YIELD SENSING TECHNOLOGY IN COTTON HARVESTING APPLICATIONS

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Abstract

A real-time cotton yield sensor for mechanical harvesters in conjunction with GPS are necessary technologies to take precision farming in cotton from a concept to a reality. While a yield monitor is not presently commercially-available, other yield mapping techniques are being implemented to document the spatial variability within cotton fields.

Introduction

In 1993, the United States had 13.4 million acres of farm land in cotton production averaging 606 pounds per acre (approximately 1.26 bales/acre) with a net value of $4.5 billion (USDA, 1994). However, with the best management practices employed by cotton farmers today, crop yields vary widely between fields and within fields (Reichenberger and Russnogle, 1989). For a given field, there are many sources of variability which affect yield. Some of the sources of spatial variability commonly found within a field include soil type, soil moisture, pH, fertility levels (N,P,K), organic matter, weed pressure areas, insect pressures, and wildlife damage. In many instances, there is as much variability within fields as between fields. It is common for one field to have several soil types with varying yield potentials. In other words, not every spot in the field has the same potential to produce a cotton crop given the same inputs. However, the common practice has been to farm a field on the average by treating the entire field as though input requirements were uniformly required.

Applying fertilizers and chemicals based on field averages results in overapplication in some areas while underapplying in other areas of the field (Russnogle, 1991). Costs associated with this variability has both economic and environmental dimensions. By addressing the fertility and chemical needs of small areas within a field, prescription application of fertilizers and chemicals can be applied on a variable rate basis. This approach has the potential to help address the inherent spatial variability concerns that are encountered within cotton fields. By knowing the areas of the field that consistently produce the highest and lowest yields, inputs such as fertilizers, herbicides, and growth regulators can be varied to potentially maximize production efficiency while minimizing the negative environmental impact.

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Review of Yield Sensing Technology

Much of the enhanced interest with precision farming in grain crops has stemmed from the commercialization of grain yield monitors. A yield monitor allows the operator to monitor the variability in crop yields during harvest. Once farmers determine the magnitude of yield variability within a field, their next question is, “What can be done about it?”. With the integration of a Global Positioning System (GPS) receiver with the yield monitor, spatially varying color-coded yield maps can be created with mapping software on a Personal Computer. Years of yield data in conjunction with soil maps, site-specific soil tests, and other variables which might affect yields can be used to make more informed management decisions for small areas within a field rather than making decisions based on the field as an average.

Extensive research has been conducted on grain yield monitoring equipment (Pfeiffer et al., 1993; Wagner and Schrock, 1987; and Klemme et al., 1992). However, very little research has been reported on the development of a cotton yield sensor for production operations. The lack of a commercially available cotton yield sensor has not prevented researchers from documenting spatial variability in cotton yields. Kvien et al.(1995) at the National Environmentally Sound Production Agriculture Laboratory in Tifton Georgia, measured yield variability by bagging and weighing cotton yield at set intervals throughout the field. Each weight was logged and a geo-reference position was established using a Differential-GPS receiver.

A cotton flow sensor is being developed at The University of Tennessee Agricultural Engineering Department to measure the mass flow rates of cotton during harvest. An optically-based, non-intrusive sensing technique was developed to measure the flow of cotton in the discharge chutes on a cotton picker. Output from the experimental sensor was shown to be correlated with mass of cotton conveyed through a chute under laboratory conditions. This sensor is being interfaced with a GPS for real-time mapping of cotton yields (Wilkerson et al.,1994).

Yield Measurement Methodologies

Mapping the spatial variability of yield within fields is an integral component for any cropping system where site-specific farming techniques will be implemented. Yield variability within cotton fields has typically been evaluated by hand harvesting small test plots within a field. While this is an effective way of characterizing yield variability between small plots, it is not a very efficient method for characterizing yield variability within large production fields.

There appears to be two basic techniques which are being pursued for real-time cotton yield sensing. The first of these methods involves weighing the cotton during harvest, either by weighing the transport basket on the picker or a smaller scale weighing device that mounts inside the existing basket. Signals from the weighing unit in conjunction with a GPS receiver can be used to generate spatially varying yield maps. One of the potential problems with this yield sensing technique is the dynamic loading condition which occur during the harvest. The transport basket on a typical cotton picker weighs over 2000 pounds empty. For this reason, a weighing system requires signal averaging over several seconds to minimize the dynamic loading conditions as the picker traverses a field. This factor will increase the minimum yield mapping unit size.

The second method is similar in concept to grain yield measuring devices in which a signal is created proportional to some flow characteristics which can be correlated to a mass flow rate. In the case of a grain flow sensor, this is typically a force measurement record as the grain impacts a load-sensing unit. However, with cotton, large air flow rates are required to convey cotton between the picker drums and basket. An in-line impact sensing device would greatly restrict the normal mode of operation for a cotton picker.

The sensor development work underway at The University of Tennessee Agricultural Engineering Department is based on a non-intrusive sensing technique. However, this technique is not without its problems. Cotton trash, dust, machine lubricants, and other foreign material must be addressed with such a measuring device.

Challenges in Cotton Yield Sensing

Physical properties of cotton make it difficult to use mechanical impact- and volume-based flow measurement techniques found in many grain yield monitoring systems. Cotton bolls are conveyed from the picker heads to the transport basket via a blower chute. Therefore, the sensing mechanism must not interfere with normal operations of the cotton picker.

Measurement accuracy for a mass flow rate of cotton presents many challenges due to the variability in cotton flow density. Cotton transferred in the picker chutes may be in the form of individual cotton bolls, cotton lint in long mats, or clumps of cotton. Therefore, an instantaneous flow measurement can be highly variable, much more so than for grains. Therefore, a minimum integration time for the flow sensor needs to be established in order to reduce the sample-to-sample variability.

On-the-go yield weighing devices have a unique challenge in that a cotton picker must travel several feet before a significant weight change can be detected. For example, A 4-row (30 inch) cotton picker harvesting 2-bale cotton must travel a distance of 15 to 20 feet to accumulate 5 pounds of cotton. Therefore, the minimum yield mapping unit is greatly dependent on the weighing mechanism.

Real-time accuracy of the GPS receiver will also influence the minimum yield mapping unit. However, with the new real-time differential sub-meter receivers, this limitation is becoming less of an issue.

One of the few advantages that cotton yield sensing has over grain yield sensing is the drastic reduction in lag time between the time cotton is picked and monitored for yield. For grain combines this lag time can be several seconds. Also, combines have an integrating effect resulting from the processing of the grain. In cotton pickers this is less of a problem. For example, the transition time for a cotton boll from the time it is picked to the time it is delivered to the basket is less than a second.

Accuracy of yield measuring monitors is another question which remains to be answered. If we are generating spatially-variable yield maps, relative accuracy within a field may be acceptable. For instance, if our objectives are to identify areas of a field that are high and low producing, relative accuracy might be sufficient. On the other hand, absolute accuracy may be required when using yield monitors to provide a farmer with total seed cotton weights before unloading the picker.

Concluding Remarks

Cotton yield sensors in conjunction with GPS are necessary technologies to take precision farming in cotton from a concept to a reality. The success or failure of this concept hinges on farmers having adequate knowledge about the inputs which affect yield potential for varying crops under varying soil type, climatic conditions, varieties, etc. In order to apply precise recommendations at precise field locations, producers need precise advice. For this reason, if it is the intent to use this new technology to maximize profits for cotton farmers, an interdisciplinary approach to problem solving must be undertaken. Research scientist in engineering, economics, plant science, and soil science must work cooperatively to design, evaluate, and implement precision farming systems to aid cotton farmers in managing their resources in a manner which maximizes profits while being good stewards of our land and water resources.

It is important to keep in mind that while much of this technology is fairly mature, especially GPS, the transfer of this technology to agriculture is in its infancy, especially in cotton production. The tools associated with site-specific farming have considerable potential to assist cotton producers.

Cotton yield monitors, GPS receivers, computers, and GIS software are only tools. Tools which hopefully will allow farmers to do a better job of managing the variability inherent within a field. This technology is much like the farm computer, the usefulness of the information obtained from the computer is no better than the quality of information going in. These tools may aid in monitoring and documenting yield variability but will not answer the "why" question. Some problems may be readily apparent while others may be very difficult to diagnose. If precision farming technologies are not used with caution, the long-term success could be jeopardized with delayed acceptance of this technology.

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