Initiating Environmentally Conscious Precision Agriculture at UMES

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Abstract

Precision agriculture is a combination of modern technologies to improve productivity in farming resulting in environmentally friendly farming and higher profit for the farmers. It involves efficient farm management that utilizes technologies such as GPS receivers; GIS data bases; grid soil sampling; variable-rate application equipment for seed, fertilizers, and pesticides; irrigation; yield monitors; sensors for detecting soil fertility and weed populations; and remote sensing imagery.

This paper will report efforts to initiate “precision farming” implementation and research at University of Maryland Eastern Shore (UMES).UMES is an 1890 land grant historically black university and it’s mission is consistent with the goals of the endeavor which includes (i) integration of advanced technologies in agricultural practices at UMES with a view to improve productivity with due emphasis on research, education and outreach; (ii) environmental stewardship and (iii) remote observation and analysis. While all aspects of “Precision Agriculture” will be integrated with the project, the initial phase involves (a) extensive data collection to record yield variability using GPS (Global Positioning System) integrated yield monitor, (b) correlating the yield data with the soil characteristics and other pertinent factors to come up with recommendations for variable rate nutrient application, (c) use of GIS (Geographical Information System) databases and maps to record and visualize the data to facilitate interpretation.

1. Introduction

The Phase-I of “Environmentally Conscious Precision Agriculture(ECPA)” was initiated in the Summer of 2004 with the identification of a 50 acre plot of land which is utilized by UMES farm management personnel to grow wheat, corn and soy beans on a rotational basis. Traditional farming practices are utilized at present on this tract with uniform application of fertilizers and seedlings. No special irrigation or weed management techniques are currently used. The overall objective of the first phase of the ECPA efforts at UMES will be to develop baseline data via systematic record keeping, while continuing with the current farming practices. This data will be valuable in the future to

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compare with similar data that will be gathered when Variable Rate Technology (VRT) is adopted for one or more of the following with progress of time: (i) nutrient application[1], (ii) seeding[2] (iii) pesticide application[3], and (iv) herbicide application[4]. Baseline data will be collected in Phase-I to monitor the run-offs into the watershed of the farm (Manokin river) with a view to improve environmental stewardship while maximizing yield during the Phase-II efforts as UMES farm personnel adopt "Precision Agriculture"[5] on the identified tract.

2. Outline of Phase-I Objectives

The Phase-I of the ECPA had significant emphasis on integration and acquisition of advanced engineering technologies with the ECPA efforts at UMES [6]. In this phase the emphasis was on developing the basic infrastructure for education, research and extension activity, while gathering data to support future directions and investments related to the effort.

The core team has developed the following specific objectives for Phase –I of the ECPA project:

I. To generate data corresponding to variations of soil on the farm tract at UMES identified for ECPA.

II. To integrate and calibrate a "Yield Monitor" with a GPS attachment with the existing UMES combine.

III. To record yield data systematically using the "Yield Monitor" and the UMES combine for wheat, soybean and corn on the 50 acre plot identified for the project.

IV. To monitor random variations in rainfall and monitor the health of the watershed of the farm.

V. To integrate remote sensing and aerial imaging efforts of the UMESAIR project[7,8], an ongoing remote sensing project in collaboration with NASA Wallops Flight Facility with the ECPA efforts to gather actionable information.

VI. To systematically compile and interpret data with extensive use of Geographical Information Systems (GIS) maps to make decisions pertaining to the next phase of the project that will utilize VRT.

VII. To involve UMES undergraduate and graduate students in a vertically integrated experiential learning framework with the ECPA efforts over a long period.

VIII. To develop a multidisciplinary team of faculty members working cohesively to address various aspects of this broad research area.

IX. To initiate development of extension projects and educational activities for local farmers to promote adoption of "Precision Agriculture" and develop the technological infra-structure at UMES to provide support services particularly for aerial imaging and remote sensing efforts.

3. Current Status and Results of Phase-I ECPA Effort

A systematic effort is underway to achieve the Phase-I objectives since the beginning of the project in the summer of 2004. The project was initiated by identifying a 50 acre plot on the UMES farm with the assistance of UMES administration and UMES farm personnel. Soil testing has been performed using "Gridding"[9,10], a systematic approach where a field is subdivided into smaller units of equal area and a separate soil sample is collected from each unit. Subsequent to soil testing a GIS map was developed to document the soil condition at the onset of ECPA activities at UMES. Using the soil map and in consultation with a local agronomist, a GIS map of the recommended variable lime rate application map was generated for the 50 acre tract identified for ECPA activities. This map is shown in Figure 1. Lime can greatly increase the yield of many crops by bringing the soil pH levels closer to neutral. It is well known that corn and soybeans do not grow well in acidic soils. In Figure 1 red areas are where lime application rate needs to be high and the green areas are where little to no lime addition is recommended. Orange, yellow and light green regions indicate different rates of lime application recommended as shown in the map.

To facilitate systematic recording of spatially distributed yield data over the ECPA tract a "Yield Monitor" [Photographs 1a & 1b] and a GPS unit have been integrated to the UMES combine [Photograph 2]. Extensive effort was devoted to accurately calibrate the "Yield Monitor" with the GPS unit for documenting yield data appropriately. A yield monitor is comprised of several sensors all of which need to be calibrated. The sensors used by the PF-Advantage yield monitor[11] installed in the UMES combine measure the following: grain elevator shaft speed, head-height, differential GPS signal, grain moisture, and grain impact. Each sensor is critical in yield estimation, and must be calibrated separately.

The grain elevator shaft speed sensor allows the monitor to calculate the speed at which the grain is thrown against the impact sensor. This sensor is calibrated as part of the installation of the yield monitor and only needs recalibration if there are major changes in the grain elevator drive system.

The head height sensor is essentially a potentiometer that is mechanically attached to the harvesting head. It is used to indicate to the yield monitor when the head of the harvester is raised or lowered. This information can then be used to turn on and off the data logging and the associated harvested area calculations. The head height monitor is calibrated for the correct operating height every time the head is changed.

The Differential GPS receiver works by triangulating the signal transmitted from orbiting satellites. It also has the ability to receive and incorporate real time correction information sent to it from the coast guard GPS correction system. This correction signal increases the resolution to sub meter accuracy. The GPS receiver does not require any further calibration or adjustment.

The grain moisture sensor bleeds a small amount of the grain off the grain elevator. Capacitive plates that determine the moisture content based on the grain type check this grain. This is calibrated for each grain harvest by measuring the moisture of several loads of harvested grain with a known sensor. The calibration offsets can then be entered into the monitor. The yield monitor automatically corrects all the previous and subsequent data for that particular grain. The moisture sensor also requires regular cleaning to prevent trapped kernels from rotting in the sensor.

The impact sensor sits at the top of the grain elevator. As the grains are thrown from the elevator they hit the impact sensor. The sensor records the impacting force. Thus over an amount of time the weight of grain can be extrapolated. The impact sensor must be calibrated using several loads. Each load is weighed at the mill and that weight is entered into the monitor. The monitor then corrects all the previous data and automatically corrects all the subsequent data. Impact sensor has to be calibrated to account for the vibration on it as well. The vibration calibration must be done for each harvesting head only once, unless changes or alterations are made to the head or drive systems. To perform this calibration the combine is parked and the harvesting drive system is engaged and brought up to an operational speed. Once at speed, the calibrate button on the yield monitor is pressed and the monitor calibrates the system.

With all the calibrations completed the system is able to achieve an error of around two percent per load. The UMES combine holds four hundred to four hundred fifty bushels. A two percent error amounts to eight or nine bushels per load.

The harvesting of the soybean crop on the 50 acre tract was performed in the month of November 2004, with the UMES combine. The yield data was recorded along with GPS information. The data was downloaded and mapped using GIS software available in the UMES GIS laboratory. Figure 2 shows the yield data map for the soybean crop harvested from the ECPA tract. Each point represents the number of bushels harvested over a two second interval by the UMES combine.

Analyzing Figure 1 and Figure 2 we find some evidence of the pH effect on the soybean crop. Looking at Figure 1 we can see that the red areas are where the lime is most needed. Predominantly that is in the south eastern fields. Figure 2 uses red to represent low yield areas. As we can see the low yield values are found predominantly in the south eastern fields. Upon further investigation of the yield data in Figure 2 it becomes clear that the north easterly section is having yield problems as well. This same area in Figure 1 is an orange area indicating poor yield expectancy.

Upon studying the Figures 1 & 2 further, it appears, there are some areas where the yield is poor or very low but the lime recommendation indicates that they should have provided higher yield. Possible explanations for the anomalies are as follows: a) the low yield in the fringe areas is most likely due to the weed growth in from beyond the field b) the second type of area is circular or roughly circular spot type areas of poor yield, these are most likely low spots in the fields where this year's heavy rain collected and drowned the plants.

Phase-II of the ECPA project will begin by applying the recommended levels of lime in accordance with Figure 1 using VRT to the ECPA farm tract after documenting the yield levels with soybeans, corn and wheat in the present soil condition.

4. Remote Sensing and Aerial Observation of ECPA Tract

In consultation with NASA WFF Observational Science Branch engineers and technicians, Bayland Aviation and UMES Aviation Science Department efforts are underway to integrate the Phase-III of the UMESAIR project with the ECPA project. Several aerial imaging platforms will be developed and implemented in Phase-III of the UMESAIR project with possible applications in selective harvesting, yield estimation, weed management and plant health assessment in concert with ECPA efforts.

The aerial imaging platforms will include:

(i) Blimp and Kite Aerial Photography
(ii) Autonomously controlled Uninhabited Aerial Vehicle (UAV) based multi-spectral imaging.
(iii) Remote controlled UAV based imaging.
(iv) Imaging from manned aircrafts operated by Bayland Aviation and UMES Aviation Faculty.

The core project team has already acquired seed grants to develop the infra-structure to support these activities with due emphasis on GPS data synchronized multi-spectral (visible and near infra-red) imaging, that can be appropriately geo-referenced. In all of the above activities safety issues and Federal Aviation Administration (FAA)[12] regulations are being addressed.

As in the earlier phases of the UMESAIR project, undergraduate and graduate involvement in multidisciplinary teams from Science, Technology, Engineering and Mathematics (STEM) is being encouraged. In the future the project will develop capability to support high technology transfer services to local farmers as they adopt "Precision Farming". The broad scope of Phase-III of the UMESAIR project parallels those reported by AEROCam/UMAC [13] project at the University of North Dakota.

5. ECPA and UMESAIR: Platforms to Synergize Education and Research

The core project team has adopted an approach based on Kolb's Experiential Learning Model [14,15] that proved to be very successful in the UMESAIR project for the ECPA activities as well. While graduate research and extension are key components of the project, the core team continues to emphasize involvement of undergraduate students from a variety of STEM disciplines. Biweekly meetings are held to discuss progress of the project with undergraduate and graduate students. In some of these meetings, engineers and technicians, from NASA GSFC's Wallops Flight Facility (WFF) also participate. Moreover, in some of the undergraduate courses students are exposed to aspects of ECPA and UMESAIR project. The fall 2004 class of freshman engineering students learned about various sensors as well as the GPS unit that were integrated onto the UMES combine to record spatial variability of yield data. The freshman design project for the semester, as in Spring 2003 [16], was to develop sensor integrated mobile robotic platforms that can interact with its environment. The students found a keen interest in the discussion of GPS and calibration of various sensors to estimate the yield. They could readily relate the material to the touch and light sensors they were integrating with their freshman design projects for the mobile robots to interact with their environment. Photograph [3] shows some students of the fall 2004, Introduction to Engineering Design (ENES 100) class gathered around the UMES combine after they were introduced to various sensors that worked with the "Yield Monitor" integrated to the combine.

Sophomore students in the Marine Botany (BIOL 202) and Introduction to MATLAB (ENME 271) were also introduced to various aspects of Phase III of the UMESAIR project that was being integrated with the ECPA efforts. In the BIOL 202 class the discussion was primarily on UAV based aerial imaging and their application in weed management, plant health assessment etc., where as in ENME 271 where the course project assignment involves "Image Processing Toolbox" of MATLAB, the discussion primarily related to image processing aspects of digital images in the visible and near infra red wavelengths. Pertinent discussions were also held about conversion to and from RGB (Red, Green, and Blue) to HSV (Hue, Saturation, and Value) representation for various data-mining operations.

Students from Natural Sciences and Engineering were also exposed to the YSI 6600 Multiparameter probe to understand the importance of monitoring of the watershed through collection of water quality data such as depth, water temperature, salinity, dissolved oxygen, turbidity, salinity, and chlorophyll a. Through the cross-disciplinary studies and application of technology from other disciplines such as use of in situ sensors for water quality sampling, computing, geostatistics, and geographic information systems, a more effective way to monitor the environment could be initiated. This would also be helpful in detecting events such as harmful algal blooms, low dissolved oxygen, or plumes of turbidity in the watershed. It is important to have adequate data to produce a more effective water quality monitoring of the river.

It is hoped that these classroom exposures will encourage more undergraduates to participate in the bi-weekly project meetings with the core project team where all undergraduate students are encouraged to participate to sustain continuity of the project as well as to integrate the activities of Phase-III of UMESAIR project with the ECPA activities.

6. Conclusions

Although a relatively new field, there are extensive research and education efforts underway at a large number of land grant universities in the United States in the field of "Precision Farming". Farmers in the US are gradually adopting this technological intensive farm management approach. Similar efforts are also underway in developed nations throughout the world in this field. The ECPA project is consistent with UMES's land grant mission and will play an important role in the education, research and service endeavors of the University. In the future the project efforts will be integrated with the extension efforts for effective outreach programs consistent with the UMES mission. The scope of the project is broad and is likely to sustain interest among the STEM undergraduate and graduate students and faculty members for a long time.

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Photograph 1a: Inside the Combine Driver's Cabin

Photograph 1b: PF Advantage Yield Monitor

Photograph 2: UMES Combine Harvesting Soybean

Photograph 3: Some Freshman Engineering Students Posing in Front of the UMES combine after learning about the sensors related to the "Yield Monitor" and the integrated GPS Unit

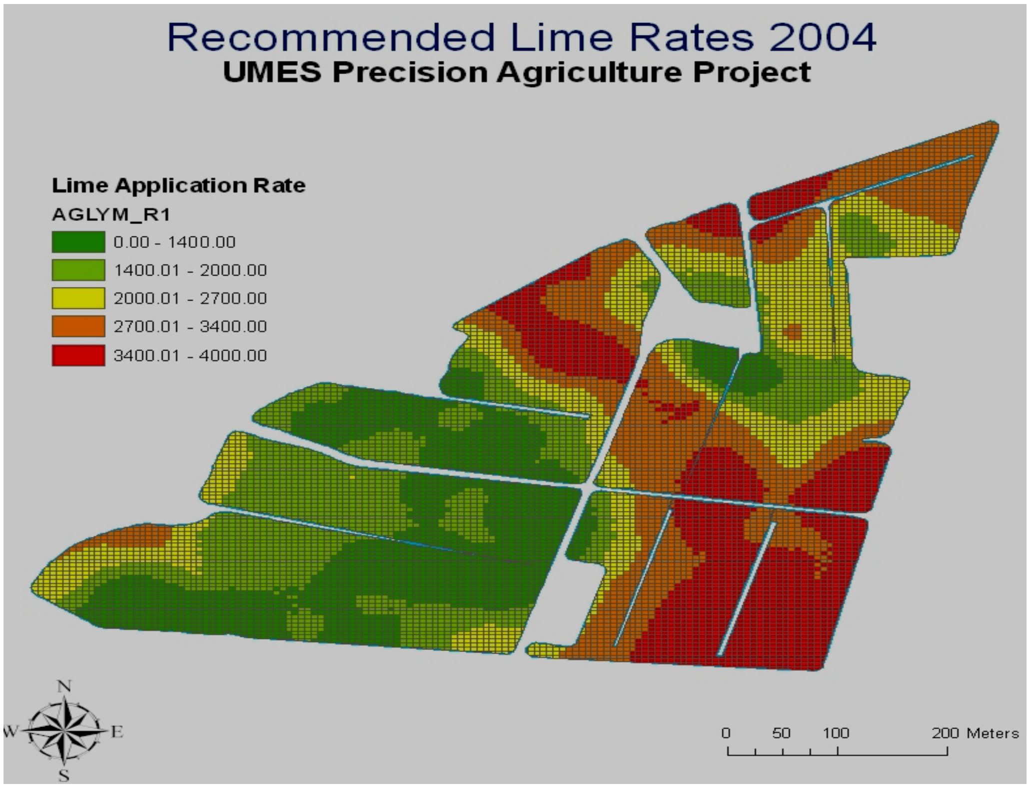

Figure 1: Lime rate recommendation for the ECPA tract after soil testing

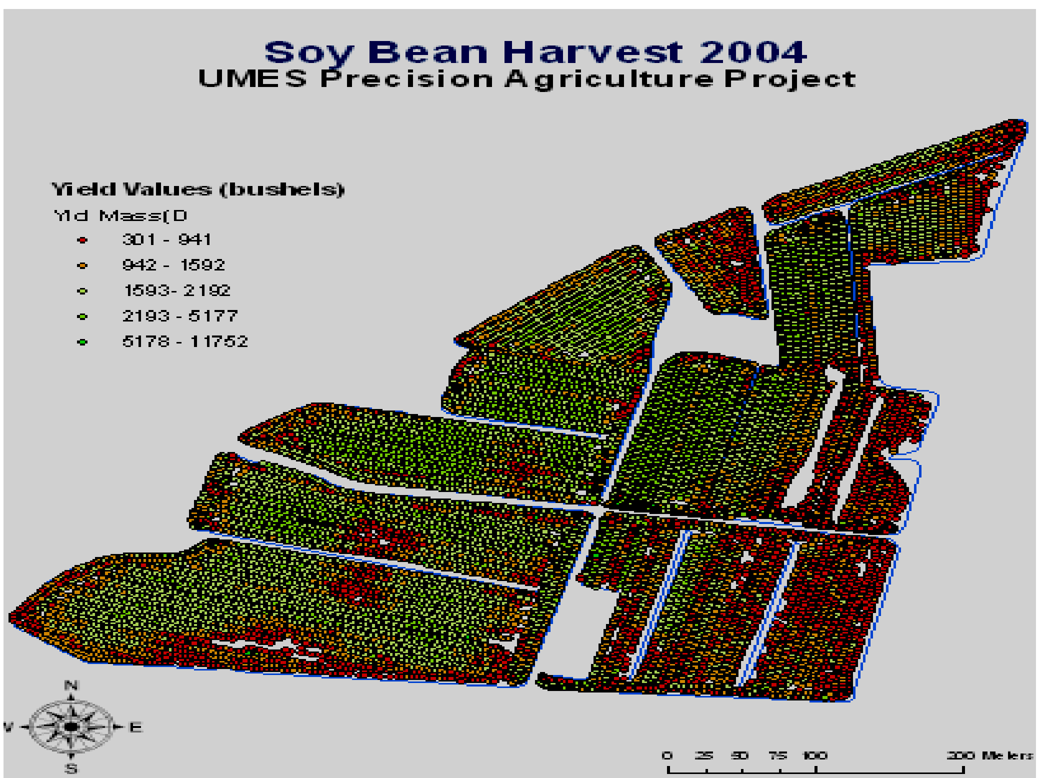

Figure 2: Soybean harvest data (ECPA tract) using UMES combine with the Yield Monitor