Sustainability Aspects of Precision Agriculture for Row Crops in Florida and the Southeast United States

D. L. Wright and I. M. Small

Precision agriculture or site-specific management has been defined as a knowledge-based technical management system that can help optimize farm profits and minimize agriculture’s impact on the environment. This technology has been on the market for more than 20 years with new applications each year. Information about a field can be obtained and continuously updated to refine management strategies. Precision farming involves using what we know about fields and correlating that to responses from specific management decisions under those conditions. Precision farming uses data to better manage the field for an improved economic response. Stated another way, it is the determination of inputs needed for profitable management decisions. Growers who get involved in precision agriculture have more information at their disposal and usually spend more time thinking about crop management and how yields and profits may be influenced.

Where We Came From and Current Status

Agricultural research has always attempted to determine precise responses to treatments under controlled or known conditions. In research plots, scientists control as many factors as possible, then study variables to determine if there is an association between treatments and a response. Farmers, likewise, want as much information as possible from soil tests, pest maps, and other information sources to make informed management decisions. In many cases, growers have no way to check responses to rates of materials applied but experienced growers typically have a good idea of what happens without that input. As soybean rotations for grain crops was introduced, for example, knowledge of soil pH was needed to inform lime application so that good growth of nitrogen fixing bacteria would occur and thus enhance crop productivity. However, growers have had little way to confirm whether low, medium, or high liming rates were most economical. Early researchers determined fertility levels of the soil on specific sites or fields and made recommendations for the proper lime application for most economic returns. Variety evaluations, likewise, have been based on matching varieties to locations, soil and climatic conditions or known pests. Planter technology now allows growers to vary plant populations across the field as moisture or fertility levels change.

In recent years, site-specific farm management has been given new life through the use of yield monitors on grain combines in the Midwest. About 50% of Midwest farms use yield monitors that were purchased with new combines (Griffin 2009). Yield monitors are now being used on cotton and peanut pickers so that better management decisions can be made on future crops. Global positioning systems have allowed variable-rate application of water, nutrients,
pesticides, or any number of management factors to be manipulated to better manage soil variability. Much has to be known about fields to vary inputs economically. Use of this technology does not necessarily mean more profit, since there are variables that are not known and purchasing appropriate equipment can be expensive. Yield maps of the same fields over years can enable farmers to determine the impact of site-specific management on their yields. Profitable site-specific management is finding the area where cost of using this technology is offset by benefits. Optimal site-specific management is very difficult to determine, since biological systems can be influenced by many factors. Recent advances in computer technology, communications, and engineering have provided us with a good opportunity to change our approach to farm management, especially in relation to pest, fertility, and water management. These are the most expensive areas of input that have a large impact on yield and economics of a farm.

Farmers and those who advise them are trying to figure out how to use these new tools to their advantage. Site-specific management depends on how crops respond to the environment. These responses are due in large part to the above-ground environment (influenced by tillage, fertility, drainage, soil properties, nematodes, etc.) while the below-ground environment (weather, pests, diseases etc.) impacts the the crop, and may be more variable. Until crop responses can be predicted for specific management applied to management zones, and profit maps show that management is profitable, widespread adoption of site-specific management will be slow. Farm profitability maps help growers make decisions on which crops to grow and best crops to rotate with. Variable rate application of fertilizer has been the predominate use of precision technology with information gained from implements that characterize soil by conductivity, pH, OM, etc. Use of this technology is increasing as farmers see how it helps the bottom line and as more technology becomes available on farm equipment and phone apps. Farm subsidy programs are now helping farmers purchase equipment needed for the new technology that can help them make decisions on where and how much of inputs are required. Additionally, there is tremendous interest and investment occurring in the area of “digital agriculture” and it will be interesting to see what developments occur in the next few years.

**Key to Good Decisions is Good Sampling**

Obtaining good samples or information about an area of management is the key to making good decisions. When sampling is done by zone samples (areas that yield the same or respond similarly), more is known about the field and the grower knows where responses begin and end. Many growers have run a harvester or grain combine over the same field for many years and know what areas or zones have similar yields or soil types and can sample accordingly. Grid soil sampling is more intensive than zone sampling and is usually done when nothing is known about the sites. Sampling field soils for nutrients has been studied intensively and at present zone sampling as appropriate for field crops has come to the forefront in the southeast United States. Zone sampling requires knowledge of where crop yields differ in areas of the field and what “zones” respond similarly. Rapid development of sampling procedures that allow for continuous sampling of soil moisture, organic matter, cation exchange capacity, and pH, will lead to more extensive data to make better management decisions. There is a vast amount of information on crop water use and a lot is known about the water-holding capacities of most soils. There are now incentives for growers to conserve water which has led to conversion of irrigation systems to variable rate irrigation (VRI) for better water management through irrigation systems. Use of site-specific pest management is being researched in the cotton belt, where many pesticide applications are made under conventional cotton production methods. Disease and insect pressure are good examples of sporadic pest problems that are difficult to predict, while soil amelioration (drainage, liming, etc.) may correct the problem for years to come. Traditional integrated pest management (IPM) is based on quantification and qualification of pest populations to determine if control measures are economically justified. There has always been a tremendous challenge to quantify pest populations and their potential economic damage in a reasonable and reliable way. The many appropriate field level sampling procedures in practice today reflect the diversity of pests, their potential for rapid population growth and dispersal, their potential for economic damage, and the types of control measures available for implementation.

**Use of Precision Agriculture in Pest Management**

At the forefront of site-specific IPM research and application is the ability to spot-treat only those areas of the field needing pest control and to manage a healthier crop by
adjusting needed inputs within the field rather than at the field level. This has a tremendous potential to reduce costs and environmental degradation. Disease, weed, and nematode site-specific management is an area that is rapidly developing. Site-specific farming provides a more precise way to sample and manage fields. By linking soil, crop, pest, disease, and environmental features into one program, crops can be managed better, with fewer trips across the field, resulting in more economic returns and reducing potential negative impacts of agricultural activities on the environment.

There has been rapid development in methods and equipment for site-specific soil sampling and to sample yield on a near-continuous basis. Sampling strategies to provide appropriate pest data are also under development, especially with insects and weeds. Site-specific management for weeds is probably the newest of the pest disciplines. However, it could one day offer the most economical and environmental benefits of any of the site-specific management areas. Soil fertility remains fairly constant over a period of years making site-specific management decisions easier than it is for weeds, which may change within one growing season dependent on the crops and herbicides used in the rotation. Options for site-specific weed control include variable rate soil applications that depend mainly on soil type, and site-specific post-emergence applications. The goal of site-specific post-emergence application is to treat only those areas with weeds present and to treat them with the appropriate material at the right rate. Weeds tend to spread as seed or vegetatively and are likely to infest the same areas the next year. Identifying weed type and density “on-the-go” is critical to successful site-specific post-emergence weed control — it is also difficult to do with current equipment. The more information known about each field, the better the site-specific management decisions can be, offering more potential for increased profit. The remaining challenge will be to develop methods to quantify the field environmental conditions so that models can be developed to link all aspects of agriculture production within a system of precision or site-specific farming (Marois 2000).

When developing sampling strategy for site-specific application, it is important to know the goal. For example, yield data, while useful for planning next year’s activities, may not be beneficial in determining what to do in the present season. These data are not as time-sensitive as sampling for pests, especially insects and disease, which may require a nearly immediate response if a predetermined threshold is exceeded. If data are to be used in a production model, it is critical that they include adequate precision to ensure that the proper management decision is made. Therefore, sampling for the purpose of developing a soil fertility map, as required in many precision agricultural activities, may be different than sampling to aid a pest management decision.

Fleischer et al. (1999) discussed how sampling for precision IPM can be done for the development of maps to better manage pests that vary within a field. Developed from the perspective of insect control, many of the concepts and principles developed apply to the sampling of any precision IPM activity. In traditional sampling, the goal is to get the best estimate of numbers and area of the field where the population is found. In general, a population becomes more difficult to quantify as its density decreases and areas of high population are further apart. Thus, it is often best to stratify samples to increase the probability of encountering the population. Many of the sampling plans result in a sampling procedure that are too intensive and therefore expensive. Nyrop et al. (1999) noted that precise procedures are often unnecessary, and that more general descriptions may be appropriate when sampling is to provide information for decision making. It is more important to concentrate on the level of pests that trigger a management practice than to fine-tune sampling designs. Sampling data for pest management should identify where the pests are in the field and at what level. Then, rather than sampling throughout the field, it may be more efficient to concentrate on those areas where the population is expected to change, providing boundaries from which maps can be constructed. Thus the size and location of the pest clusters becomes more important than the overall mean, and it is now possible to apply spot applications of pesticides by linking the pest maps with onboard tractor or airplane GPS and automated spray application linked directly to the GPS controller. Fleisher et al. (1999) and Delp et al. (1985) concluded that placement of samples is more important in precision IPM mapping because of the need to identify the boundaries of a population. Stratified samples, distributed in a pattern throughout the field, would be used to sample plant disease.

The ability to efficiently map the distribution of pest populations will impact the future of pest management. At present, maps are being used to determine where pesticides should be applied. By integrating the pest population distribution with economic models, incorporating yield and crop value, it will be possible to determine where pest control measures should be applied, or if the potential economic return justifies application at all. By integrating potential pest population growth with density maps, it is
possible to determine if and when a control action would be warranted.

The identification and quantification of plant diseases and the dynamics of their spread have been studied extensively (Gregory 1968). Disease foci in the field could be identified and the surrounding areas at high risk of infection could be predicted based on the anticipated spread of the disease. The potential to predict when and where the foci are likely to occur could be an important tool in the precision application of fungicides, especially protectant fungicides that cannot stop the infection once it has begun (Zadoks 1999). By predicting the advancing front of infection, it would be possible to design precision farming fungicide applications that would enhance disease control for certain diseases and reduce the potential of resistance development. For example, areas with visible and latent infections could be treated with a systemic fungicide, while a different protectant fungicide could be applied to the areas that are unlikely to have been infected. This differential fungicide application would not only reduce the chance of resistance development by the pathogen, but would also reduce application costs, as many of the protectant fungicides are cheaper than the systemics.

Recent advances in GPS and application equipment have set the stage for rapid advancement of the application of GPS technology to pest and disease control. New management tools have the potential to provide novel and more efficient methods of pest and disease control, while reducing input costs and possible resistance of the pest to pesticides.

**Conclusion**

Several aspects of precision agriculture have been adopted as many producers have access to technology through their agri-supply dealers such as zone soil sampling and yield monitors, especially if harvested by custom operators. Growers had to make relatively few changes to adapt to using genetically modified crop seed technology; they still had to plant seed and spray herbicides, but they did not have to purchase additional inputs or modify equipment. Biotech seeds have allowed growers to do things as they had been doing them, but has made it easier, less expensive, and less labor intensive until weed resistance became a problem. In precision agriculture or site-specific management, the equipment and techniques are continuing to be developed and improved. It is more akin to movement from horses and mules to the tractor, which required money and development of equipment and much learning. There is enough industry support and research being conducted that rapid advances are being made; additionally, many young farmers grew up with computers and smart phones, making using this technology a natural and easily understood part of farming.

High investment costs for growers has required fertilizer dealers to purchase variable rate equipment since there can be wide use over many farms, making the adoption of this technology fairly rapid. Doerge (1999) and others have listed several reasons growers are making the decision to invest in precision agriculture technology: 1) better information for diagnosing crop problems; 2) on-farm experimentation, especially variety trials; 3) improved identification of management zones, 4) quantitative evaluation of whole-field improvements, such as drainage, etc.; 5) benefits at harvest through improved truck scheduling and drying logistics, and better marketing with greater confidence of meeting contract obligations; and 6) off-farm uses such as knowing crop yield potential for insurance purposes or determining what rental prices should be paid for land dependent on yield history. Precision agriculture technology will continue to improve, offering more benefits to producers and making it common technology on farms in the 21st century.

A key to the successful use of precision ag technology will be the availability algorithms that translate data, such as weather data, UAV imagery, and yield maps, into actionable information that can be used by growers to improve efficiency and profitability of their operations. A second important factor will be availability of education and training for growers to inform them on how to use the technology as well as technical support when problems arise.

**Literature Cited**


