AC 2009-423: SIMPLIFIED MANAGEMENT ZONES FROM ANALYSES AND MAPPING OF MULTIPLE YEARS OF SPATIALLY DISTRIBUTED HARVEST DATA

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Simplified Management Zones from Analyses and Mapping of Multiple Years of Spatially Distributed Harvest Data

Abstract

The National Science Foundation's Louis Stokes Alliances for Minority Participation (LSAMP), and HBCU Undergraduate Program (HBCU-UP) have paved the way for undergraduate research involvement in Science, Technology, Engineering, and Mathematics (STEM) disciplines at University of Maryland Eastern Shore(UMES) among the underrepresented minority students. Ongoing multidisciplinary experiential learning and research efforts titled (i) AIRSPACES : Aerial Imaging and Remote Sensing for Precision Agriculture and Environmental Stewardship funded by the Maryland Space Grant Consortium and (ii) Environmentally Conscious Precision Agriculture (ECPA) : A Platform for Active Learning and Community Engagement funded by the United States Department of Agriculture provide synergistic platforms for undergraduate involvement that promotes both the LSAMP and HBCU-UP objectives, while enhancing the proposed outcomes for the AIRSPACES and ECPA projects. The principal author who serves as the principal investigator for the AIRSPACES and ECPA projects at UMES mentored one of the undergraduate students in the LSAMP program in the spring and summer of 2008. The student was partially supported by the HBCU-UP program. The undergraduate student who is also the co-author of this paper got an opportunity to work with the NASA and the USDA collaborators, UMES farm personnel, graduate students, and a team of interdisciplinary UMES faculty collaborators, while performing analyses of geo-referenced harvest data collected over one of the UMES agricultural fields since the inception of the project in 2004. At early stages of the ECPA project, the UMES combine was retrofitted with a yield monitor and GPS unit, and spatial distribution of harvest data have been recorded for the field for all subsequent harvests. The student got an opportunity to learn spatial mapping software such as “ARCGIS” and “SMS Advanced”, while getting exposed to various aspects of the growing field of “precision agriculture”. Based on the analyses of several years of yield data, a simplified “management zone” framework for the field has been obtained. This framework will be refined and utilized for “variable rate seeding” effort in the future for improving the profitability of the field.

1.0 Introduction

The benefits of implementing undergraduate research for faculty, students, institution, and the nation as a whole particularly in the STEM disciplines are well documented [1]. The involvement in experiential learning and research by students not only improves content knowledge, and motivation to pursue graduate studies, but also promotes creativity, critical thinking, and self-assurance. The faculty mentor benefits through improved teaching skills and by broadening opportunities for securing funding. The primary author serves as principal investigator for two synergistic projects titled "AIRSPACES: Aerial Imaging and Remote Sensing for Precision Agriculture and Environmental Stewardship", and "Environmentally Conscious Precision Agriculture : A Platform for Active Learning and Community Engagement" that promotes involvement of undergraduate students from all the STEM disciplines. The former is supported by NASA and the Maryland Space Grant Consortium, while the latter is supported by the United States Department of Agriculture. Involving underrepresented minority undergraduate students in these projects is facilitated through the National Science Foundation's HBCU-UP and LSAMP programs. These efforts are strongly aligned to both the UMES' land-grant (UMES is an 1890 Land Grant Institution) mission and the historic mission to serve the underrepresented minority populations.

In the summer of 2004, the UMES combine was retrofitted with a yield monitor and a GPS unit as the first step towards engaging in a comprehensive "Precision Agriculture" program [2]. Subsequently, significant progress has been made in enhancing aerial imaging and remote sensing efforts, improving geospatial information technology facilities, development of variable rate application capability, and acquisition of field sensors and data collection tools to support precision agriculture at UMES [3-5]. Significant effort related to the precision agriculture project at UMES has utilized Bozman, a 50 acre production field as the primary test facility. Since the initiation of the project, yield data have been archived for Bozman and other production fields at UMES for further analyses at a later date. This paper reports a study that was performed by an undergraduate engineering student who worked as part of the precision agriculture team to develop simplified "Management Zones" based on multiple years of harvest data of the Bozman field.

Appropriate delineation of "management zones" within a production field allows the farmer to manage seeding rate and other nutrients through variable rate application methods with improved efficacy and profitability. Researchers and practitioners have explored several approaches for identifying appropriate "management zones" that utilize soil fertility information, electrical conductivity data, remote imagery of the fields, and yield data [6-8]. Sophisticated computational techniques and statistical analyses have also been utilized to delineate management zones [9, 10]. The approach described in this paper utilizes multiple years of spatially distributed harvest data obtained from the yield monitor, and incorporates simple analyses techniques using software tools such as EXCEL, ARCGIS, and SMS Advanced that may be readily available and used by farmers.

2.0 Site Location, Software Tools, and Data Analysis

UMES is an 1890 land grant institution. Figure 1 shows the agricultural fields within the UMES campus. The work described in this paper involves analyses of multiple years of harvest data acquired using combine mounted yield monitor on the Bozman field (shown in light green in Figure 1). The yield monitor system retrofitted on UMES New Holland combine has been acquired from Agleader Technologies [11]. PF-Advantage yield monitor records location information using a GPS against a variety of harvest related data from agricultural fields as shown in the Table 1. The information is recorded in a data card and can be read into a digital computer with PCMCIA slot. In this project, only the data for the “dry yield volume” that appear on the 16th column in Table 1, are utilized along with GPS information. SMS Advanced, a software tool that has also been acquired from Agleader is used for initial data processing efforts. Spatial distribution maps of yield volume data can be easily developed using SMS Advanced. Figure 2 shows map of grain harvest data of portion of the Bozman field developed using SMS Advanced.

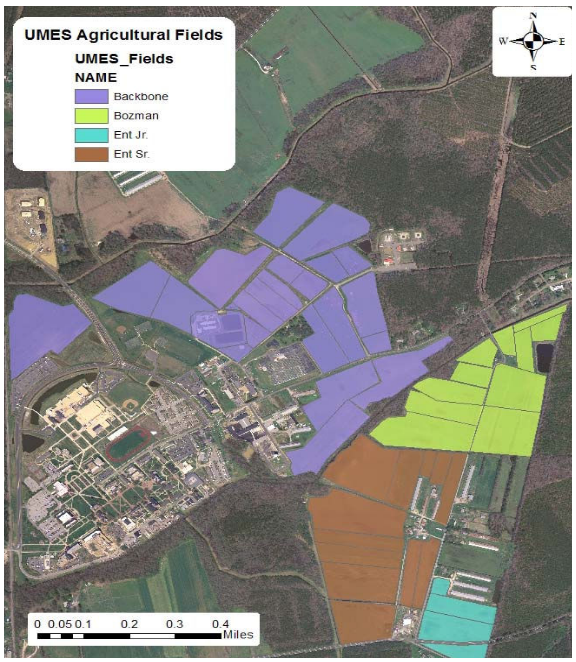

Figure 1: UMES Agricultural Fields

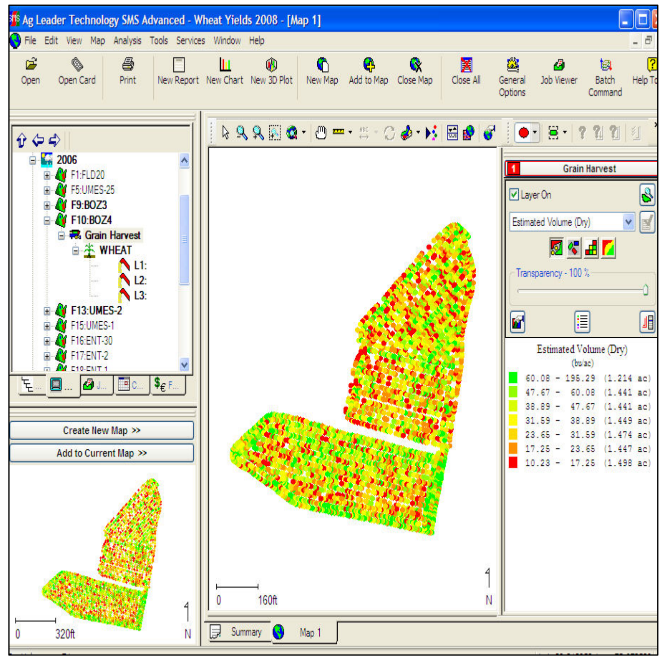

Figure 2: Yield Map on SMS Advanced

TABLE 1: Yield Monitor Data Fields

Field	Dataset	Product	Obj_Id	Track_deg	Swth_Wdth	Distance_f	Duration_h	Elevation_	Area_Count	Diff_Statu	Time	Crop_Flow_	Moisture_	Yld_Mass_D	Yld_Vol_Dr	Yld_Mass_W	Yld_Vol_W	Pass_Num	Speed_mph_	Prod_ac_hr
BOZ4	L1: (2004180264)	WHEAT	1.0000	333.8458	19.3333	3.4500	0.0006	17.7165	On	Yes	6/26/2008	4.8143	17.0000	6068.8314	101.1472	6288.1867	104.8031	1.0000	1.1761	2.7562
BOZ4	L1: (2004180264)	WHEAT	2.0000	329.4900	19.3333	4.4500	0.0006	17.7165	On	Yes	6/26/2008	3.6762	17.0000	3592.8263	59.8804	3722.6875	62.0448	1.0000	1.5170	3.5551
BOZ4	L1: (2004180264)	WHEAT	3.0000	321.8430	19.3333	4.4500	0.0006	18.0446	On	Yes	6/26/2008	2.7451	17.0000	2682.8259	44.7138	2779.7955	46.3299	1.0000	1.5170	3.5551
BOZ4	L1: (2004180264)	WHEAT	4.0000	315.5164	19.3333	4.7500	0.0006	18.0446	On	Yes	6/26/2008	4.1935	17.0000	3839.5369	63.9923	3978.3154	66.3053	1.0000	1.6193	3.7948
BOZ4	L1: (2004180264)	WHEAT	5.0000	309.0048	19.3333	4.8000	0.0006	18.0446	On	Yes	6/26/2008	5.0729	17.0000	4596.3187	76.6053	4762.4507	79.3742	1.0000	1.6364	3.8347
BOZ4	L1: (2004180264)	WHEAT	6.0000	310.3143	19.3333	5.0000	0.0006	17.7165	On	Yes	6/26/2008	3.1072	17.0000	2702.6763	45.0446	2800.3634	46.6727	1.0000	1.7045	3.9945
BOZ4	L1: (2004180264)	WHEAT	7.0000	310.3143	19.3333	5.6000	0.0006	18.0446	On	Yes	6/26/2008	2.7451	17.0000	2131.8884	35.5315	2208.9446	36.8157	1.0000	1.9091	4.4738
BOZ4	L1: (2004180264)	WHEAT	8.0000	314.3929	19.3333	5.4000	0.0006	17.7165	On	Yes	6/26/2008	3.1614	16.9000	2549.2210	42.4870	2638.1830	43.9697	1.0000	1.8409	4.3140
BOZ4	L1: (2004180264)	WHEAT	9.0000	306.5913	19.3333	5.3000	0.0006	17.7165	On	Yes	6/26/2008	4.3071	16.7000	3547.0691	59.1178	3662.0401	61.0340	1.0000	1.8068	4.2341

The SMS Advanced map data can be exported for use by other software tools such as EXCEL and ARCGIS 9.2. The “Export” option from SMS Advanced pull down menu generates three independent files with extensions .shx, .dbf, and .shp. The .dbf file can be opened on EXCEL to

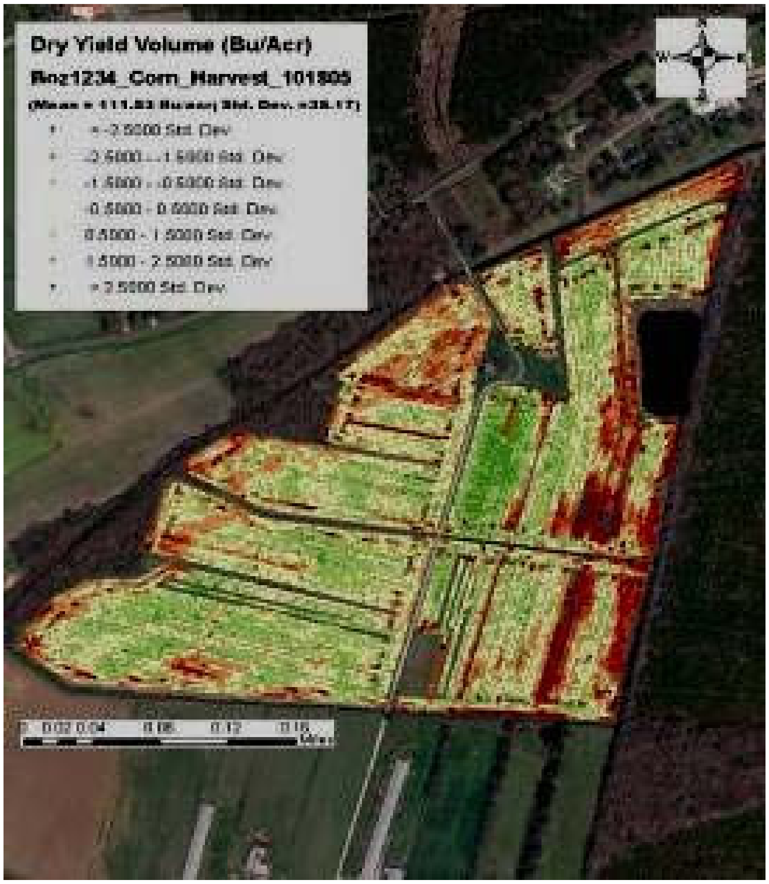

Figure 3: Bozman Corn Yield Data 2005 Fall

display the recorded data as in TABLE 1. Harvest information for roughly ten acres of Bozman field (Figure 2), yields more than 3000 rows of data. The .shp file is a standard "shape file", and can be opened in ARCGIS 9.2 and other GIS software environments. The prevailing practice at UMES among the ECPA and AIRSPACES project participants, is to use ARCGIS 9.2 in conjunction with SMS Advanced for mapping, data analysis, spatial interpolation, geo-referencing, image mosaicking, and other related efforts. For example, utilizing ARCGIS 9.2, appropriately processed yield data can be overlaid on orthorectified base images of proper portion of the UMES agricultural fields to provide a comprehensive view of the spatial distribution of yield data (Figure 3).

The "simplified management zones" approach adopted in this paper is based on dividing the field into regions of " high yield ", " average yield", and "low yield" using multiple years of yield data, and observing the trends from year to year. The "management zones" are based on these data trends, as well as taking into consideration the contiguity of the regions. The appropriately filtered "yield volume dry" data column is processed in either EXCEL or ARCGIS 9.2 for obtaining the mean or average yield value. Subsequently, in a new column the results of "yield volume dry" values divided by mean or average value obtained earlier are entered for getting the mean normalized yield values. The values close to "1" indicate regions of average yield, values that are substantially above or below "1" correspond to "high" and "low" yield regions, respectively. These yield values are then mapped using GIS software to obtain the spatial distribution of normalized yield map. By studying patterns and trends in these normalized yield maps of multiple years, contiguous regions of "high", " average", and "low" yield regions are obtained so that they may be managed differently resulting in higher productivity and profit. The initial efforts using this approach for management zone delineation have been used for Bozman farm. The results are discussed in the following section.

3.0 Results and Discussion

Figure 4 illustrates the process of obtaining normalized yield maps using the corn yield data displayed in Figure 3. In Figure 4, the map on the left is the "raw yield map" as displayed in Figure 3. In the spread sheet data shown in Figure 4, the extreme right column is the normalized yield volume dry data which have been obtained by dividing the “raw yield volume dry data” by mean or average yield data. The new attribute data column has the same location variables obtained by the GPS unit that are associated with the original yield data and can be easily displayed on a GIS map. This normalized yield map is shown to the right in Figure 4. In this case, the average is chosen as normalized yield values that range from 0.8 – 1.2. These regions are displayed in “yellow”, while regions with normalized yield data value above 1.2 are in “green”,and the ones below 0.8 are shown in “red”.

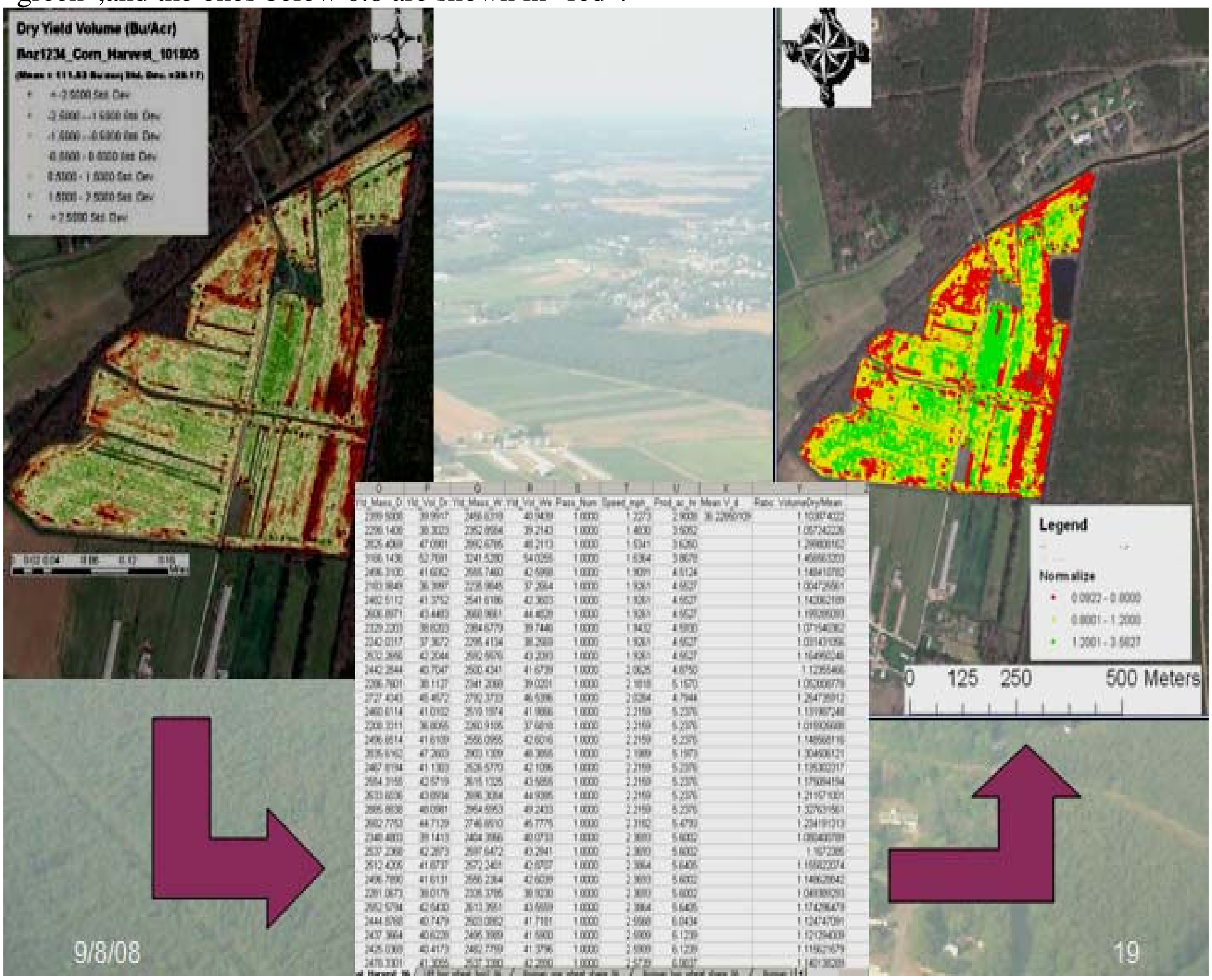

Figure 4: Yield Data Analysis to Develop Normalized Yield Map

Similar analyses were performed for harvest data of Bozman field for different crops such as corn, wheat, and soybean planted in rotation in Bozman for multiple years. Some of these results are shown in Figures 5 and 6 for 2005 and 2006 wheat yield data. The left hand map in each of these figures display the normalized yield map, whereas, the right hand map shows zoning efforts based on this specific normalized map. The undergraduate student participant working on the project in consultation with the UMES farm manager, and other project participants analyzed the multiple years of normalized yield maps for delineating the simplified management (Figure 7) zone. The zones would be used for future studies and experiments in the “Precision Agriculture” project. The region outlined in “blue” is the high yield region, the one outlined in "white" is the low yield region, and the one outlined in pink is the "average" yield region. The raw zone designations from the data analyses had to be refined for contiguity of regions and practical considerations as suggested by the UMES farm manager.

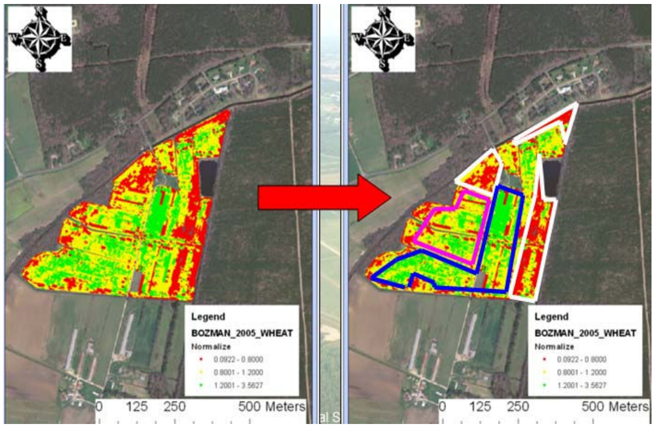

Figure 5 : Analysis of 2005 Wheat Data

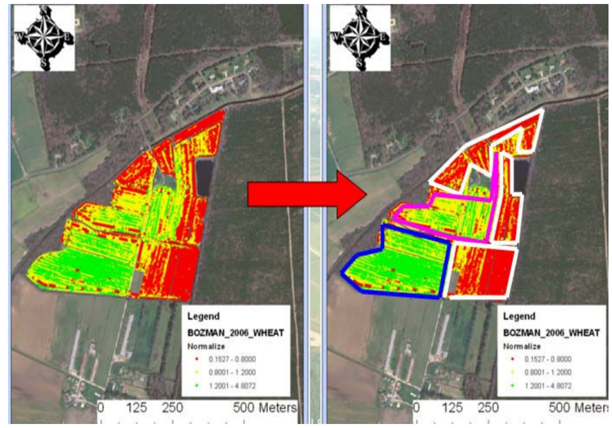

Figure 6 : Analysis of 2006 Wheat Data

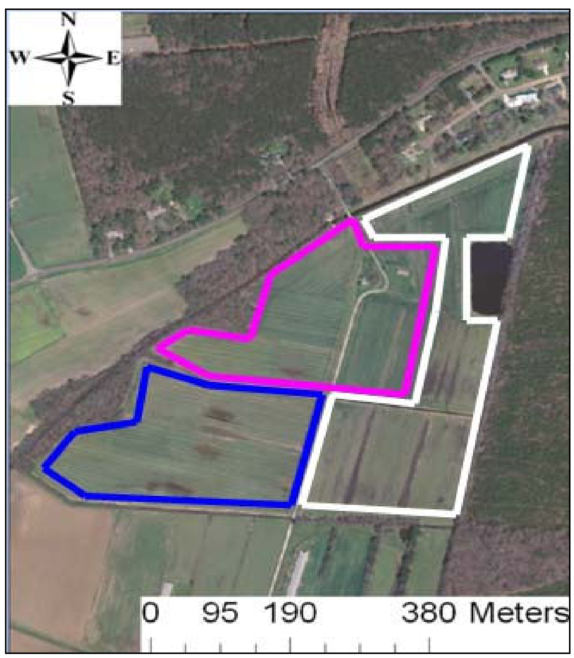

Figure 7: Management Zones for Bozman

4.0 Future Effort

These zones will be utilized to manage the regions differently to yield higher profit. In the past, UMES farm manager has used uniform seeding rate across the entire field. This study indicates that the use of varying seed rates and nutrients in accordance with the management zones delineated, have the potential to increase profit. In consultation with the UMES farm manager, the seeding rates as indicated in Table 2 have been chosen for high, average, and low yield regions for the crop rotations in Bozman field. Experiments will be conducted in the Bozman field using this framework, and yield and productivity analyses will be performed.

TABLE 2 : Proposed Seeding Rate for Management Zones Project

Crop	High Seed Rate	Medium Seed Rate	Low Seed Rate
Corn	30,000 seeds/acre (7’’ between seeds in 30’’ row)	26,000 seeds/acre (8’’ between seeds in30’’ row)	22,000 seeds/acre (9.5” between seeds in 30’’ row)
Soybean	175,000 seeds/acre (5.0 seeds per ft of 15” row)	150,000 seeds/acre (4.3 seeds per ft of 15” row)	125,000 seeds/acre (3.6 seeds per ft of 15” row)
Wheat	40 seeds/sq.ft (18 seeds per ft of 7’’row)	35 seeds/sq.ft (20 seeds per ft. of 7’’row)	30 seeds/sq.ft (23 seeds per foot of 7’’row)

5.0 Conclusion and Learning Outcomes

The initial efforts devoted towards the “management zones” delineation have taken into account only the yield monitor data. Efforts reported by other researchers and experimenters have involved soil fertility, slope and elevation data, aerial imagery, as well as electrical conductivity measurements. All these additional information can be used to refine management zones delineation efforts at UMES, along with more mathematically and statistically rigorous approaches for the analyses of data for zone classification. The intent in this work has been to keep the zoning efforts simple and intuitive; however, based on the results of variable seeding rate experiment, additional complexity may be introduced in future zoning approaches.

Figure 8: Student Presenting Project Results

A significant component of the AIRSPACES and ECPA projects is to involve undergraduate students in experiential learning and research efforts. The undergraduate engineering student involved in the project worked with a multidisciplinary team of faculty, graduate students, USDA and NASA scientists, as well as UMES farm manager and other farm personnel. The student learned new software tools and got introduced to the expanding field of geospatial information technologies. The student also participated in a team presentation of the project at the Mid Atlantic Regional meeting of the NASA Space Grant Consortium (see Figure 8), and a poster presentation for the 2008 HBCU Research Day at the UMES campus.

The student gained knowledge on the contemporary issues related to sustainability, alternative energy sources, and environmentally friendly engineering solutions that were discussed in the context of the project, as well as broader issues of globalization and global warming. In the context of learning outcomes advocated by ABET [12] for engineering students, the involvement in the project provided a platform to influence several of the *"a through k"* outcomes outlined by the Engineering Accreditation Commission, in particular, the ones delineated below:

- an ability to apply knowledge of mathematics, science, and engineering;
- an ability to design and conduct experiments, as well as to analyze and interpret data;
- an ability to function on multidisciplinary team;
- an ability to communicate effectively;
- a recognition of the need for, and an ability to engage in lifelong learning;
- broad education necessary to understand engineering solution in a global and societal context;
- a knowledge of contemporary issues; and
- an ability to use techniques, skills, and modern engineering practice.

6.0 Acknowledgement

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