For example, if there is uncertainty about the price assumption for the spring wheat in the reseeding problem, sensitivity analysis could be used to see how the results would change at different prices. For example, if a grower only receives $5.75 per bushel, the net change in income drops to $56.23 per acre. The price ($6.25 per bushel) can also be replaced with a variable, or unknown (“x”), and then solved algebraically for x. This will give the breakeven price for spring wheat. In other words, at this breakeven price, you would recover all of your reseeding expenses.

The breakeven price for spring wheat can be determined using an equation that has all the benefits (additional returns and reduced costs) on one side and all the costs (additional costs and reduced returns) on the other side, as follows:

($6.25 per bushel) x (50 bushels) =
$73.77 (additional costs) + $157.50 (reduced returns)

Solve for the breakeven price for spring wheat, replacing $6.25 per bushel with “x”:

50x = $231.27

x = $4.62 per bushel

Finding the breakeven price, or yield, or solving for any particularly critical variable, may be helpful for determining the amount of risk involved with this decision. In the example above, if it seems that obtaining a price higher than $4.62 per bushel for spring wheat will be easily achieved, then there is little risk involved with this decision. The breakeven yield can be calculated using the same technique:

($6.25 per bushel) x (50 bushels) = $73.77 + $157.50

Solve for the breakeven yield for spring wheat, replacing 50 bushels with "x":

$6.25x = $231.27

x = 37 bushels per acre

### *Breakeven analysis*

Another technique, called breakeven analysis, analyzes economic risk for a specific enterprise using total production cost and estimates for yield and crop price to determine breakeven values that will cover these costs. Here, total production costs are divided by estimated yield to determine the breakeven price per bushel necessary to cover these costs. The breakeven yield is determined similarly, by dividing total production costs by the crop price per bushel. In the previous example, an additional $73.77 per acre is necessary to grow a crop of spring wheat. Dividing those costs by the expected yield of 50 bushels per acre, the breakeven spring wheat price is $1.47 per bushel. Similarly, the breakeven yield, assuming a spring wheat price of $6.25 per bushel, is 11.8 bushels per acre.

## Summary

A successful research project is one that provides a grower with a clear and accurate answer to the question being asked. By identifying funding sources, following the scientific method, conducting a well-designed experiment, and following the strategies for record keeping, data collection, and analysis outlined in this publication, growers can conduct on-farm research and make informed, scientifically based management decisions, appropriate for their farming operations.

To accurately measure the economic impacts using on-farm research, economic analysis should be integrated into the initial planning of an on-farm trial. If there is an existing enterprise budget that can serve as a template for the experiment, this will be useful and save time. Partial budgeting, as presented in this document, allows explicit evaluation of two alternatives, by focusing on the differences in income and expenses for the two systems. Sensitivity analysis can be used to investigate how sensitive the results are to the underlying assumptions. Breakeven analysis gives the necessary yield (or price) needed to cover production costs, given price (or yield) assumptions. Breakeven analysis gives producers an idea of the degree of risk involved for a proposed change.

## References and further reading


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