A CONTENT REVIEW OF PRECISION

AGRICULTURE COURSES ACROSS THE UNITED STATES

A Thesis

presented to

the Faculty of the Graduate School

at the University of Missouri – Columbia

In Partial Fulfillment

of the Requirements for the Degree

Masters of Science

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by

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Dr. Leon Schumacher, Thesis Supervisor

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

A CONTENT REVIEW OF PRECISION

AGRICULTURE COURSES ACROSS THE UNITED STATES

presented by Danielle Skouby

a candidate for the degree of Master of Science,

and hereby certify that, in their opinion, it is worthy of acceptance.

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Dr. Leon Schumacher

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Karen Funkenbusch

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Dr. Newell Kitchen

DEDICATION

I dedicate this research work to my husband, Justin Skouby, who encouraged me to continue my education. Without his support and love for our family this project would not have happened. Thank you for taking care of the kids and keeping me grounded!

Acknowledgements

I would like to thank the following people for their help and encouragement in earning my Master's.

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A CONTENT REVIEW OF PRECISION AGRICULTURE COURSES ACROSS THE U.S.

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Abstract

Knowledge of what Precision Agriculture (PA) content is currently taught across the U.S. will help build a better understanding for what PA instructors should incorporate into their classes in the future. For this assessment, the University of Missouri (MU) partnered with several universities throughout the nation on a United States Department of Agriculture (USDA) challenge grant. A survey was conducted with PA instructors from 44 institutions from across the U.S. participating. Each institution was assessed to determine amount of time they spent teaching on 59 different PA topics in their PA-related courses. Results were obtained from 56 PA courses. Scope of PA, Global Positioning System (GPS), Differential GPS, Yield Monitoring, and Yield Map were all topics that were frequently discussed in PA courses, whether they were entry- or advanced-level or two-year or four-year institutions. Review of the content showed a need for a more standardized curriculum.

Chapter 1

1. Introduction

1.1 Statement of the Problem

There are constant changes, adaptations, and improvements to technology and methods used to enable and understand Precision Agriculture (PA). These changes require that farmers learn how to adopt information that can help them understand new technology. Farmers learn knowledge and the skills of PA in many ways but examples of continuing education opportunities include farm field days, farm tours (Heiniger, Havlin, Crouse, Kvien, & Knowles, 2002), and online courses. In contrast for college students seeking degrees in agriculture, with PA content, courses developed over the last 20 years have somewhat independently emerged within the U.S. This is in large measure because no standardized curriculum or text has developed for PA. It was therefore presumed that the nature of PA course content across the country to be independent. Little research has been done related to the content of PA courses to test this assumption. Further the high costs associated with PA and the time that it takes to learn and develop the skill sets needed to teach PA have greatly reduced the distribution of knowledge about PA across the country (Reichardt, Jürgens, Klöble, Hüter, & Moser, 2009). The extent and quality of instructor education impacts the learning effectiveness in the classroom (Darling-Hammond, 2000). Researchers have found that this is the case for the content presented within PA courses throughout the nation. Finally industry is a driving force for stimulating PA product development and adoption, causing educators and researchers to look to industry for research and education content (Kitchen, Snyder, Franzen, & Wiebold, 2002). The importance of knowing the skills and knowledge in support of the industry workforce can and should shape the core, pertinent principles for PA courses across the nation.

1.2 Purpose of the Study

The purpose of this study was to evaluate the PA topic taught in two-year and four-year U.S. college institutions. The survey assessed time spent on topic areas and included both entry- and advanced-level courses. The proposed outcome of this PA course assessment was to compare PA course content with identified PA industry needs to determine the gaps within the PA curriculum.

1.3 Objectives of the Study

1. Determine the predominant PA topics taught in PA courses across the U.S.
2. Quantify the time spent on PA topics for entry level and advanced level PA courses.
3. Compare the time spent teaching PA topics between two-year and four-year institutions.

1.4 Assumption of the Study

The following assumptions were made when considering any conclusions or recommendations.

1. Search techniques (Colleagues, Google, and ERIC [Education Resources Information Center] database) identified the institutions that were teaching entry level and advanced PA courses.
2. Surveys were delivered to instructors that were teaching PA related courses.
3. Completed surveys from instructors resulted in reasonably accurate information.
4. Researcher knew that some of the surveys would be delivered to some instructors that had retired, took a different job, or moved.

1.5 Limitations of the Study

Any conclusions or suggestions proposed by this study were limited by the following factors.

1. The study is limited to those institutions that teach PA courses.
2. The ability to recognize and make contact with PA instructors.
3. The instructor's ability to accurately portray the PA content taught in each PA course.

Chapter 2

2. Review of Literature

The number and percentage of U.S. youth obtaining post high school education before entering the workforce continues to rise each year. Approximately 20.5 million students were expected to attend colleges and universities in the fall of 2016, roughly 7.2 million would attend 2 year colleges and 13.3 million would attend 4 year institutions. This is an increase of 5.2 million since the fall of 2000 ("Fast Facts," 2016). The advantage of earning a post-secondary education is that it provides students with an opportunity to enhance their knowledge of personal development and technical skills through detailed curriculum designed for their specific fields (Martens, 2012). This added enrichment of a more specific course curriculum leads to a better understanding and a broader knowledge base for a rapidly changing and fast-paced work environment. Such quickly changing education needs are common for many fields of study. For agriculture-related work, it is especially characteristic of employment using PA technologies and methods.

There is a very high precedent set by industry and the world to use PA technology (precision inputs, precision data collection, and data analysis). By the year 2050 the world population is projected to increase to 9 billion people, which equates to roughly a 70% increase in needed food (Futrell, 2014). This is a significant challenge for researchers and farmers alike with crop production needing to increase at a rate of 2.4% per year, an increase almost double of the average increased rate of 1.3% per year

(Martínez, Egea, Agüera, & Pérez-Ruiz, 2017). Concurrent to increasing food production is the need to do so in sustainable ways. At the University of Missouri, a 36-ha (89 acre) field was used for 11 years to implement a 'precision agriculture system' utilizing various PA practices and technologies to reduce inputs, costs and hopefully show increases in yield. The use of a 'PA system' for long-term production showed improved grain yield stability and resilience in a volatile changing climate (Yost et al., 2016). Precision Agriculture does not have to exclusively mean grain/crop production. The use of PA can be used for animal production. Precision livestock farming technology can include sensors, detectors, cameras, and microphones all designed to keep the livelihood and well-being of the animal top priority (Fournel, Rousseau, & Laberge, 2017).

Several institutions across the nation recognized the value and benefit of adding a PA content to degree programs (B.S. degree, minor, and/or certificate). In the fall of 2016 the University of Missouri implemented a PA certificate program to the Agricultural Systems Management degree program. The University of Missouri noted the value of partnering with other universities to teach PA since most instructors and professors do not have the formal training for the breadth of topics discussed by that described as PA. The University of Missouri developed this certificate so MU graduates would be recognized as PA trained graduates (Schumacher, 2016). South Dakota State University (SDSU) established a Bachelor's of Science degree program in Precision Agriculture. The rationale for this new degree was that future graduates required a broader competency in agronomy, statistics, mathematics, and engineering for the best performance from rapidly emerging technology used in PA (*New Undergraduate Degree*

Program - Bachelor of Science Precision Agriculture, 2016). Dr. Bruce Erickson, Purdue University, stated that the traditional classroom coursework was no longer adequate for students engaged in PA. Erickson listed six skill sets that play a major role in PA learning: 1) a foundation of agronomy knowledge, 2) a foundation of technology knowledge, 3) a foundation of agricultural economics, 4) analytical skills, 5) communication skills, and 6) ethics (Schrimpf, 2017).

Scott Fausti and Bruce Erickson, completed a study that focused on the Knowledge, Skills, and Abilities (KSA's) of ten different objectives pertaining to five different work roles (equipment operator, agronomist, equipment technician, technical support, and precision sales specialist) in PA (Fausti et al., 2017). The study was sent to PA educators (asking the KSA's that educators perceived students must have for different PA work roles) and retail dealerships (asking the KSA's that industry needed for employees to be able to fill open positions) to determine if PA training gaps existed in the workforce. One of the KSA's that the study inquired was "3. Ability to produce accurate digital maps of fields using spatial information within specialized software". Within this KSA four of the five work roles had significant difference between the PA educators and retail dealership responses. Retail dealerships viewed this KSA as less important for equipment operator and agronomist work roles than PA educators.

The retail dealerships put more emphasis on this KSA for equipment technicians and precision sales specialists than the PA educators. Another KSA objective, "8. Working understanding of statistical standards to produce means and standard deviations", had significant differences for all five work roles. PA educators placed more importance for this objective for equipment operators than the retail dealerships. Agronomist, equipment technicians, technical support, and precision sales specialist the retail dealerships put a higher emphasis on this objective than the PA educators.

CropLife Magazine partnered with Purdue University for assessing within the U.S., through surveys, information about PA from 2500 CropLife retail crop input dealership readers. The goal has been to determine the impact of PA technologies. These surveys asked several questions pertaining to the use of PA technologies, customer adoption, the potential profit associated with the adoption of PA technologies, and the possible adoption of PA technology. These surveys determined the adoption and acceptance of PA technology both among the dealerships that market these products and with the customers that benefit the most from PA practices. The CropLife dealership surveys have circulated since 1997. The following is a summary of some of the trends over the past decade.

In 2006 the survey report indicated the primary growth of PA technology was within the dealerships themselves rather than in services for growers. The percentage of dealerships that provided custom application to their customers was at 84% with 60% custom applying fertilizer and 54% custom applying pesticides. In the 2006 study 76% of the respondents used manual/lightbar GPS guidance where only 20% used auto steer for the PA systems (Whipker & Akridge, 2006).

In 2007 the CropLife agricultural services dealership survey reported that PA technology was around to stay. Over ¾ of the retail dealerships in the Midwest and over

½ of the retail dealerships outside of the Midwest consistently continued to use PA technology. As with the past year the dealerships continued to use more PA services for their own use than the PA services that they offered to their customers. The 2007 survey also revealed that sensors, either on-the-go or mounted, were starting to grow in popularity among the dealerships (Whipker & Akridge, 2007).

In the 2008 CropLife survey researchers noted increased use of PA technologies due to rising crop production inputs. Technology barriers existed as six out of 10 respondents noted that PA equipment changed too quickly. There were concerns as 45% of respondents reported that the data collected via PA systems could not be easily transferred to another PA system (cross platform compatibility). However, the use of PA technology continued to grow partially as the technology had become more user friendly and the training needed to learn how to use PA technology was less challenging (Whipker & Akridge, 2008).

In 2009 researchers noted that the demand for PA services continued to grow. The most growth was in auto steer GPS guidance systems. As with past CropLife surveys, concerns existed about cross platform compatibility and the technology changes needed to launch new PA equipment. The dealerships were willing to invest in PA technologies to improve accuracy and data collection/use in their businesses and to enhance the services they offered to their customers (Whipker & Akridge, 2009).

The next CropLife Precision Agricultural Services Dealership Survey was conducted in 2011. By 2011 the economy was starting to stabilize and was returning to levels that had been reached in 2009; the demand for PA services continued a slow climb. The most growth continued to be with auto steer. Dealerships reported that their biggest barrier to PA technology (55%) was that they were unable to charge high enough fees to make PA services profitable. The second highest barrier was the rapid change in PA technology; this impacted the overall bottom line for return on investment (Whipker & Erickson, 2013).

As PA technology was adopted over time, the survey results changed to reflect the technology being offered for PA, such as grid/zone sampling and remote sensing. GPS guidance; the adoption of both auto steer and manual control continued to climb. However, other technology breakthroughs such as planter row unit controls and sprayer section controls showed rapid growth. By 2013 the survey results had a higher shift in the adoption of grid/zone sampling, remote sensing, and variable rate technology. (Holland, Erickson, & Widmar, 2013)

In the most recent 2015 survey (Erickson & Widmar, 2015) the authors discussed the increasing availability of faster processing computers, connecting devices to store, share and analyze data and a workforce that was more technology savvy. The benefits of a better connected internet; variable rate technology, remote sensing, better use of soil test results, and soil or yield maps helped farmers see and understand the variability in every field and farm. These new features helped keep GPS guidance, sprayer section control, and row controllers on a steady sales climb as more and more farmers adopted PA technologies that made sense for their farm/operation. (Erickson & Widmar, 2015)

Chapter 3

3. Methodology

3.1 Introduction

A team of faculty representing eight universities throughout the U.S. (research team), submitted and were awarded a USDA challenge grant titled: Precision farming workforce development: standards, working groups, and experimental learning curricula. As a part of this grant the University of Missouri was charged with identifying common core objectives for each PA course regardless of where a course was taught. This research was conducted to address this objective.

For this analysis, two survey studies were conducted. The first was a survey of syllabi of PA courses. The second was a PA course content survey that was directed to instructors of PA. Results of the former, shaped the survey questions of the latter.

3.2 Precision Agriculture Course Syllabi Survey

Researchers searched online databases to develop an exhaustive list of institutions that taught PA in the U.S. and Canada. For each institution a letter was sent to either the PA instructor or the department chair requesting their assistance to share PA course syllabi for analysis. A total of 43 course syllabi were obtained (one syllabi being from Montreal, Canada). Prerequisites, both college core prerequisites and courses needed before enrolling in advanced PA courses were identified. The researchers next determined common PA topics for PA curriculum to attempt to develop an understanding of what was currently taught in PA courses. These topics were then used when searching the syllabi. The data that was analyzed in the pilot study (syllabi) varied greatly. Some syllabi had great detail while, other syllabi only contained general university syllabi information.

The objectives for this PA research were to:

1. Determine PA entry level topics taught within PA courses and what phrases were used to address these topics.
2. Determine PA advanced level topics taught within PA courses and what phrases were used to address these topics.
3. Gain insight about the level of detail needed to teach PA to students attending colleges/universities.

3.3 Syllabi Survey Evaluation Methods

The researcher first identified universities across the U.S. and Canada that were teaching PA. The universities that had PA programs or coursework were found by contacting colleagues, Google searches, and ERIC database searches. A letter and email were sent to these universities to determine if they would be willing to share their course syllabi. It was reasoned that the syllabi would contain information about PA topics taught at each institution. In order to determine the specific content taught in each course (from the syllabi), a list of keywords and phrases were generated from the table of contents of the revised PA manual under development by Kent Shannon (Shannon & Clay, 2017). The overall goal of the PA manual was to serve as an updated text for those teaching PA at the undergraduate level (Shannon & Clay, 2017).

The University of Missouri requested a copy of all PA course syllabi that were taught at their institution. Letters were first sent out asking for syllabi beginning in August 2015. A second reminder email was sent to the entire list of participants during the latter part of August 2015. Once the researcher received copies of the syllabi they were saved as a searchable PDF. If hard copies of the syllabi or word documents were received, they were converted into a searchable PDF format. After all the syllabi were converted to a searchable PDF format, they were saved to one folder.

A list was compiled of all the syllabi that had been received. Within that list the syllabi were sorted by entry- or advanced-level courses. The entry level courses were identified as the first class in the series of courses taught at that institution or if they were the only PA course taught. Advanced level courses were any course **NOT** classified as an entry level course.

Using the find tool within Adobe Acrobat all the syllabi were searched for each topic. There were variations made to the topics. The topics were searched based on acronyms (e.g., "GPS" for "Global Positioning System") or the order that certain words would appear (e.g., "yield monitor" or "monitor yield") or abbreviations (e.g., "vari" for "variability" or "variable" or "manage" for "management" or "managements"). A total of 59 topics were identified and were used to search each syllabi. Once all topics were searched, a tally was created to quantify the number of times a topic was listed. The topics were ordered in relation to the frequency that they were found in the syllabi. Once the topics were tallied they were separated based on whether they were an entry level course or an advanced level course.

3.4 Instructor Survey Evaluation Methods

Conclusions from the pilot study (syllabi) determined a survey (Appendix E) should be developed and delivered electronically (Qualtrics, 2016) and by U.S. mail to PA instructors. The survey was approved by the University of Missouri Institutional Review Board (IRB) on April 22, 2016 and mailed to 134 instructors on June 20, 2016. The invitational letter and electronic link (Appendix D) for the survey were emailed to 134 instructors on June 22, 2016. A reminder email was delivered on June 27, 2016 (Appendix F) and a second reminder email was delivered on July 25, 2016 (Appendix G). In an effort to include as many instructors and professors of PA courses as possible, a hard copy of the survey was shared with the International Society of Precision Agriculture (ISPA) committees that the USDA research team members were in association with on June 29, 2016. The last survey was received on August 18, 2016. The research team received 44 surveys for a total of 56 PA courses. A total of five surveys were incomplete.

The instructor survey was developed with the same list of topics that were used to search the syllabi survey. Within the survey, the topics were sorted by the amount of time each instructor taught each topic. The responses for each topic were grouped and coded as such: N/A or None (1), 0-15 minutes (2), 16-30 minutes (3), or 30+ minutes (4) per topic.

The quantitative data was analyzed using SAS 9.4 software. The researcher noted low data numbers for each group. This limited the number of statistical tests that could be used to analyze the data. The first statistician contacted by the researcher suggested that a Chi-Square test be conducted to determine if there were any significant differences. However, when using a Chi-Square test the population (n) should be approximately 20. In order to achieve groups where n=20 the time groupings of 1 (N/A or None), 2 (0-15min.), 3 (16-30min.), & 4 (30+min.) would need to be collapsed to properly conduct the Chi-Square analysis. The researcher felt information pertaining to each topic would be lost after the time groups were collapsed so they could properly conduct the Chi-Square analysis. A second statistician was consulted and advised the researcher to contact yet a third statistician. The third statistician determined the categorical data that had been collected could be properly analyzed by comparing mean and median and by running the Wilcoxon Rank Sum Nonparametric Test. The data from this research was not normally distributed, therefore it was not appropriate to analyze the data via a t-test analysis. The researcher ran both the Shapiro-Wilk test and the Kolmogorov-Smirnov goodness-to-fit test to confirm non-normality of the data.

Chapter 4

4. Data Analysis and Findings

4.1 Syllabi Survey Findings

A total of 24 institutions sent in 43 syllabi to the researcher (Figure 1). While most of the syllabi came from the central part of the United States, there were syllabi received from California, Washington, Idaho, and Montreal, Canada. The syllabi were searched to determine the prerequisites that were required or recommended for each course. Nineteen of the syllabi did **NOT** list any prerequisites. Eight courses required the students to have had college algebra or an equivalent. Four of the syllabi required an introductory PA class before they could enroll in a second (advanced level) PA course (Table 1). Within the 43 course syllabi there were only two syllabi that listed a suggested prerequisite for their course. The two suggested prerequisites were: 1) an understanding of crop production and agronomic principles and 2) previous PA courses.

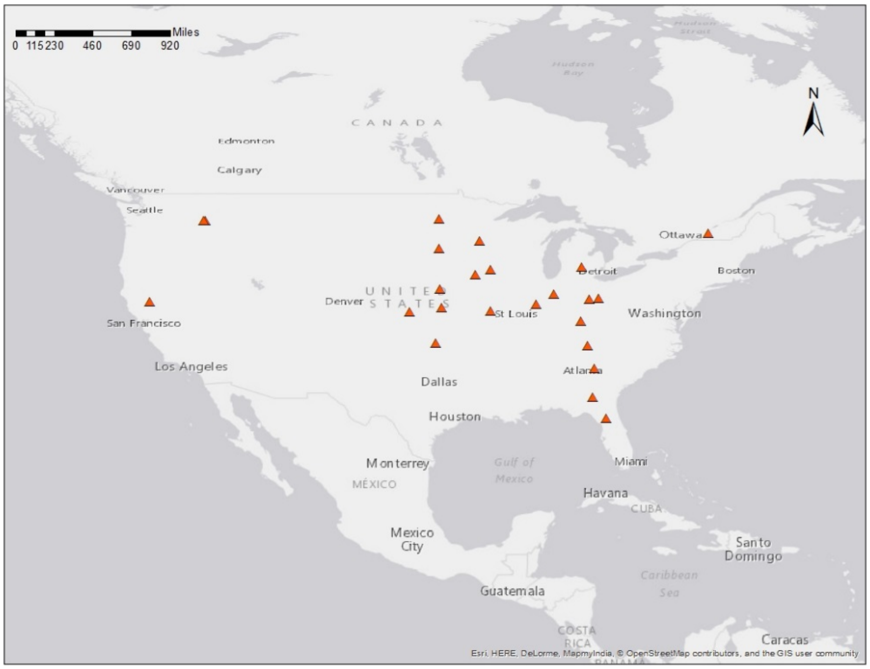

Figure 1. Colleges/Universities That Provided Precision Agriculture Course Syllabi, Shown By Location.

Table 1. Prerequisites Required For Students Enrolled In Precision Agriculture Courses (N=43)

Prerequisite Listed	# of Syllabi	Prerequisite Listed	# of Syllabi
None	19	GIS	2
College Algebra	8	Farm Management	2
Precision Ag (Intro.)	4	Agribusiness	1
Junior/Senior Standing	4	Insect Biology	1
Physics	3	Remote Sensing	1
Soils	3	Statistics	1
Graduate Standing	3	Basic Computing Class	1
Plant Pathology	2		

A total of 15 syllabi required *The Precision-Farming Guide for Agriculturists* (Ess & Morgan, 2010) as text for their course (34.9%, N=43). Another three syllabi had the text listed as an optional text for the course. Nine of the syllabi indicated that there was no textbook for the course (21%, N=43). Six of the syllabi listed course notes for the required reading (14%, N=43). The most commonly used textbook (Ess & Morgan, 2010) for these PA courses was last updated in 2010.

The data collected was examined by comparing the frequencies that each topic was taught. The researcher analyzed the frequency that topics surfaced for any entry level course. An entry level course was so named because it was listed as an introductory course or if it was the only syllabi received from that institution. There were 25 entry level and 18 advanced level syllabi received. Variable Rate Technology and Geographical Information System (GIS) were the most commonly taught topics within these entry level courses with 21 and 23 instances, respectively. (Figure 2.)

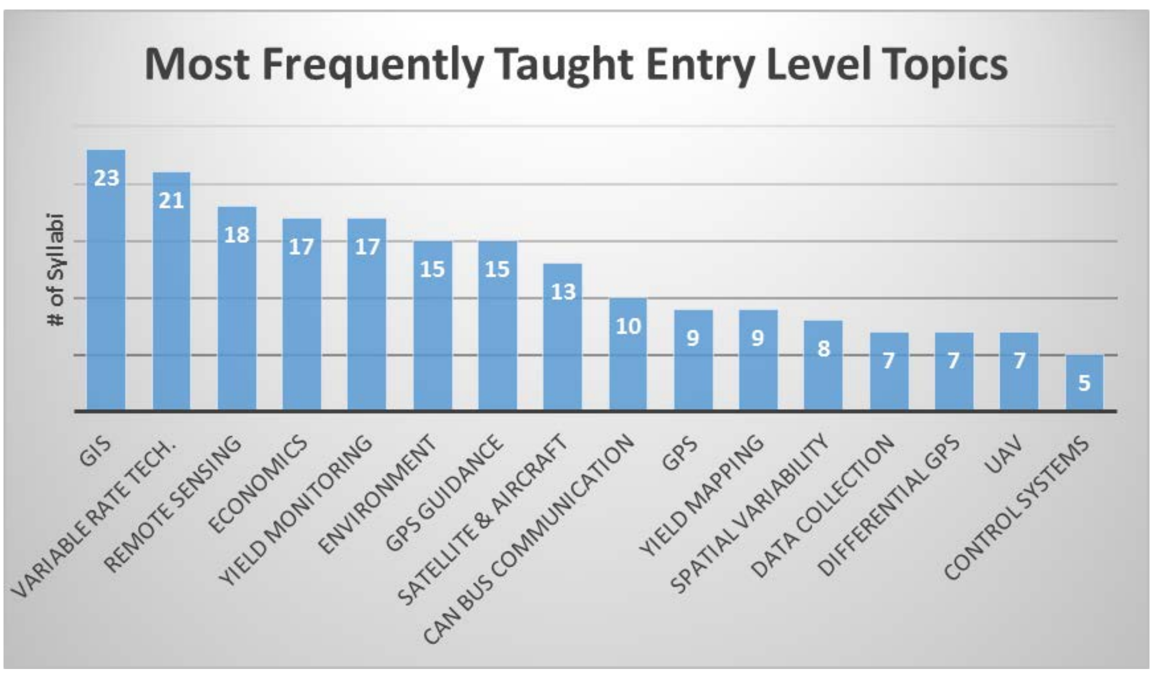

Figure 2. Most Frequently Taught Entry Level Precision Agriculture Topics (N=43)

The researcher analyzed the topics that were **ONLY** found in entry level courses. (Figure 3.) Few topics were taught only within an entry level course. The most frequent of those topics **ONLY** taught in entry level courses were Coordinate Systems, Map Projections, and GPS Accuracy.

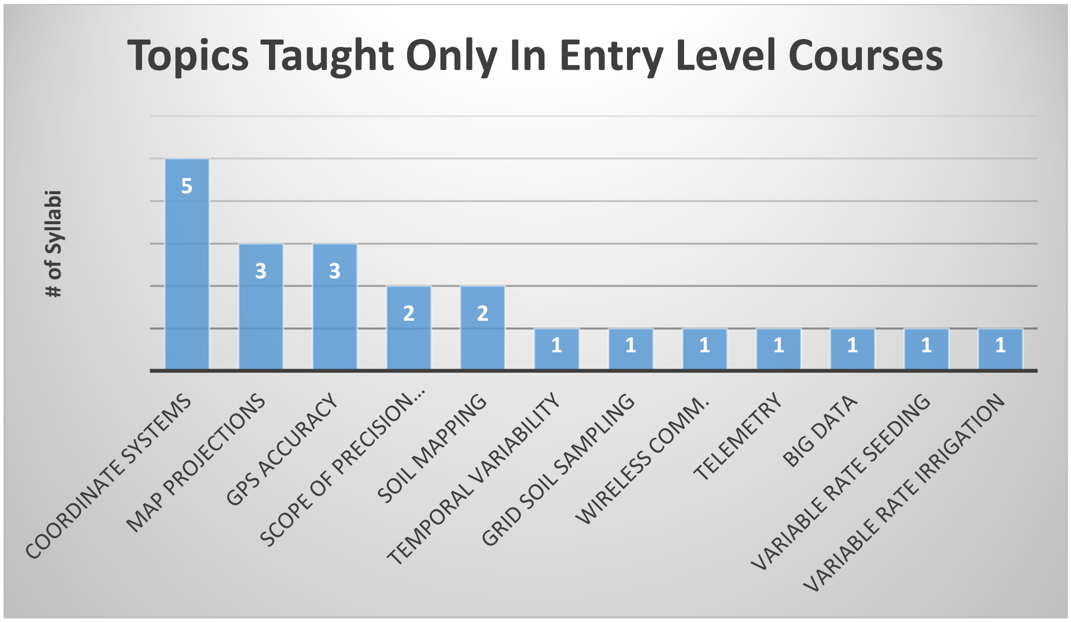

Figure 3. Precision Agriculture Topics Taught Only In Entry Level Precision Agriculture Courses (N=43)

The researcher next wanted to determine how many of the topics were taught within both an entry level and an advanced level PA course (Figure 4). GIS (23 entry level and 11 advanced level), Economics (17 entry level and 13 advanced level), and Variable Rate Technology (21 entry level and 7 advanced level) were the most frequently taught PA topics in the recorded PA courses. The overall findings were that the topics were introduced within an entry level course and then also reintroduced or expounded upon in an advanced level course.

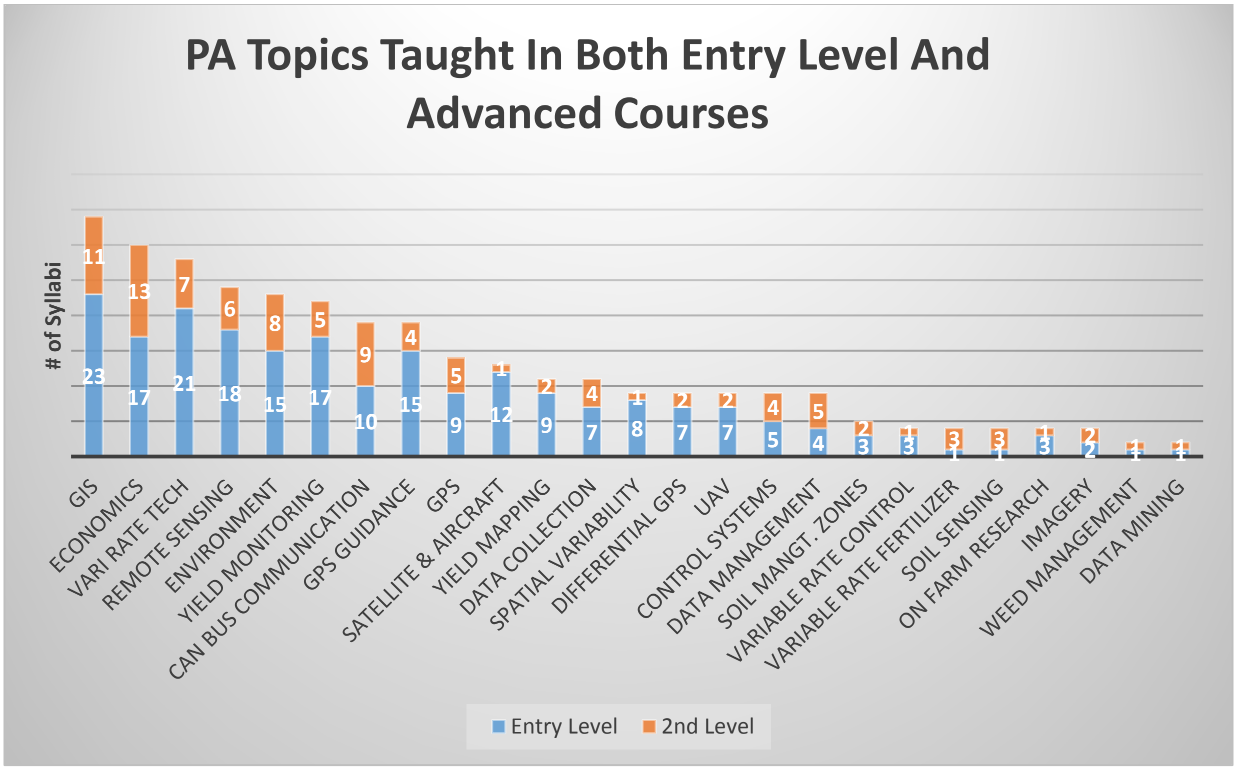

Figure 4. Precision Agriculture Topics Taught In Both Entry And Advanced Precision Agriculture Courses (N=43)

An analysis of the topics **ONLY** discussed in an advanced level course were analyzed. There were three topics that were only found taught in the advanced PA courses; Pest Management (which were found in two syllabi), Disease Management, and Data Interpretation. The last two topics only surfaced once in advanced level courses.

There were several topics that, when searched, yielded no responses for entry level or advanced level courses. Table 2 has a list of PA topics that were **NOT** found in syllabi. The researcher concluded that the instructors most likely did teach these topics within the classroom but did **NOT** include every topic phrase discussed during class in the syllabi.

Table 2. Topics With Zero Occurrences In Precision Agriculture Course Syllabi (N=43)

Weather Variability	Product Comparisons	Crop Sensing
Yield Monitor Calibration	Data Compatibility	Nitrous Oxide
Yield Map Cleaning	Data Ownership	Ultrasonic
Yield Stability	Eutrophication	Machine Vision
Soil Variability	Leaching	Variable Rate Pest
Topography	Hypoxia	
Insect Management	Soil Erosion	

4.2 Syllabi Survey Discussion

The compiled results were presented to the entire research team involved in the USDA challenge grant. The consensus was that many of the syllabi lacked enough specific detail to accurately determine which topics were taught or **NOT** taught among institutions. There were instances where an instructor would state that they indeed did teach certain topics, but those topics were marked as having no findings. The research team reasoned that it would also be beneficial to know the amount of time that instructors spent on each topic that they taught in the classroom. The researcher determined that an instructor survey was needed to develop a better understanding and knowledge about the topics that were taught in PA courses. The results from the syllabi survey were summarized and presented at the International Society of Precision Agriculture 13th International Conference on Precision Agriculture in St. Louis, Missouri (Skouby, Schumacher, Yost, & Kitchen, 2016).

4.3 Instructor Survey Findings

The researcher received 44 of 134 surveys for a total of 56 PA courses. A total of five surveys were incomplete. This provided a 29% completion rate for this instructor survey study. Figure 5 shows the disbursement of the surveys that were collected. The vast majority of the surveys collected were located within the central part of the United States. There was one outlier with a survey being completed by an instructor from Israel. The survey resulted in information from 39 entry level courses and 17 advanced level PA courses. Nineteen of the courses were from two-year institutions; 15 entry level courses and four advanced level courses. Thirty-seven of the courses were from four-year institutions; 24 entry level courses and 13 advanced level courses.

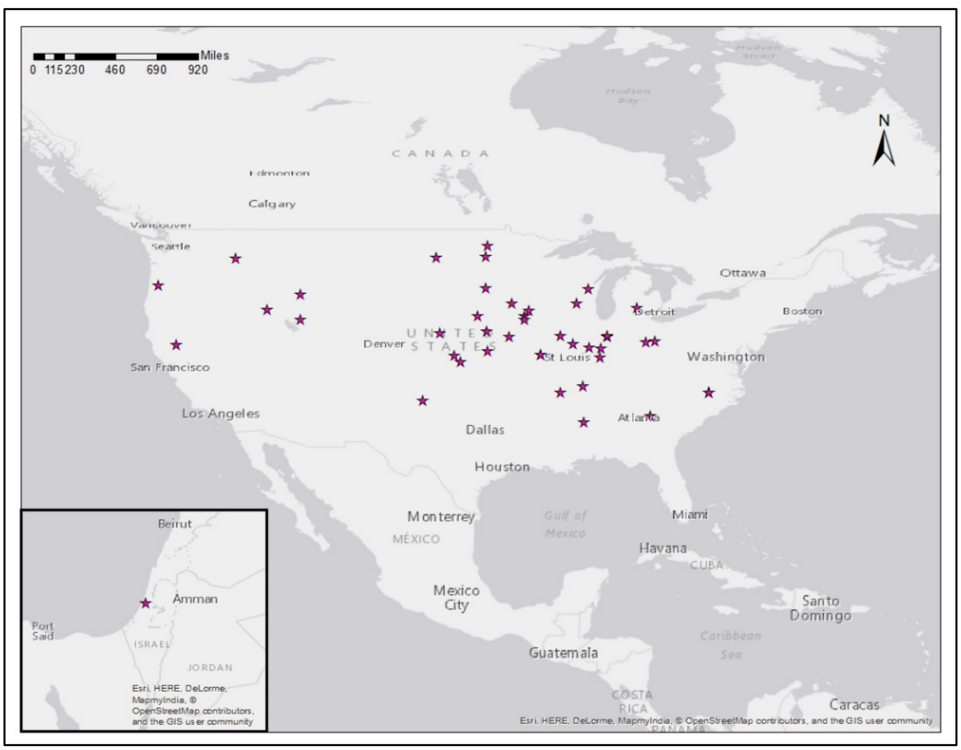

Figure 5. Colleges/Universities That Participated In Precision Agriculture Survey, Shown By Location

The researcher reviewed the time that the instructors spent 30 or more minutes on a topic. The topics were sorted into entry level and advanced level courses to determine if there were similarities among the topics listed. (Figures 6 & 7). GIS was the highest topic taught in entry level courses for both the syllabi survey and the instructor survey study. Variable Rate Technology was another topic within the top three for both the syllabi survey (#2) and the instructor survey (#3). The topics instructors indicated that they discussed for 30+ minutes in advanced level courses varied greatly from the information gathered via the syllabi survey. The most frequent PA topics for the syllabi survey were Economics (13), GIS (11), CAN BUS Communication (9) and Environment (8). However, the topics with the most replies for the instructor survey, in advanced level courses, were Spatial Variability (12), Crop Sensing (12), Variable Rate Nutrient (12) and Data Interpretation (12).

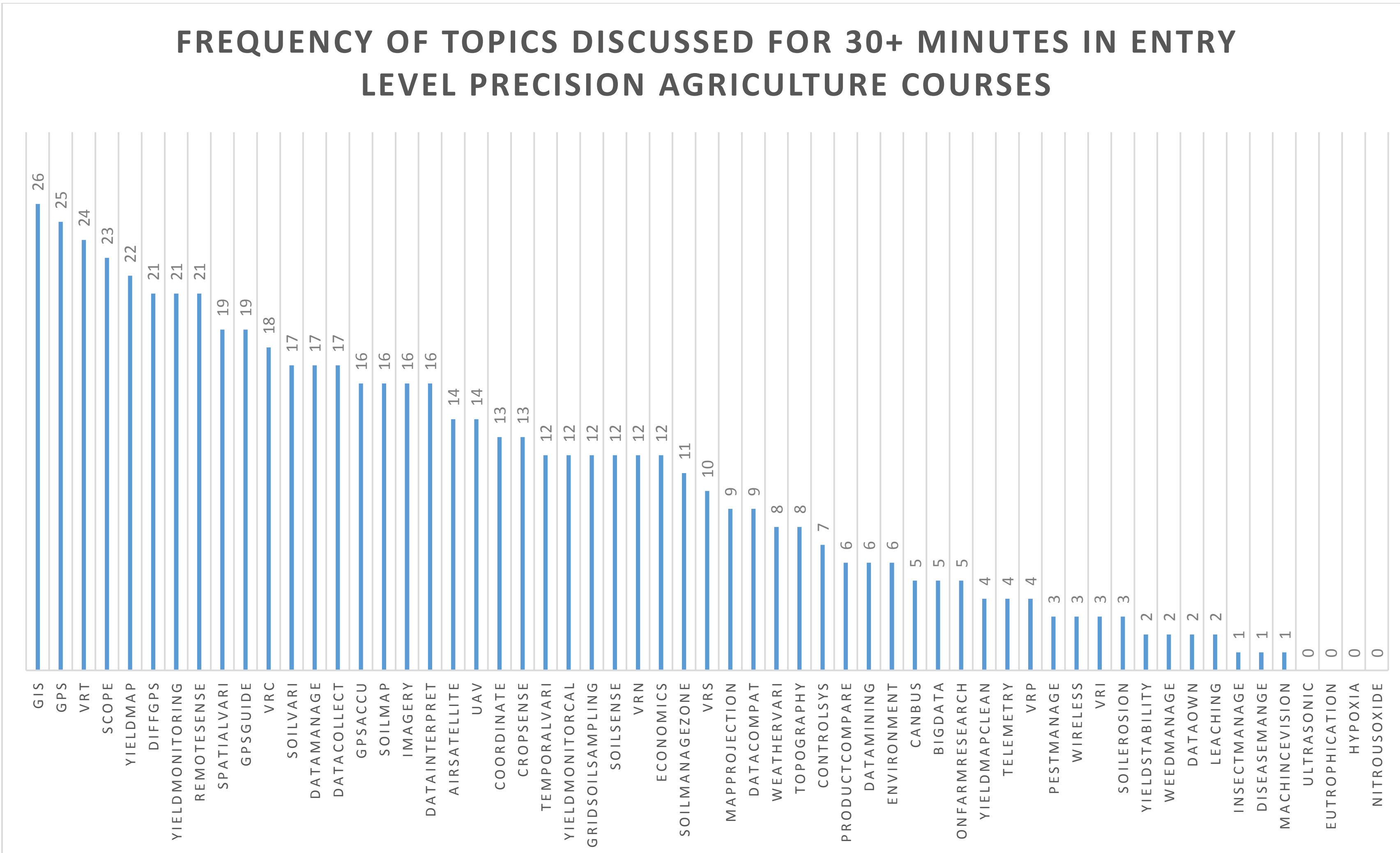

Figure 6. Frequency of Precision Agriculture Topics Discussed For 30+ Minutes in Entry Level Precision Agriculture Courses

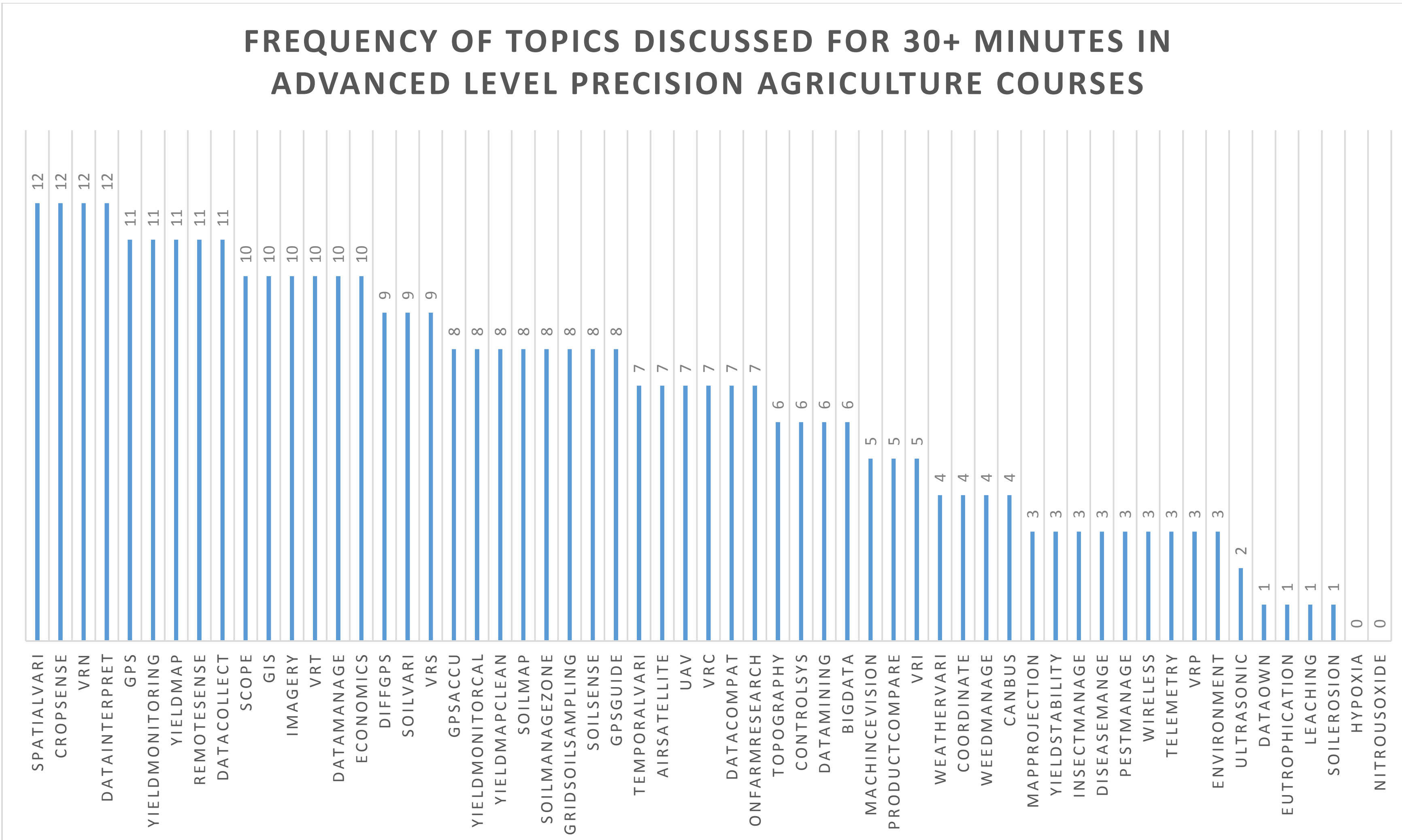

Figure 7. Frequency of Precision Agriculture Topics Discussed For 30+ Minutes in Advanced Level Precision Agriculture Courses

Topics were reviewed that instructors indicated they did **NOT** spend any time teaching in their PA courses (Figures 8 & 9). Instructors indicated a wide range of topics among the entry level courses that they did **NOT** discuss or were **NOT** applicable to their PA course. Topics with the highest number of results (N/A or None) for entry level courses were Nitrous Oxide (23), Ultrasonic (21) and Eutrophication (19) (n=39). The researcher examined the advanced level courses and determined Nitrous Oxide was again the top ranked topic with 9 responses, Eutrophication (7), and Ultrasonic, Leaching, and Hypoxia tied with 6 responses each (n=17).

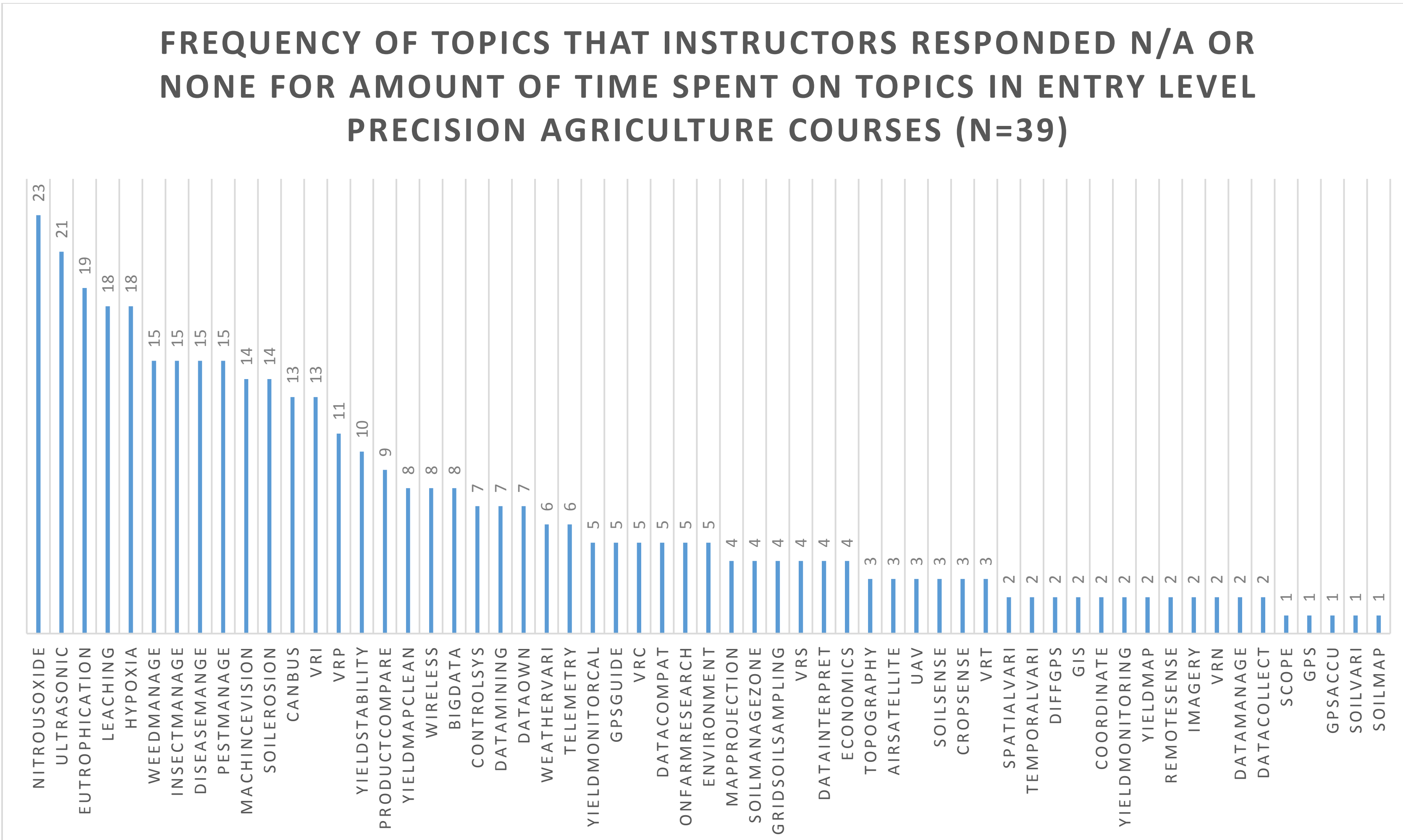

Figure 8. Frequency of Precision Agriculture (PA) Courses That Indicated NOT Applicable/Spent Zero Minutes on PA Topics In Entry Level PA Courses

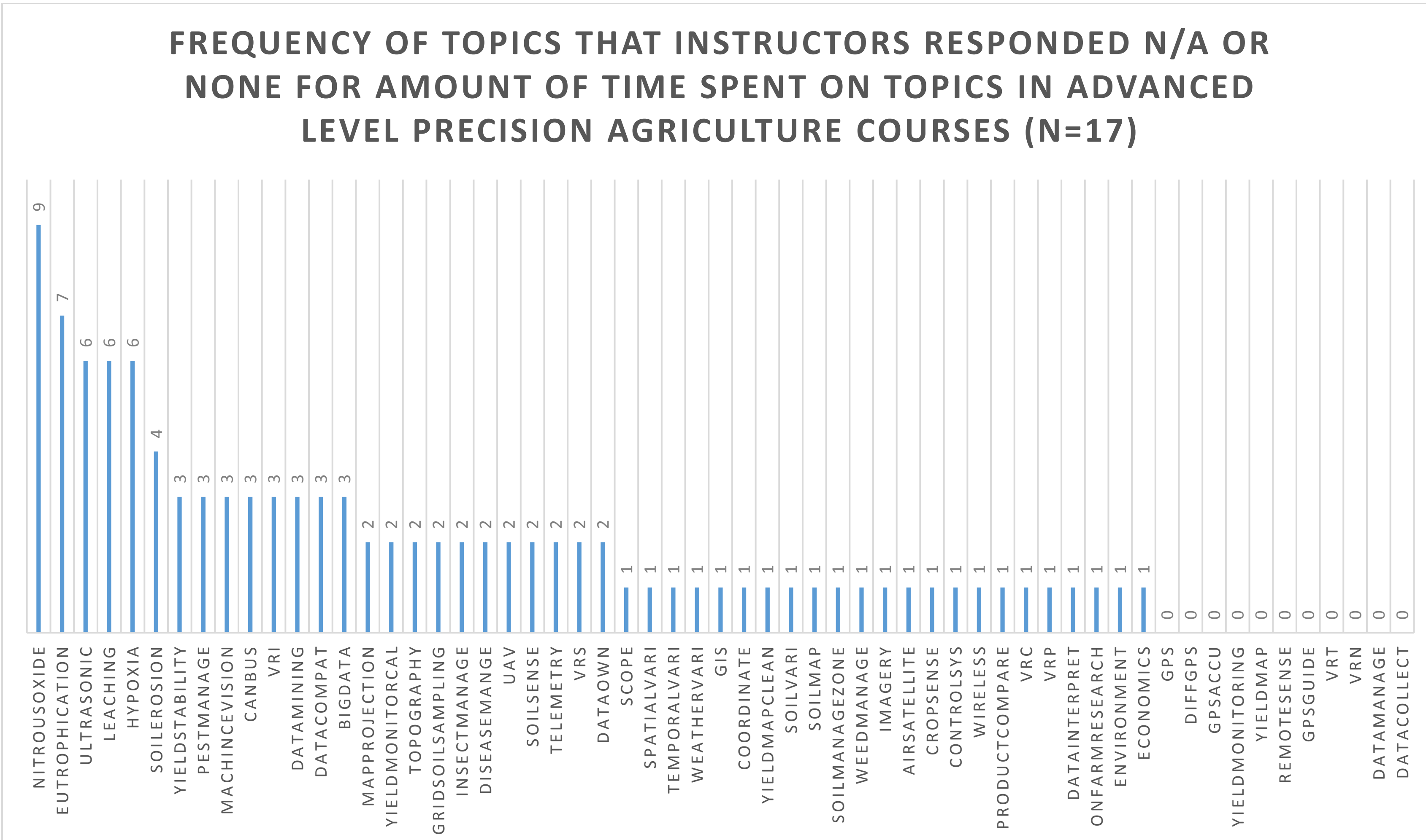

Figure 9. Frequency of Precision Agriculture (PA) Courses That Indicated NOT Applicable/Spent Zero Minutes on PA Topics In Advanced Level PA Courses

4.4 Objective One - Predominant Precision Agriculture Topics Taught

The list of PA topics consisted of 59 different topics relating to varying content associated with PA. All 59 topics listed were discussed in at least a few PA courses. The topic with the highest frequency taught (30+ minutes) was GIS with 36 out of 50 responding (72%). GPS was a close second with 36 of out 52 returned responses (69.3%). The next highest topic was Variable Rate Technology with 34 out of 51 responses (66.7%). (Appendix A)

Nitrous Oxide was one of the least taught topics. A total of 32 of the 50 course instructors responded that Nitrous Oxide was **NOT** taught or **NOT** applicable (N/A) to their course (64%). Ultrasonic was taught infrequently with only 27 of the 48 instructors (56.2%). Eutrophication was also a topic that few instructors taught within their classrooms (26 of the 50 instructors or 52%). (Appendix A)

4.5 Objective Two - Time Spent on Precision Agriculture Topics for Entry- and Advanced-Level Courses

The content taught within a classroom varies from year to year as the subject matter changes from year to year. The researcher sought to determine the amount of time that was being spent teaching PA topics to students in an entry or advanced level PA course.

The mean and median were compared using the Wilcoxon Rank Sum Nonparametric Test to determine the differences between the time devoted to entry level and advanced level PA topics. The researcher reviewed the time that instructors reported spending 30+ minutes teaching PA topics. The topics instructors spent the most time teaching (Scope of PA, Spatial Variability, GPS, Differential GPS, GIS, Yield Monitoring, Yield Map, Remote Sensing, GPS Guidance, & Variable Rate Technology) all had medians of 4. Except for Scope of PA the other topics listed above, the means in the advance level courses were higher as compared to the entry level course. (Appendix B)

The researcher noted that for both entry level and advanced level PA courses, Nitrous Oxide was a topic discussed very little (median of 1 (N/A or None) and a mean of 1.4 for both entry level and advanced level). Eutrophication had a median of 1 for entry level and a median of 1.5 for advanced level courses. Ultrasonic had median of 1 for entry level courses and a median of 2 for the advanced level courses. (Appendix B)

No significant differences existed for a majority of the topics that were taught in the entry level and advanced level PA courses. There were 11 topics of the 59 topics that had a significant difference in length of time taught based on the mean scores from the Wilcoxon Rank Sum Test. There was more time spent teaching Yield Map Cleaning, Weed Management, Insect Management, Disease Management, Crop Sensing, Machine Vision, Wireless Technology, Product Comparison, Variable Rate Nutrient, Data Interpretation, and On Farm Research topics in an advanced level PA course than in an entry level course (Table 3).

Table 3. Wilcoxon Rank Sum Test Comparing Entry vs. Advanced Level Precision Agriculture Courses

	n		Median		Mean		
Topic	**Entry**	**Adv.**	**Entry**	**Adv.**	**Entry**	**Adv.**	**P >|z|**
Crop Sensing	36	15	3	4	3	3.7	0.0107
Variable Rate Nutrient	36	16	3	4	2.9	3.7	0.006
Data Interpretation	36	15	3	4	3	3.7	0.0269
Yield Map Cleaning	35	15	2	4	2.3	3.3	0.0046
Wireless	36	14	2	3	2.1	2.7	0.0363
Product Comparison	36	16	2	3	2.2	2.9	0.0281
On Farm Research	36	15	2	3	2.4	3.2	0.0086
Weed Management	36	14	2	2.5	1.9	2.7	0.0232
Disease Management	36	14	2	2.5	1.8	2.6	0.0233
Machine Vision	35	14	2	2.5	1.8	2.6	0.0223
Insect Management	36	14	2	2	1.8	2.5	0.039

Note: $P < 0.05$

4.6 Objective Three - Precision Agriculture Topics in Two-year and Four-year Institutions

The time that instructors spent teaching PA topics were compared between two-year and four-year institutions. Variable Rate Technology was the PA topic that instructors spent the most time teaching with a median of 4 (30+ minutes) for both two-year and four-year institutions and a mean of 3.7 for two-year and a mean of 3.4 for four-year institutions. GPS had a median of 4 for both two-year and four-year institutions and a mean of 3.4 for two-year and a mean of 3.6 for four-year institutions. Differential GPS, Yield Monitoring, and Yield Mapping had medians of 4. The means for Differential GPS was 3.4 for two-year and 3.5 for four-year institutions, Yield Monitoring was 3.5 for two-year and 3.4 for four-year institutions, and Yield Mapping was 3.4 for two-year and 3.5 for four-year institutions.

The researcher again determined that the least amount of time was spent teaching Nitrous Oxide. Nitrous Oxide had a median of 1 (N/A or None) and a mean of 1.4 for both the two-year and four-year institutions. Ultrasonic was very similar to Nitrous Oxide. A median of 1 was noted for both the two-year and four-year institutions and a mean of 1.5 for the two-year and a mean of 1.6 for the four-year institutions.

There were five PA topics that had a significant difference between the amounts of time taught in a two-year institution compared to that of a four-year institution (Table 4). As with the entry and advanced level PA courses the topics were all discussed for a longer period of time in four-year institutions.

Table 4. Wilcoxon Rank Sum Test Comparing Precision Agriculture Topics Taught At Two-year Institutions vs. Four-year Institutions

	n		Median		Mean		
Topic	**2 yr.**	**4 yr.**	**2 yr.**	**4 yr.**	**2 yr.**	**4 yr.**	**P < |z|**
Spatial Variability	18	33	3	4	2.9	3.6	0.0456
Imagery	18	33	3	4	2.9	3.5	0.0476
GIS	18	32	3.5	4	3	3.8	0.0095
Data Interpretation	18	33	2.5	4	2.7	3.4	0.0304
Economics	18	34	2	3.5	2.5	3.3	0.0173

Note: P < 0.05

The researcher examined the PA topics that were taught a longer amount of time in the two-year vs. four-year institutions (Table 5). When looking at the following table the topics that two-year institutions were more likely to teach for a longer amount of time were based on the application of PA technology and not the processes leading up to the technology that was used.

Table 5. Precision Agriculture Topics That Are Taught In Precision Agriculture Courses In Greater Length At Two-year Institutions Compared To Four-year Institutions

	n		Median		Mean		
Topic	**2 yr.**	**4 yr.**	**2 yr.**	**4 yr.**	**2 yr.**	**4 yr.**	**P < |z|**
GPS Guidance	18	33	4	3	3.4	3	0.093
Variable Rate Control	18	33	4	3	3.4	3.1	0.2191
UAV	18	33	3.5	3	3	3.1	0.7702
Variable Rate Nutrient	18	34	3.5	3	3.2	3.1	0.8535
Variable Rate Seed	18	34	3.5	3	3.2	2.8	0.1687
Product Comparison	18	34	3	2	2.8	2.3	0.079
Variable Rate Pest	18	31	2.5	2	2.6	2.2	0.3158

Note: P < 0.05

4.7 Prerequisite Discussion for PA Courses

Prerequisites that were required for each of these PA courses can be found in Table 6. Results reported in Table 6 include both the prerequisites required from the syllabi survey (n=43) and what was required from the instructor survey (n=56). As with the information from the syllabi survey 18 of the 56 courses did **NOT** have any prerequisites before they could enroll in the designated PA course. College algebra and soils were the next highest prerequisites with totals of 17 and 18 respectively.

Table 6. Prerequisite Courses For Students Enrolled In Precision Agriculture Courses

Prerequisite Listed	# of Syllabi Surveys (N=43)	# of Instructor Surveys (N=56)
None	19 (44%)	18 (32%)
College Algebra	8 (19%)	17 (30%)
Precision Ag (Intro.)	4 (9%)	4 (7%)
Junior/Senior Standing	4 (9%)	4 (7%)
Physics	3 (7%)	0
Soils	3 (7%)	18 (32%)
Graduate Standing	3 (7%)	1 (1.8%)
Plant Pathology	2 (4.7%)	0
GIS	2 (4.7%)	5 (9%)
Farm Management	2 (4.7%)	0
Agribusiness	1 (2.3%)	0
Insect Biology	1 (2.3%)	0
Remote Sensing	1 (2.3%)	0
Statistics	1 (2.3%)	1 (1.8%)
Basic Computing Class	1 (2.3%)	1 (1.8%)
Other	-	3 (5.3%)

Chapter 5

5. Summary, Conclusions and Recommendations for Future Research

5.1 Statement of Problem

By 2050 the population of the world will be at a point where food production will need to double to provide food for everyone. The advancements with grain yields are exceeding expectations, but the predicted grain yield increases are still projected to fall short of future demands. "We believe that to double food production, it is critical that we produce a workforce that understands how to empower farmers in the creation of locally-based adaptive management strategies that engage ecological concepts to match crop production systems with landscape-specific features and processes." (Clay, 2014). These changes will require that farmers learn how to adopt information that can help them understand new technology. Examples of these continuing education opportunities include farm field days, farm tours (Heiniger et al., 2002), and online courses. In contrast, within colleges of agriculture, there is little research related to the content analysis of PA courses. The high costs associated with PA and the time that it takes to learn and develop the skill sets needed to teach PA have greatly reduced the distribution of knowledge about PA across the country (Reichardt et al., 2009). The extent and quality of instructor education impacts the instructor's effectiveness in the classroom (Darling-Hammond, 2000). Researchers have found that this is the case for the content presented within PA courses throughout the nation. Industry is the driving force for stimulating PA product development and adoption, causing educators and researchers to look to industry for research and education about PA technology (Kitchen et al., 2002). The importance of knowing what is being applied by industry helps identify trends and develop pertinent core principles for PA courses across the nation.

5.2 Objectives of the Study

1. Determine the predominant PA topics taught in PA courses across the U.S.
2. Quantify the time spent on PA topics for entry level and advanced level PA courses.
3. Compare the time spent teaching PA topics between two-year and four-year institutions.

5.3 Summary of Findings for Objective One

The topic with the most time spent teaching a topic (30+ minutes) was GIS with 72%. GPS was a close second with a 69.3% response from the instructors. The next highest topic was Variable Rate Technology with a 66.7% response rate. Concerning environmental implications of PA the topic Nitrous Oxide had 32 of the 50 instructors that indicated Nitrous Oxide was **NOT** taught or was **NOT** applicable (N/A) to their course (64%). Ultrasonic (soil crop sensing) was taught infrequently (27 of the 48 instructors). Eutrophication was infrequently taught as well (26 of the 50 [52%]).

5.4 Conclusions for Objective One

When looking at the frequencies for the topics in this study, the researcher saw that GPS and GIS were the topics that instructors would spend the most time teaching.

As the transverse of this information, Nitrous Oxide, Hypoxia, Eutrophication and Ultrasonic were topics that roughly half of the instructors did **NOT** choose to discuss in their courses (Appendix A) General sciences and basic concepts that are widely used within PA practices are all topics that instructors spend a significant amount of time teaching. Instructors may be less knowledgeable about these topics. This might explain why they devoted less time to topics that are more closely related to crop production practices and the more technical, intricate practices of PA. Their lack of knowledge about these topics might explain why they spent the the least amount of time teaching them.

5.5 Summary of Findings for Objective Two

There were no significant differences between the amount of time teaching entry level PA courses and advanced level PA courses for the majority of the topics. There were 11 topics, out of the 59 topics, that had a significant difference in length of time spent teaching based on the mean scores from the Wilcoxon Rank Sum Test. In each of these topics (Yield Map Cleaning, Weed Management, Insect Management, Disease Management, Crop Sensing, Machine Vision, Wireless Technology, Product Comparison, Variable Rate Nutrient, Data Interpretation, and On Farm Research) there was more time spent teaching the topic in advanced level PA courses than in an entry level course (Table 4).

5.6 Conclusions for Objective Two

The research was consistent in its findings showing that PA topics that had higher frequencies were those topics that instructors taught longer in their PA courses. These findings suggested that PA courses introduced basic information in entry level courses. Advanced level PA courses however, focused on the intricacies of more specified topics within PA.

5.7 Summary of Findings for Objective Three

Variable Rate Technology instruction time varied little between two-year and four-year institutions. This PA topic had a median of 4 for both two-year and four-year institutions and a mean of 3.7 for two-year and a mean of 3.4 for four-year institutions. GPS was similar in that the researcher noted a median of 4 for both two-year institutions and four-year institutions and a mean of 3.4 for two-year and a mean of 3.6 for four-year institutions. Differential GPS, Yield Monitoring, and Yield Mapping were similar in this regard with medians of 4. The means for Differential GPS was 3.4 for two-year and 3.5 for four-year institutions, Yield Monitoring was 3.5 for two-year and 3.4 for four-year institutions, and Yield Mapping was 3.4 for two-year and 3.5 for four-year institutions.

The researcher noted the least taught instructional topic, Nitrous Oxide, had a median of 1 (N/A or None) and a mean of 1.4 for both the two-year and four-year institutions. Ultrasonic was very similar to Nitrous Oxide with a median of 1 for both the two-year and four-year institutions and a mean of 1.5 for the two-year and a mean of 1.6 for the four-year institutions.

The researcher found five PA topics that had a significant difference between the amount of time taught in a two-year institution compared to that of a four-year institution (*Table 5*). As with the entry and advanced level PA courses the topics of Spatial Variability, Imagery, GIS, Data Interpretation, and Economics, were all discussed for a longer period of time in four-year institutions.

5.8 Conclusions for Objective Three

As with objective two and three the findings were consistent among the PA topics that were discussed for greater lengths of time and those that were discussed infrequently in the two-year and four-year institutions. The researcher concluded that two-year institutions are more focused on the application of the PA technology. Four-year institutions are more concerned with the implementation along with the applications that go into PA technology.

5.9 Discussion

In a related research study researchers designed a survey for PA educators that asked the instructor's perspective of the Knowledge, Skills, and Abilities (KSA's) that a PA student should acquire to work in PA. The research study then looked at retail dealerships and asked the same questions to know what PA educational training (knowledge, skills, and abilities) employers expected of their employees. With this research the retail dealerships stated that many of the potential employees had low or deficient knowledge in each of the knowledge, skills, and abilities (KSA's) objectives related to those PA positions (Fausti et al., 2017).

The researcher noted discrepancies about the information that PA educators deemed important and the educational training that the retail dealerships desire for future employees. The same is true for more intricate, complicated PA topics within this research. The main, broad sweeping topics are discussed in the courses in great deal, but when it comes to the more technical topics of PA there was a lag in acquiring information. The information may briefly be introduced within these PA courses, but from the instructor survey the researchers were able to identify that minimal time was devoted to teaching a majority of the PA topics.

5.10 Recommendations for Future Studies

The use of PA technology will continue to grow and develop as new technologies emerge. Curriculum that relates to the growing and changing PA technologies will greatly benefit agricultural production, soil science, plant science, and animal science. This research study investigated the topics taught within PA courses and the length of time that was spent on those topics helped identify trends and show relationships based on geographical area, type of class offered (entry or advanced level), and type of institution (two-year vs. four-year). As with any study the addition of even more responses back helps to validate the data received. Researchers should continue to acquire PA instructors to add to the survey. The respondents checked the categorical data that corresponded to their course (N/A or None, 0-15 minutes, 16-30 minutes, or

30+ minutes). Future research would provide better, more detailed information if the researcher left the categorical times blank and asked the respondents to estimate the time spent teaching PA topics (interval data). The researcher would be able to conduct a wider variety of statistical tests to analysis the data.

Appendix

A. Frequencies Of Precision Agriculture Course Topics Based On Length Of Time Taught

Table 7. Frequencies Of Precision Agriculture Course Topics Based On Length Of Time Taught

Topic		Frequencies (*f*) (1) N/A or None	(2) 0- 15 min.	(3) 16-30 min.	(4) 30+ min.	*f* Missing
GPS	n (%)	1 (1.9)	5 (9.6)	10 (19.2)	36 (69.3)	4
GIS	n (%)	3 (6)	4 (8)	7 (14)	36 (72)	6
Variable Rate Technology	n (%)	3 (5.9)	1 (1.9)	13 (25.5)	34 (66.7)	5
Scope of PA	n (%)	2 (3.8)	6 (11.5)	11 (21.2)	33 (63.5)	4
Yield Map	n (%)	2 (3.9)	5 (9.8)	11 (21.6)	33 (64.7)	5
Yield Monitoring	n (%)	2 (3.9)	4 (7.7)	14 (26.9)	32 (61.5)	4
Remote Sensing	n (%)	2 (3.9)	6 (11.8)	11 (21.6)	32 (62.7)	5
Spatial Variability	n (%)	3 (5.9)	7 (13.7)	10 (19.6)	31 (60.8)	5
Differential GPS	n (%)	2 (3.8)	2 (3.8)	18 (34.6)	30 (57.8)	4
Data Collection	n (%)	2 (3.9)	7 (13.7)	14 (27.5)	28 (54.9)	5
Data Interpretation	n (%)	5 (9.8)	8 (15.7)	10 (19.6)	28 (54.9)	5
Data Management	n (%)	2 (3.9)	7 (13.8)	15 (29.4)	27 (52.9)	5
GPS Guidance	n (%)	5 (9.8)	8 (15.7)	11 (21.6)	27 (52.9)	5
Imagery	n (%)	3 (5.9)	4 (7.8)	18 (35.3)	26 (51)	5
Soil Variability	n (%)	2 (3.9)	9 (17.6)	14 (27.5)	26 (51)	5
Variable Rate Control	n (%)	6 (11.8)	3 (5.9)	17 (33.3)	25 (49)	5
Crop Sensing	n (%)	4 (7.8)	7 (13.7)	15 (29.4)	25 (49.1)	5
GPS Accuracy	n (%)	1 (1.9)	5 (9.8)	21 (41.2)	24 (47.1)	5
Soil Map	n (%)	2 (3.9)	10 (19.6)	15 (29.4)	24 (47.1)	5
Variable Rate Nutrient	n (%)	2 (3.8)	12 (23.1)	14 (26.9)	24 (46.2)	4
Economics	n (%)	5 (9.6)	11 (21.2)	14 (26.9)	22 (42.3)	4
Aircraft & Satellite	n (%)	4 (7.8)	8 (15.7)	18 (35.3)	21 (41.2)	5
UAV	n (%)	5 (9.8)	7 (13.7)	18 (35.3)	21 (41.2)	5
Soil Sensitivity	n (%)	5 (9.8)	10 (19.6)	16 (31.4)	20 (39.2)	5

Table 7 Continued. Frequencies Of Precision Agriculture Course Topics Based On Length Of Time Taught

Topic		Frequencies (*f*) (1) N/A or None	(2) 0- 15 min.	(3) 16-30 min.	(4) 30+ min.	*f* Missing
Yield Monitor Calibration	n (%)	7 (13.5)	10 (19.2)	15 (28.8)	20 (38.5)	4
Grid Soil Sampling	n (%)	6 (11.8)	11 (21.6)	14 (27.4)	20 (39.2)	5
Soil Management Zone	n (%)	5 (9.8)	6 (11.8)	21 (41.2)	19 (37.2)	5
Variable Rate Seed	n (%)	6 (11.5)	9 (17.3)	18 (34.6)	19 (36.6)	4
Coordinate Systems	n (%)	3 (6)	10 (20)	20 (40)	17 (34)	6
Data Compatibility	n (%)	8 (16)	18 (36)	8 (16)	16 (32)	6
Topography	n (%)	5 (9.8)	16 (31.4)	16 (31.4)	14 (27.4)	5
Control Systems	n (%)	8 (16)	18 (36)	11 (22)	13 (26)	6
Map Projection	n (%)	6 (12)	14 (28)	18 (36)	12 (24)	6
Yield Map Cleaning	n (%)	9 (18)	14 (28)	15 (30)	12 (24)	6
On Farm Research	n (%)	6 (11.8)	19 (37.2)	14 (27.5)	12 (23.5)	5
Data Mining	n (%)	10 (20)	20 (40)	8 (16)	12 (24)	6
Weather Variability	n (%)	7 (14)	20 (40)	12 (24)	11 (22)	6
Product Comparison	n (%)	10 (19.2)	19 (36.5)	12 (23.1)	11 (21.2)	4
Big Data	n (%)	11 (22)	17 (34)	11 (22)	11 (22)	6
Environment	n (%)	6 (11.8)	20 (39.2)	16 (31.4)	9 (17.6)	5
CANBUS Communication	n (%)	16 (31.4)	19 (37.3)	7 (13.7)	9 (17.6)	5
Variable Rate Irrigation	n (%)	16 (32)	17 (34)	9 (18)	8 (16)	6
Variable Rate Pest	n (%)	12 (24.5)	16 (32.6)	14 (28.6)	7 (14.3)	7
Telemetry	n (%)	8 (16.3)	27 (55.1)	7 (14.3)	7 (14.3)	7
Weed Management	n (%)	16 (32)	16 (32)	12 (24)	6 (12)	6
Wireless	n (%)	9 (18)	24 (48)	11 (22)	6 (12)	6
Pest Management	n (%)	18 (36)	16 (32)	10 (20)	6 (12)	6

Table 7 Continued. Frequencies Of Precision Agriculture Course Topics Based On Length Of Time Taught

Topic		Frequencies (*f*) (1) N/A or None	(2) 0- 15 min.	(3) 16-30 min.	(4) 30+ min.	*f* Missing
Machine Vision	n (%)	17 (34.7)	20 (40.9)	6 (12.2)	6 (12.2)	7
Yield Stability	n (%)	13 (26)	16 (32)	16 (32)	5 (10)	6
Disease Management	n (%)	17 (34)	18 (36)	11 (22)	4 (8)	6
Soil Erosion	n (%)	18 (36)	22 (44)	6 (12)	4 (8)	6
Data Ownership	n (%)	9 (18)	25 (50)	13 (26)	3 (6)	6
Leaching	n (%)	24 (48)	17 (34)	6 (12)	3 (6)	6
Ultrasonic	n (%)	27 (56.2)	17 (35.4)	2 (4.2)	2 (4.2)	8
Eutrophication	n (%)	26 (52)	17 (34)	6 (12)	1 (2)	6
Hypoxia	n (%)	24 (48)	21 (42)	5 (10)	0	6
Nitrous Oxide	n (%)	32 (64)	16 (32)	2 (4)	0	6

B. Time Spent Teaching Precision Agriculture Topics In Entry Level Courses Compared To Advanced Level Courses With Median & Mean And P < |z| Values From The Wilcoxon Rank Sum Nonparametric Test. (Coded Results Were: 1 = N/A or None, 2 = 0-15 min., 3 = 16-30 min., 4 = 30+ min.)

Table 8. Time Spent Teaching Precision Agriculture Topics In Entry Level Courses (Entry) Compared To Advanced Level Courses (Adv.) With Median & Mean And P < |z| Values From The Wilcoxon Rank Sum Nonparametric Test. (Coded Results Were: 1 = N/A or None, 2 = 0-15 min., 3 = 16-30 min., 4 = 30+ min.)

	n		Median		Mean		
Topic	**Entry**	**Adv.**	**Entry**	**Adv.**	**Entry**	**Adv.**	**P |z| †**
Scope of PA	36	16	4	4	3.5	3.4	0.8268
Spatial Variability	36	15	4	4	3.2	3.7	0.0825
GPS	36	16	4	4	3.6	3.6	0.9613
Differential GPS	36	16	4	4	3.4	3.5	0.9641
GIS	36	14	4	4	3.5	3.6	0.9349
Yield Monitoring	36	16	4	4	3.4	3.6	0.4128
Yield Map	36	15	4	4	3.4	3.7	0.3461
Remote Sensing	36	15	4	4	3.3	3.7	0.2547
GPS Guidance	36	15	4	4	3.1	3.3	0.8397
Variable Rate Technology	36	15	4	4	3.5	3.6	0.9407
Temporal Variability	36	15	3	4	2.9	3.3	0.1127
GPS Accuracy	36	15	3	4	3.3	3.4	0.6674
Soil Variability	36	15	3	4	3.2	3.4	0.3837
Soil Map	36	15	3	4	3.2	3.3	0.6188
Soil Management Zone	36	15	3	4	2.9	3.4	0.0797
Grid Soil Sampling	36	15	3	4	2.8	3.3	0.1271
Imagery	36	15	3	4	3.2	3.5	0.2417
Soil Sensitivity	36	15	3	4	2.9	3.3	0.1599
Crop Sensing	36	15	3	4	3	3.7	0.0107*
Variable Rate Nutrient	36	16	3	4	2.9	3.7	0.0060**
Variable Rate Seed	36	16	3	4	2.8	3.2	0.1055
Data Management	36	15	3	4	3.2	3.5	0.2331
Data Collection	36	15	3	4	3.2	3.7	0.0795
Data Interpretation	36	15	3	4	3	3.7	0.0269*
Economics	36	16	3	4	2.9	3.4	0.0757
Yield Map Cleaning	35	15	2	4	2.3	3.3	0.0046**
Yield Monitor Calibration	36	16	3	3.5	2.8	3.2	0.2069
Variable Rate Control	36	15	3.5	3	3.2	3.1	0.6954
Coordinate Systems	36	14	3	3	3.1	2.8	0.4198
Map Projection	36	14	3	3	2.8	2.6	0.7364
Topography	36	15	3	3	2.7	2.9	0.3746
Aircraft & Satellite	36	15	3	3	3	3.3	0.4193
UAV	36	15	3	3	3.1	3.1	0.8782

Note: * Denotes a level of significance of $P < 0.05$
** Denotes a level of significance of $P < 0.01$
† The P-value was calculated by using the means of each topic.

Table 8 Continued. Time Spent Teaching Precision Agriculture Topics In Entry Level Courses (Entry) Compared To Advanced Level Courses (Adv.) With Median & Mean And P < |z| Values From The Wilcoxon Rank Sum Nonparametric Test. (Coded Results Were: 1 = N/A or None, 2 = 0-15 min., 3 = 16-30 min., 4 = 30+ min.)

	n		Median		Mean		
Topic	**Entry**	**Adv.**	**Entry**	**Adv.**	**Entry**	**Adv.**	**P |z| †**
Data Compatibility	36	14	2	3.5	2.5	2.9	0.2636
Weather Variability	36	14	2	3	2.5	2.7	0.4059
Yield Stability	35	15	2	3	2.1	2.6	0.1177
Control Systems	35	15	2	3	2.4	2.9	0.1318
Wireless	36	14	2	3	2.1	2.7	0.0363*
Product Comparison	36	16	2	3	2.2	2.9	0.0281*
Variable Rate Pest	36	13	2	3	2.2	2.8	0.069
Data Mining	36	14	2	3	2.3	2.8	0.1143
On Farm Research	36	15	2	3	2.4	3.2	0.0086**
Weed Management	36	14	2	2.5	1.9	2.7	0.0232*
Disease Management	36	14	2	2.5	1.8	2.6	0.0233*
Machine Vision	35	14	2	2.5	1.8	2.6	0.0223*
Variable Rate Irrigation	36	14	2	2.5	2	2.6	0.0888
Big Data	36	14	2	2.5	2.3	2.7	0.3181
Environment	36	15	2.5	2	2.5	2.6	0.8625
Insect Management	36	14	2	2	1.8	2.5	0.0390*
Pest Management	36	14	2	2	1.9	2.4	0.1476
CANBUS Communication	36	15	2	2	2	2.5	0.1328
Telemetry	35	14	2	2	2.2	2.5	0.2673
Data Ownership	36	14	2	2	2.2	2.2	0.9814
Soil Erosion	36	14	2	2	1.9	1.9	0.8354
Leaching	36	14	1.5	2	1.7	1.8	0.6245
Hypoxia	36	14	1.5	2	1.6	1.6	0.7934
Ultrasonic	34	14	1	2	1.4	2	0.0742
Eutrophication	36	14	1	1.5	1.6	1.8	0.6266
Nitrous Oxide	36	14	1	1	1.4	1.4	0.878

Note: * Denotes a level of significance of P < 0.05

** Denotes a level of significance of P < 0.01

† The P-value was calculated by using the means of each topic.

C. Basic Statistics And Wilcoxon Rank Sum Test For Two-year and Four-year Institutions And The Time Spent Teaching Precision Agriculture Topics (Coded Results Were: 1 = N/A or None, 2 = 0-15 min., 3 = 16-30 min., 4 = 30+ min.)

Table 9. Basic Statistics And Wilcoxon Rank Sum P For Two-year and Four-year Institutions And The Time Spent Teaching Precision Agriculture Topics (Coded Results Were: 1 = N/A or None, 2 = 0-15 min., 3 = 16-30 min., 4 = 30+ min.)

	n		Median		Mean		
Topic	**2 yr.**	**4 yr.**	**2 yr.**	**4 yr.**	**2 yr.**	**4 yr.**	**P < |z| †**
Scope of PA	18	34	4	4	3.4	3.4	0.5396
GPS	18	34	4	4	3.4	3.6	0.3192
Differential GPS	18	34	4	4	3.4	3.5	0.7267
Yield Monitoring	18	34	4	4	3.5	3.4	0.6423
Yield Map	18	33	4	4	3.4	3.5	0.9539
Variable Rate Technology	18	33	4	4	3.7	3.4	0.2401
GIS	18	32	3.5	4	3	3.8	0.0095**
Remote Sensing	18	33	3.5	4	3.2	3.6	0.1461
Data Collection	18	33	3.5	4	3.1	3.4	0.3458
Spatial Variability	18	33	3	4	2.9	3.6	0.0456*
Soil Variability	18	33	3	4	2.9	3.4	0.1593
Imagery	18	33	3	4	2.9	3.5	0.0476*
Crop Sensing	18	33	3	4	2.8	3.4	0.0649
GPS Guidance	18	33	4	3	3.4	3	0.093
Variable Rate Control	18	33	4	3	3.4	3.1	0.2191
Data Management	18	33	3	4	3.1	3.4	0.2508
Data Interpretation	18	33	2.5	4	2.7	3.4	0.0304*
UAV	18	33	3.5	3	3	3.1	0.7702
Variable Rate Nutrient	18	34	3.5	3	3.2	3.1	0.8535
Variable Rate Seed	18	34	3.5	3	3.2	2.8	0.1687
GPS Accuracy	18	33	3	3	3.3	3.4	0.8123
Coordinate Systems	18	32	3	3	2.9	3.1	0.5511
Map Projection	18	32	3	3	2.5	2.8	0.2868
Yield Monitor Calibration	18	34	3	3	3	2.8	0.5546
Soil Map	18	33	3	3	2.9	3.3	0.2798
Soil Management Zone	18	33	3	3	2.9	3.1	0.7376
Grid Soil Sampling	18	33	3	3	2.9	3	0.9344
Aircraft & Satellite	18	33	3	3	2.9	3.2	0.3994
Soil Sensitivity	18	33	3	3	2.7	3.2	0.234
Economics	18	34	2	3.5	2.5	3.3	0.0173*
Temporal Variability	18	33	2.5	3	2.7	3.2	0.0982
Yield Map Cleaning	17	33	2	3	2.4	2.7	0.3606

Note: * Denotes a level of significance of $P < 0.05$

** Denotes a level of significance of $P < 0.01$

† The P-value was calculated by using the means of each topic.

Table 9 Continued. Basic Statistics And Wilcoxon Rank Sum P For Two-year and Four-year Institutions And The Time Spent Teaching Precision Agriculture Topics (Coded Results Were: 1 = N/A or None, 2 = 0-15 min., 3 = 16-30 min., 4 = 30+ min.)

	n		Median		Mean		
Topic	**2 yr.**	**4 yr.**	**2 yr.**	**4 yr.**	**2 yr.**	**4 yr.**	**P < |z| †**
Topography	18	33	2	3	2.4	3	0.0561
Product Comparison	18	34	3	2	2.8	2.3	0.079
Data Mining	18	32	2	3	2	2.6	0.0683
Data Compatibility	18	32	2	3	2.4	2.8	0.2257
Big Data	18	32	2	3	2.2	2.6	0.1926
On Farm Research	18	33	2	3	2.3	2.8	0.0622
Environment	18	33	2	3	2.3	2.7	0.1414
Weather Variability	18	32	2	2.5	2.3	2.6	0.2623
Variable Rate Pest	18	31	2.5	2	2.6	2.2	0.3158
Yield Stability	17	33	2	2	2.1	2.3	0.3566
Weed Management	18	32	2	2	2.2	2.1	0.9331
Insect Management	18	32	2	2	2.1	2	0.8485
Disease Management	18	32	2	2	2.1	2	0.9158
Pest Management	18	32	2	2	2.2	2	0.6434
Machine Vision	17	32	2	2	1.8	2.1	0.4196
Control Systems	17	33	2	2	2.7	2.5	0.5816
CANBUS Communication	18	33	2	2	2.5	2	0.1601
Wireless	18	32	2	2	2.5	2.2	0.3509
Telemetry	17	32	2	2	2.5	2.2	0.4417
Variable Rate Irrigation	18	32	2	2	2.2	2.2	0.7932
Data Ownership	18	32	2	2	2.2	2.2	0.8446
Soil Erosion	18	32	2	2	1.9	1.9	0.7789
Leaching	18	32	1	2	1.7	1.8	0.5636
Hypoxia	18	32	1	2	1.5	1.7	0.3631
Eutrophication	18	32	1	1.5	1.7	1.6	0.8939
Ultrasonic	17	31	1	1	1.5	1.6	0.7521
Nitrous Oxide	18	32	1	1	1.4	1.4	0.7197

Note: * Denotes a level of significance of P < 0.05
** Denotes a level of significance of P < 0.01
† The P-value was calculated by using the means of each topic.

D. Invitational Letter To Survey Respondents With Survey Link

Hello,
The University of Missouri, in collaboration with the USDA and several other universities across the nation, is working to develop common language between Precision Agriculture teachers and operators within the industry. We are hoping to use this information to modernize the sequencing of content taught within these courses. Our goal is to update curriculum that is being taught throughout the nation to help standardize the precision agriculture curriculum.

We are asking for your participation in this survey because of your experience(s) teaching Precision Agriculture course(s). We previously asked if precision agriculture teachers would each share their course syllabus with us. Our goal was to learn what topics were being taught within Precision Agriculture. It has come to our realization that we were not able to obtain enough information about the courses taught by just reviewing course syllabi. We would like you to complete a short survey (15-30 min.) to help us achieve a better understanding of what is being taught in your class. Your participation in this survey is completely voluntary and all identifiable information will remain confidential.

We are also working to update a textbook commonly used by precision agriculture teachers. Karina Kitchen, one of our research assistants, is creating short videos about precision agriculture systems to enhance the learning experience for those using this book. If you have any videos that you have used in your precision agriculture courses and are willing to share them, please forward them to Karina at KitchenK@missouri.edu or Danielle at dmdc55@mail.missouri.edu.

We greatly appreciate your collaboration in this effort! If you have any further questions, please feel free to call 573-882-2126 or email Dr. Leon Schumacher at SchumacherL@missouri.edu or email Danielle at dmdc55@mail.missouri.edu.

Follow this link to the Survey:
survey link

Or copy and paste the URL below into your internet browser:
survey url

Follow the link to opt out of future emails:
opt out link

Best Regards,

Leon	Danielle
Leon Schumacher	Danielle Skouby
Professor & Chair	Graduate Student
University of Missouri	University of Missouri
Phone: 573-882-2126	Phone: 573-864-8644
SchumacherL@missouri.edu	dmdc55@mail.missouri.edu

E. Precision Agriculture Topic Content Survey

Precision Agricultural Curriculum Content Survey

1) Please list your name and university you are affiliated with.

____

2) What is the **title and course number** of the Precision Agriculture (PA) course that you teach?

____

3) What prerequisites are required for this course? (Please select all that apply)

- ❑ College Algebra
- ❑ Physics
- ❑ Soils
- ❑ None
- ❑ Other: ____________________

4) Are there any suggested courses that would be helpful before taking this course?

____

5) Is this course considered an entry level or advanced level course?

Note: Entry Level: The first class in a series (or only PA course at this time) Advance Level Course: Course taught 2nd or farther along in a series of courses

- ❍ Entry Level Course
- ❍ Advanced Level Course

6) This course is intended to be taught to: (Please select all that apply)

- ❑ Freshmen
- ❑ Sophomores
- ❑ Juniors
- ❑ Seniors
- ❑ Graduates

7) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Scope of Precision Ag	❍	❍	❍	❍
Spatial Variability	❍	❍	❍	❍
Temporal Variability	❍	❍	❍	❍
Weather Variability	❍	❍	❍	❍
GPS	❍	❍	❍	❍
Differential GPS	❍	❍	❍	❍
GPS Accuracy	❍	❍	❍	❍
GIS	❍	❍	❍	❍
Coordinate Systems	❍	❍	❍	❍
Map Projection	❍	❍	❍	❍

8) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Yield Monitoring	❍	❍	❍	❍
Yield Mapping	❍	❍	❍	❍
Yield Monitor Calibration	❍	❍	❍	❍
Yield Map Cleaning	❍	❍	❍	❍
Yield Stability	❍	❍	❍	❍
Soil Variability	❍	❍	❍	❍
Soil Mapping	❍	❍	❍	❍
Topography	❍	❍	❍	❍
Soil Management Zones	❍	❍	❍	❍
Grid Soil Sampling	❍	❍	❍	❍

9) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Weed Management	❍	❍	❍	❍
Insect Management	❍	❍	❍	❍
Disease Management	❍	❍	❍	❍
Pest Management	❍	❍	❍	❍
Remote Sensing	❍	❍	❍	❍
Imagery	❍	❍	❍	❍
Aircraft & Satellites	❍	❍	❍	❍
UAV's	❍	❍	❍	❍
Soil Sensing	❍	❍	❍	❍
Crop Sensing	❍	❍	❍	❍

10) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Ultrasonic	❍	❍	❍	❍
Machine Vision	❍	❍	❍	❍
Control Systems	❍	❍	❍	❍
CAN BUS Communication	❍	❍	❍	❍
Wireless	❍	❍	❍	❍
Telemetry	❍	❍	❍	❍
Product Comparisons	❍	❍	❍	❍
GPS Guidance	❍	❍	❍	❍
Variable Rate Technology	❍	❍	❍	❍
Variable Rate Control	❍	❍	❍	❍

11) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Variable Rate Nutrient	❍	❍	❍	❍
Variable Rate Seeding	❍	❍	❍	❍
Variable Rate Pest	❍	❍	❍	❍
Variable Rate Irrigation	❍	❍	❍	❍
Data Management	❍	❍	❍	❍
Data Collection	❍	❍	❍	❍
Data Mining	❍	❍	❍	❍
Data Compatibility	❍	❍	❍	❍
Data Interpretation	❍	❍	❍	❍
Data Ownership	❍	❍	❍	❍

12) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Big Data	❍	❍	❍	❍
On Farm Research	❍	❍	❍	❍
Environment	❍	❍	❍	❍
Eutrophication	❍	❍	❍	❍
Leaching	❍	❍	❍	❍
Hypoxia	❍	❍	❍	❍
Soil Erosion	❍	❍	❍	❍
Nitrous Oxide	❍	❍	❍	❍
Economics	❍	❍	❍	❍

13) What types of educational programs are offered for PA in your department? (Please select all that apply)

- ❑ Certificate
- ❑ Associates Degree
- ❑ Emphasis in PA
- ❑ Specialization
- ❑ Minor
- ❑ Bachelor's Degree

14) Do you teach another PA course? If so, will you take the survey again for that course?

- ❍ Yes
- ❍ No

15) What is the **title and course number** of the PA course that you teach?

____

16) What prerequisites are required for this course? (Please select all that apply)

- ❑ College Algebra
- ❑ Physics
- ❑ Soils
- ❑ None
- ❑ Other ____________________

17) Are there any suggested courses that would be helpful before taking this course?

____

18) Is this course considered an entry level or advanced level course?

NOTE: Entry Level: The first class in a series (or only PA course offered at this time) Advanced Level Course: Course taught 2nd or farther along in a series of courses

- ❍ Entry Level Course
- ❍ Advanced Level Course

19) This course is intended to be taught to: (Please select all that apply)

- ❑ Freshmen
- ❑ Sophomores
- ❑ Juniors
- ❑ Seniors
- ❑ Graduates

20) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Scope of Precision Ag	❍	❍	❍	❍
Spatial Variability	❍	❍	❍	❍
Temporal Variability	❍	❍	❍	❍
Weather Variability	❍	❍	❍	❍
GPS	❍	❍	❍	❍
Differential GPS	❍	❍	❍	❍
GPS Accuracy	❍	❍	❍	❍
GIS	❍	❍	❍	❍
Coordinate Systems	❍	❍	❍	❍
Map Projection	❍	❍	❍	❍

21) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Yield Monitoring	❍	❍	❍	❍
Yield Mapping	❍	❍	❍	❍
Yield Monitor Calibration	❍	❍	❍	❍
Yield Map Cleaning	❍	❍	❍	❍
Yield Stability	❍	❍	❍	❍
Soil Variability	❍	❍	❍	❍
Soil Mapping	❍	❍	❍	❍
Topography	❍	❍	❍	❍
Soil Management Zones	❍	❍	❍	❍
Grid Soil Sampling	❍	❍	❍	❍

22) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Weed Management	❍	❍	❍	❍
Insect Management	❍	❍	❍	❍
Disease Management	❍	❍	❍	❍
Pest Management	❍	❍	❍	❍
Remote Sensing	❍	❍	❍	❍
Imagery	❍	❍	❍	❍
Aircraft & Satellite	❍	❍	❍	❍
UAV's	❍	❍	❍	❍
Soil Sensing	❍	❍	❍	❍
Crop Sensing	❍	❍	❍	❍

23) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Ultrasonic	❍	❍	❍	❍
Machine Vision	❍	❍	❍	❍
Control Systems	❍	❍	❍	❍
CAN BUS Communication	❍	❍	❍	❍
Wireless	❍	❍	❍	❍
Telemetry	❍	❍	❍	❍
Product Comparisons	❍	❍	❍	❍
GPS Guidance	❍	❍	❍	❍
Variable Rate Technology	❍	❍	❍	❍
Variable Control	❍	❍	❍	❍

24) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Variable Rate Nutrient	❍	❍	❍	❍
Variable Rate Seeding	❍	❍	❍	❍
Variable Rate Pest	❍	❍	❍	❍
Variable Rate Irrigation	❍	❍	❍	❍
Data Management	❍	❍	❍	❍
Data Collection	❍	❍	❍	❍
Data Mining	❍	❍	❍	❍
Data Compatibility	❍	❍	❍	❍
Data Interpretation	❍	❍	❍	❍
Data Ownership	❍	❍	❍	❍

25) Please indicate the amount of time that you take to cover each of these topics in your class

	N/A or None	0-15 min.	16-30 min.	30+ min.
Big Data	❍	❍	❍	❍
On Farm Research	❍	❍	❍	❍
Environment	❍	❍	❍	❍
Eutrophication	❍	❍	❍	❍
Leaching	❍	❍	❍	❍
Hypoxia	❍	❍	❍	❍
Soil Erosion	❍	❍	❍	❍
Nitrous Oxide	❍	❍	❍	❍
Economics	❍	❍	❍	❍

F. Reminder Email To Respondents With Link To Survey

Hello Everyone,
I hope that you have had a relaxing weekend. Please remember to finish your survey on the precision agriculture content that you teach within your courses. There is room within the survey to fill out information for 2 different courses if you teach more than one precision agriculture course. We are very excited about this research and very much appreciate you taking the time to fill out this survey.

Sincerely,
Danielle Skouby

Follow this link to the Survey:
survey link

Or copy and paste the URL below into your internet browser:
Survey url

Follow the link to opt out of future emails:
Opt out link

G. Final Email Reminder With Link To Survey

Hello Everyone,
I hope that you have been enjoying your summer! If you have not yet completed our precision ag. curriculum survey please consider doing so. Any information you can give us would be very helpful. If you do not teach a precision agriculture course but have a contact that you can forward to us, please send it to Danielle at dmdc55@mail.missouri.edu. Again, the link for the survey is below if you have not taken the survey yet.

Follow this link to the Survey:
survey link

Or copy and paste the URL below into your internet browser:
survey url

Follow the link to opt out of future emails:
Opt out link

Thank you!
Danielle Skouby & Dr. Leon Schumacher
University of Missouri

H. List Of PA Topics And Abbreviations

List of PA Topics and Abbreviations

AirSatellite	Aircraft & Satellites
BigData	Big Data
CANBUS	CAN BUS Communication
Coordinate	Coordinate System
ControlSys	Control Systems
CropSense	Crop Sensing
DataCollect	Data Collection
DataCompat	Data Compatibility
DataInterpret	Data Interpretation
DataManage	Data Management
DataMining	Data Mining
DataOwn	Data Ownership
DiffGPS	Differential GPS
DiseaseManage	Disease Management
Economics	Economics
Environment	Environment
Eutrophication	Eutrophication
GIS	Geographical Information System
GPS	Global Positioning System
GPSAccu	GPS Accuracy
GPSGuide	GPS Guidance
GridSoilSampling	Grid Soil Sampling
Hypoxia	Hypoxia
Imagery	Imagery
InsectManage	Insect Management
IRB	Institutional Review Board
ISPA	International Society of Precision Agriculture
KSA’s	Knowledge, Skills, and Abilities
Leaching	Leaching
MachineVision	Machine Vision
MapProjection	Map Projection
MU	University of Missouri
NitrousOxide	Nitrous Oxide

N/A	Not Applicable
OnFarmResearch	On Farm Research
PA	Precision Agriculture
PestManage	Pest Management
ProductCompare	Product Comparisons
RemoteSense	Remote Sensing
Scope	Scope of Precision Agriculture
SDSU	South Dakota State University
SoilErosion	Soil Erosion
SoilManageZone	Soil Management Zone
SoilMap	Soil Mapping
SoilSense	Soil Sensing
SoilVari	Soil Variability
SpatialVari	Spatial Variability
Telemetry	Telemetry
TemporalVari	Temporal Variability
Topography	Topography
UAV	Unmanned Aerial Vehicle
USDA	United States Department of Agriculture
U.S.	United States
Ultrasonic	Ultrasonic
VRC	Variable Rate Control
VRI	Variable Rate Irrigation
VRN	Variable Rate Nutrient
VRP	Variable Rate Pest
VRS	Variable Rate Seeding
VRT	Variable Rate Technology
WeatherVari	Weather Variability
WeedManage	Weed Management
Wireless	Wireless
YieldMap	Yield Mapping
YieldMapClean	Yield Map Cleaning
YieldMonitorCal	Yield Monitor Calibration
YieldMonitoring	Yield Monitoring
YieldStability	Yield Stability

References

Clay, D. (2014). *Precision Farming Workforce Development: Standards, Working Groups, and Experimental Learning Curricula Proposal*.

Darling-Hammond, L. (2000). How Teacher Education Matters. *Journal of Teacher Education, 51*(3), 166-173. doi:10.1177/0022487100051003002

Erickson, B., & Widmar, D. A. (2015). *2015 Precision Agricultural Services Dealership Survey Results*. Retrieved from West Lafayette, Indiana.

Ess, D. R., & Morgan, M. T. (2010). *The Precision-Farming Guide For Agriculturists*. Moline, IL: Deere & Company.

Fast Facts. (2016). Retrieved from https://nces.ed.gov/fastfacts/display.asp?id=372

Fausti, S., Erickson, B., Clay, S., Schumacher, L., Clay, D., & Skouby, D. (2017). Educator Survey: Do Institutions Provide the Precision Agriculture Education Needed by Agribusiness? . *Environmental Education Research, DRAFT*.

Fournel, S., Rousseau, A. N., & Laberge, B. (2017). Rethinking environment control strategy of confined animal housing systems through precision livestock farming. *Biosystems Engineering, 155*, 96-123. doi:http://dx.doi.org/10.1016/j.biosystemseng.2016.12.005

Futrell, A. (2014). Food shortages could be most critical world issue by mid-century. Retrieved from http://aglifesciences.tamu.edu/blog/2014/04/23/food-shortages-could-be-most-critical-world-issue-by-mid-century/

Heiniger, R. W., Havlin, J. L., Crouse, D. A., Kvien, C., & Knowles, T. (2002). Seeing is Believing: The Role of Field Days and Tours in Precision Agriculture Education. *Precision Agriculture, 3*(4), 309-318. doi:http://dx.doi.org/10.1023/A:1021532603441

Holland, J. K., Erickson, B., & Widmar, D. A. (2013). *2013 Precision Agricultural Services Dealership Survey Results*. Retrieved from West Lafayette, Indiana.

Kitchen, N. R., Snyder, C. J., Franzen, D. W., & Wiebold, W. J. (2002). Educational Needs of Precision Agriculture. *Precision Agriculture, 3*(4), 341-351. doi:10.1023/a:1021588721188

Martens, W. (2012). *Employers perceptions of agricultural systems management (ASM) graduates competencies and skill level in the work environment*: [Columbia, Missouri]: [University of Missouri--Columbia], 2012.

Martínez, J., Egea, G., Agüera, J., & Pérez-Ruiz, M. (2017). A cost-effective canopy temperature measurement system for precision agriculture: a case study on sugar beet. *Precision Agriculture, 18*(1), 95-110. doi:10.1007/s11119-016-9470-9

New Undergraduate Degree Program - Bachelor of Science Precision Agriculture. (2016). Plant Science & Agriculturral Biosystems Engineering. South Dakota State University

Reichardt, M., Jürgens, C., Klöble, U., Hüter, J., & Moser, K. (2009). Dissemination of precision farming in Germany: acceptance, adoption, obstacles, knowledge transfer and training activities. *Precision Agriculture, 10*(6), 525-545. doi:10.1007/s11119-009-9112-6

Schrimpf, P. (2017). 6 Essential Competencies for Any Precision Agriculture Staff. Retrieved from http://www.precisionag.com/professionals/6-essential-competencies-for-any-precision-agriculture-staff/?utm_source=knowledgemarketing&utm_medium=newsletter&utm_campaign=paenews+02232017&omhide=true

Schumacher, L. (2016). *Undergraduate Certificate Program Proposal - Precision Agriculture Technology*. Agricultural Systems Management. University of Missouri.

Shannon, K., & Clay, D. (2017). Precision Farming Basics. ASA/Crop Science/SSSA digital library, Madison WI.

Skouby, D., Schumacher, L., Yost, M., & Kitchen, N. R. (2016). *A content review of precision agriculture courses acrocss the U.S.* Paper presented at the International Society of Precision Agriculture 13th International Conference on Precision Agriculture, St. Louis, Missouri, U.S. .

Whipker, L., & Akridge, J. (2006). 2006 PRECISION AGRICULTURAL SERVICES DEALERSHIP SURVEY RESULTS.

Whipker, L., & Akridge, J. (2007). 2007 Precision Agricultural Services Dealership Survey Results. *Working Paper*.

Whipker, L., & Akridge, J. (2008). 2008 PRECISION AGRICULTURAL SERVICES DEALERSHIP SURVEY RESULTS.

Whipker, L., & Akridge, J. (2009). *2009 PRECISION AGRICULTURAL SERVICES DEALERSHIP SURVEY RESULTS*.

Whipker, L., & Erickson, B. (2013). 2011 Precision Agriculture Services Dealership Survey Results. *Working Paper #13-2*.

Yost, M. A., Kitchen, N. R., Sudduth, K. A., Sadler, E. J., Drummond, S. T., & Volkmann, M. R. (2016). Long-term impact of a precision agriculture system on grain crop production. *Precision Agriculture*, 1-20. doi:10.1007/s11119-016-9490-5