PRECISION AGRICULTURE

Precision Agriculture in Kentucky:

Research Projects and Findings

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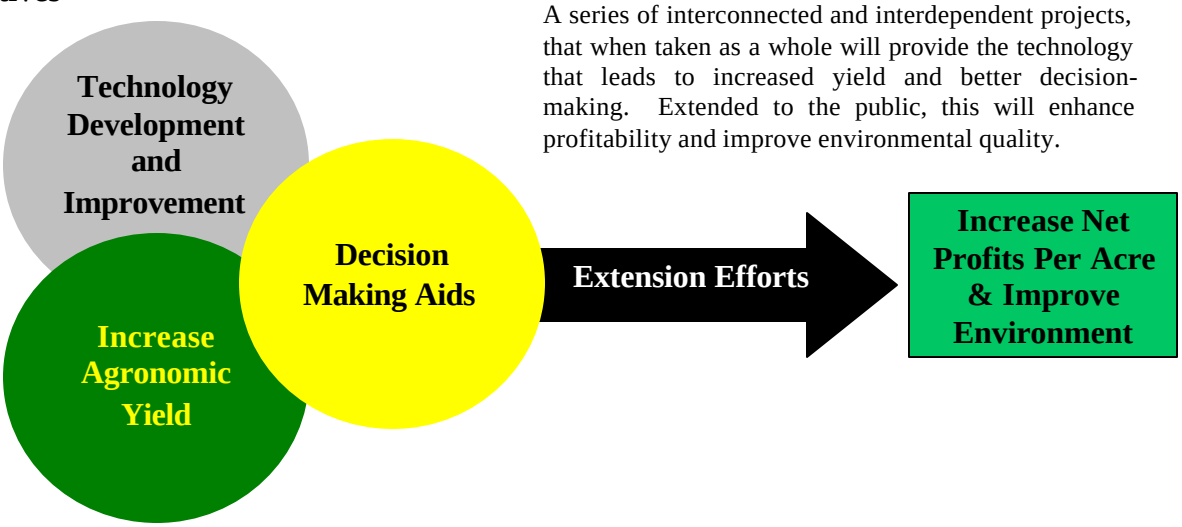
Mission

The overall project goal is to develop and assess precision agriculture equipment and technologies for implementation on Kentucky farms to enhance profitability and improve environmental quality.

Objectives

A series of interconnected and interdependent projects, that when taken as a whole will provide the technology that leads to increased yield and better decision-making. Extended to the public, this will enhance profitability and improve environmental quality.



In the pages that follow, you'll read about the projects that are underway. Findings and progress from these studies are itemized with bullets following the project description.

Current Projects & Findings

Grain Yield Monitor Accuracy - *Scott Shearer, Richard Barnhisel, Sam McNeill, Tom Mueller, Larry Wells, Steve Higgins*

Accuracy of yield monitoring devices is a key component of precision agriculture. This project will assess the accuracy of yield monitors in the laboratory and field.

- Plot and yield monitor values differ, but in a predictable fashion.
- In general, the inaccuracy of in-field hand-held moisture meters prevents proper calibration of yield monitors.
- The greatest deviation in accuracy occurs at the margins of the elevator capacity.
- There is no observed influence from hillside operation.

Soil Characteristics and Yield- *Lloyd Murdock, Tom Mueller, Paula Howe*

Fertility variation in the surface layer of soil has not successfully explained yield variability, implying that factors other than soil fertility may have influence yields. The study's objective is to map soil morphological characteristics, both on the soil surface and in the horizon, and then determine if it is associated with yield variability of corn and/or soybeans.

- Of the 15 characteristics that were investigated, topsoil depth was the most important, describing 70-90% of the yield variability in data collected so far.
- Having 8 in. of topsoil is important, as each inch increased the corn yields by 10.1 bu/ac up to 8 in. on average.

Variability of High Value Components Within a Field- *Sam McNeill, Scott Shearer and Steve Higgins*

Variations may exist among the highly valued chemical components of common grain crops. This project will identify the spatial variability of moisture, protein and fiber components of corn, soybeans and soft red winter wheat and the oil components of corn and soybeans.

Variable-Rate Seeding and Nitrogen Application - *Richard Barnhisel, Morris Bitzer, Scott Shearer, Lloyd Murdock, Paula Howe*

Prior work suggests that varying seeding and nitrogen rates based on topsoil depth could have an economic benefit to the grower. The purpose of this study is to evaluate techniques for varying seeding and nitrogen rates.

- Yields from the variable seeding rate plots, based on topsoil thickness exceeded the yields from the constant seeding on the similar soil depths.
- The highest yield was on the deepest soil, where the variable seeding rate increased net return $20.89/a and $32.63/a compared to the 24K and 27K seeding rates, respectively, the first year averaged over the seven locations.
- Averaged over three years and seven locations each year, variable seeding increased net return $ 17.51/a per year (range was $5.73 to $34.95) over the recommended constant 27K seeding rate.
- Varying both the seeding and nitrogen produced the greatest net returns, varying seeding and N increased gross returns by $39.10 per acre compared to the constant 24K, 27K & 30K seeding rate with a constant 160 pounds N.

Variable-Rate P, K and Lime Application - *Scott Shearer, Tom Mueller, Richard Barnhisel, Sam McNeill, Lloyd Murdock, Steve Isaacs, Carl Dillion, Steve Higgins*

Variable-rate application of fertilizer and other soil amendments has generated a significant amount of interest among producers and service providers, yet there are many ancillary issues that may influence the profitability associated with this technology. The goal of this investigation will be to assess crop response and the economics of variable-rate application.

- Work completed to date includes extensive grid sampling and multiple years of variable-rate application of P, K and ag lime application on farms in Shelby and Woodford Counties.
- Cluster analysis provides ~$4.86/a in corn.
- This study is currently being extended to include multiple operators from other regions within Kentucky.

Site-Specific Banding of Phosphorus/Potassium - *John Grove, Tom Mueller*

Pop-up and/or starter fertilizer applications have been proposed to alleviate early season nutrient stress, to improve crop stands, and to improve early plant development. The crop's ability to recover soil phosphorus and potassium is related to soil chemical and physical properties, thus a map of the spatial distribution of these properties should drive crop response to banded nutrition and the decision to apply banded fertilizer.

Distribution and Impact of Perennial Weeds - *Bill Witt, Richard Barnhisel, J.D. Green and Jim Martin*

Over the past few years, the appearance of perennial weedy species has become the greatest challenge to weed management. GPS technology would allow growers to target specific weed management strategies at those areas of the field where the perennial weeds occur. In addition to the lower cost of inputs, significant environmental stresses may be averted.

Potential of Precision Tillage - *Larry Wells, Scott Shearer, Lloyd Murdock*

Negative impacts on yield due to soil compaction by equipment traffic can be reversed by tillage. The objectives for this project are: 1) to measure the soil compaction via cone penetrometer resistance; 2) to apply precision tillage to those fields where penetrometer resistance exceeds 2.5 MPa; and 3) to determine the cost effectiveness of precision tillage of this practice.

- Preliminary 2001 yield maps indicate positive response to deep tillage while ongoing work seeks to determine a recommendation on deep tillage that will result in maximum net revenue. Remote aerial near infrared (NIR) images of the fields have been acquired in an attempt to identify a low cost method of verifying that adverse soil compaction exists and that deep tillage should be applied. Results to date have not produced a strong correlation between remote aerial NIR reflectance and soil compaction

Evaluation of Soil Sampling Strategies - *Tom Mueller, Scott Shearer, Tasos Karathanasis, Mark Coyne, Richard Barnhisel, Carl Dillon, Michael Collins*

Precision agriculture technologies have allowed farm fields to be managed at finer and finer scales, yet the scale of measurement is related to the costs and profitability of grid soil sampling, it is important to understand the relationship between map quality and the intensity of sampling.

- Work complete on this project to date includes:
  - assessment of the efficacy of grid soil sampling,
  - a better understanding of soil electrical conductivity,
  - assessment of the utility of precision agriculture technologies used to enhance soil surveys, and
  - assessment of the spatial variability of microbial processes in Kentucky soils.

Investigation of Machinery Limitations - *Scott Shearer, Sam McNeill, Tom Mueller, Richard Barnhisel, Larry Wells, Steve Higgins*

Site-specific management is currently limited by the cost of obtaining and utilizing information about a given field such as soil fertility as well as the limitations of variable-rate application equipment. This project is intended to assess and quantify machinery limitations and cost/life of the equipment.

- A machine has been developed and tested for the extraction and composting of up to five soil sample cores simultaneously with a 30 second time frame.
- GPS receiver testing protocol has been revised to include dynamic testing in a continuous curvilinear path.
- This testing has revealed that the use of digital filters from some manufacturers, intended to improve static accuracy, actually degrade dynamic receiver performance.
- Application errors when using spinner spreaders to accomplish VRT application where in excess of 5% for more than 30% of the applied area.

The Economics of Precision Agriculture and Decision Aids - *Carl Dillon, Steve Isaacs, Ron Fleming and Gregg Ibendahl*

An economic assessment of the costs and benefits of precision agriculture technologies is needed to understand their impact on profitability. The primary objective of this work involves evaluating profitability of alternative precision agriculture technologies and production practices as well as determining costs of implementation.

- Custom hire of precision agriculture services appears to be more cost effective for average or small sized producers. Decisions regarding CRP enrollment driven by the combination of economic analysis and yield maps can increase profitability and reduce risk.
- Extending this analysis to consider variable rate planting dates with new chemical seed coatings has the potential to enhance profitability as well as help manage risk.

Explaining and Understanding Variability in Grain Yield - *Tom Mueller, Scott Shearer, Tasos Karathanasis, Lloyd Murdock, Richard Barnhisel, Carl Dillon, Than Hartsock*

Historical grain yield maps are of great value to growers in Kentucky; however, many producers lack the tools and, therefore, the ability to fully utilize them. The objective of this study is to develop an economically feasible approach for producers to create maps that define limitations to yield within agricultural fields.

- A computer program for creating management opportunity maps is in the development stages.

Evaluating Nutrient Removal as a Basis for Nutrient Management - *John Grove, Mark Coyne*

Precision nutrient management requires consideration of the unique combinations of crop and soil responses within a field. Soil sampling to aid nutrient management is expensive, however yield monitoring has the potential to estimate nutrient removal.

- Early indications are that fertilizer P and K prescriptions based on yield maps are inferior to soil sample based recommendations.

Using Trends in Soil Formation to Differentiate Crop Management Zones - *John Grove*

Common methods for characterizing the variability of a field's soil, such as grid sampling, can be expensive and do not consider the primary cause of soil variability—processes of soil formation. Instead of characterizing the observed patterns, linking patterns of soil characteristics, such as topsoil depth and soil organic matter/clay content, within a field with processes of soil development may prove to be more valuable.

- Early indications are that crop management zones can be predicted from soil formation characteristics more cheaply than with grid sampling.

Remote Sensing of Pasture Mass and Quality - *Michael Collins, Tom Mueller, David Ditsch, C.T. Dougherty*

Remote sensing and terrain attribute information available for large areas at a low cost could be valuable management tools for pasture and hay crops. This study will (1) evaluate the use of soil:plant relationships within a field to develop more efficient forage management systems and (2) improve forage utilization by using remotely sensed spectral data to provide livestock producers with accurate, timely information on forage availability and quality.

Dynamic Testing of Force-Impetus Yield Monitors Under Rough Terrain Conditions - *Thomas Burks, Scott Shearer, Larry Wells, Sam McNeill, John Fulton, Steve Higgins*

The traditional combine yield monitor used in the United States is a force impetus system. Consequently, motion in the grain elevator could have a significant effect on instantaneous grain yield prediction.

- A grain elevator gimble with instrumentation to collect elevator acceleration and vibration data has been developed as a component of the yield monitor test facility.
- Laboratory and field tests are planned for the '02 harvest season.

Evaluation of the Effects of Topography Attributes on Yield - *Richard Barnhisel, Ronald Fleming*

Topographic attributes, such as slope and aspect, are important contributors to soil formation and topsoil depth. Soil types are often mapped according to these characteristics. The topographic position also influences the water availability (runoff and run-on), which contributes to variations in corn yield.

- Corn yields were affected when both seeding and nitrogen rates were varied according to topographic position and/or topsoil thickness, resulting in ~$15/a greater net return.

Varying Nitrogen Rates Based on Yield Maps - *Lloyd Murdock, Paula Howe*

A history of past yield maps can be used to determine the low, medium and high producing areas in the field. This project will help determine if varying nitrogen rates based on mapped historical averages of yield could be successfully and profitably applied to corn production.

- Early indications are that the nitrogen rates needed for optimum yields were almost the same in the high yielding areas as well as the low yielding areas. If nitrogen mineralization is taken into account, the nitrogen recommendations, on well-drained soils, can probably be reduced by 20 to 25 lbs/ac. This would amount to a savings of about $6.00/ac or 3 million dollars over 500,000 acres.

Comparison of Two NIR Monitors for Corn and Wheat - *Sam McNeill, Michael Montross*

The grain industry is moving towards a value-enhanced marketing system where market premiums are based on specific grain quality traits. Grain buyers are currently using near infrared (NIR) instruments to determine the fiber, moisture, oil, protein, and starch content of corn. This study will compare quality values from two NIR instruments--a mobile experimental unit mounted on a combine and a commercial laboratory unit with that of an independent lab.

- Progress to date includes the use of a commercial NIR instrument to measure protein and oil content of corn, soybeans and wheat. Unfortunately, the mobile NIR instrument has not been made available for testing by the manufacturer.

Low Cost GPS-Based Sensors for High Speed Agricultural Vehicle Guidance - *Tim Stombaugh, Larry Wells, Scott Shearer*

One of the major hindrances to adoption of automated guidance technology for agricultural field machinery is the cost and complexity of the sensors used to measure vehicle position. The goal of this project is to develop a low cost sensor system that can be used for guidance of high-speed agricultural vehicles.

- Progress to date includes the development and testing of A DGPS-based automatic guidance system on an agricultural tractor and high-speed field sprayer. This system uses very low cost components that are common in precision agriculture and could have a significant impact on the chemical application industry.

Precision Farming Adoption in Kentucky: The Role of Capital Costs and Farm Size - *David Debertin, Ronald Fleming, Carl Dillon*

Precision farming encompasses a broad array of technologies that have potential to improve agricultural production profitability, particularly field crop production. These technologies vary both in complexity and in cost. This project represents an effort to determine the extent to which costs will limit the adoption of alternative precision farming technologies and to measure the potential benefits to Kentucky farmers.

- Findings illustrate that precision farming technologies are generally not cost effective for farms producing 500 acres of grain or less annually, given the current equipment costs and costs of implementation.
- Precision farming technologies might be cost effective for farms producing more than 1600 acres of grain annually, but this depends on the particular characteristics of the farmland as well as prices for the various grains.
- A spreadsheet model has been developed that allows a farmer to determine the cost-effectiveness of each of a number of specific precision farming technologies given the farm size and other specific characteristics of the farm. This model specifies grain and capital input prices, but these can be altered to suit a particular farmer's situation.

Spatial Applications for Agriculture: Educational Case Studies - *Scott Shearer, Tom Mueller, Carl Dillon, Sam McNeill*

Training producers, service providers, and college students in the acquisition and analysis of spatial data is required for assessing the profitability of precision agriculture practices. The focus of this effort will be to develop training modules for delivery to undergraduate students at the University of Kentucky and other institutions, and in workshops dedicated to county agents, services providers and producers.

- Project progress to date includes the development of a web-based course with 16 educational modules. This course was offered during the Spring Semester of 2001 with an enrollment of 17 upper level undergraduate and graduate students. The course will be offered again during Spring Semester of 2002.
- A second phase will extend this training to county agents, service providers, and producers.

New and Expanded Projects

Sensors and Variable Rate Management - *Tom Mueller, Tim Stombaugh, Scott Shearer, Richard Barnhisel, Carl Dillon, Lloyd Murdock, Morris Bitzer, Mike Collins, John Grove, Larry Wells*

Previous work has shown that soil type and depth can be used to predict crop response to nitrogen, however soil surveys were not created at a scale to micro-manage this variability. Therefore, developing methods to utilize sensors to help predict where in fields there will be an agronomic response to nitrogen is critical. We have two objectives in this project: 1) to develop methodologies to collect and calibrate remote and ground based sensor data for precision agriculture applications and 2) to develop methodologies for utilizing sensors for variable rate nitrogen management.

Outreach Education for Precision Agriculture - *Tim Stombaugh, Scott Shearer, John Fulton, Tom Mueller, Carl Dillon*

One of the many challenges faced by precision agriculture users is managing spatial data. Too often, the available data sets are not projected in compatible coordinates. In addition, the software tools to manage the data can be complex and cumbersome. The goal of this project is to develop an outreach program that will help producers and service providers to learn to use precision agriculture software (Geographic Information Systems and mapping packages) to properly manage and analyze spatial data. The outreach program will address issues of data availability and compatibility while providing hands-on educational experience with field data collection, building spatial farm databases, and data analysis.

Kentucky Precision Agriculture Education Consortium - *Scott Shearer, Thomas Mueller, Carl Dillon*

This project is a Kentucky precision agriculture education consortium consisting of a multi-disciplinary team of faculty from Murray State University, Western Kentucky University and the University of Kentucky. The focus of this project is to jointly develop and implement standalone educational modules that are web-based and can be used to teach a dedicated course on precision agriculture, or selected elements could be incorporated into existing courses.

Assessment of Alternative Methods of Applying Precision Deep Tillage - *Larry Wells, Tim Stombaugh, Carl Dillon, Tom Mueller*

Previous work has indicated that precision deep tillage reduces the adverse affects of soil compaction. Determining if this is feasible on a larger scale with the use of remote NIR images of the farm to define areas of soil compaction is critical. Our objective will be to determine the method of applying remedial tillage that results in the greatest increase of net crop returns.

Improving Equipment for Variable-Rate Application - *Scott Shearer, Steve Higgins, Tom Mueller, Tim Stombaugh, Carl Dillon, John Fulton*

The primary focus of precision agriculture technology is variable-rate delivery of inputs to optimize the production from specific locations within a field given existing soil water availability, soil type and structure, and nutrient levels. Heretofore research in this area has been conducted with field-scale machinery. It must be recognized that much of the precision agriculture equipment has been sold as aftermarket modifications. To this end researchers have ignored shortcomings of the modified equipment. These shortcomings include errors in yield estimates arising from less that desirable sensor designs and locations, as well as the errors associated with rate changes and distributions patterns of inputs (e.g. fertilizer application via spinner spreaders, retrofitted yield monitors).

Voice Activation to Scout Fields While Operating Machinery- *John Fulton, Scott Shearer, Tom Mueller, Sam McNeil*

Yield monitors and other sensing technologies such as satellite images and soil conductivity measurements are providing producers valuable information about soil landscapes and yield performance. Unfortunately, the single greatest source of performance information, human observations, remains untapped since a system does not exist to easily record site-referenced scouting notes during field operations without interfering with normal machine operation. This project seeks to perfect the use of voice recognition for field scouting concurrently with spraying and harvesting operations.

Break-Even Analysis and Interest Rate Considerations in Precision Agriculture Adoption - *Carl Dillon, Steve Isaacs*

The relative profitability differences of precision agriculture are not always clearly or easily determined. The costs of adoption must be offset by increased yields or lower input costs. Break-even analysis with results expressed in terms of the yield increase required to cover additional costs is a straightforward way for farmers to assess precision agriculture adoption choices. This project will develop quantitative tools using enterprise, partial, and break-even budgeting techniques to address these questions and issues.

Optimal Management Zone Size - *Carl Dillon, Scott Shearer, Tom Mueller*

The identification of profit maximizing management zones, including optimal uniform grid size, is a complex issue that is key to the successful implementation of variable rate applications. This vastly important decision has alluded experts. However, a modeling approach that identifies both the most profitable grid size and permits economic comparison of alternative decision rules to determine such zones is being developed. Consequently, findings from this project will prove key to the profitability of precision agriculture and represents a first stage of addressing this problem.

Economic Advisory Aids for Precision Agriculture Users - *Steve Isaacs, Carl Dillon*

Precision agriculture technologies have the potential to overwhelm producers with information while not providing clear solutions to production or economic problems. This project will develop methods and tools to assist farmers with economic decisions based on yield and input data from precision agriculture data. Procedures will be developed to generate net returns maps, risk maps, and CRP enrollment maps from farmer's yield map data submitted electronically to UK College of Agriculture personnel. Resulting maps and recommendations will be transmitted back to the participating farmers. This project will develop and test these procedures. If demand is adequate, the potential for offering these types of services on a fee basis analogous to soil testing services will be assessed in a cost/benefit analysis.

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