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University Council

February 9, 2018

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Dear Colleagues:

The attached proposal from the College of Agricultural and Environmental Sciences for a new Graduate Certificate in Agricultural Data Science will be an agenda item for the February 16, 2018, Full University Curriculum Committee meeting.

Sincerely,

Alison Alexander

Alison F. Alexander, Chair
University Curriculum Committee

cc: Provost Pamela S. Whitten
Dr. Rahul Shrivastav

INTERDISCIPLINARY CERTIFICATE PROGRAM PROPOSAL

I. Basic Information

1. **Institution:** University of Georgia **Date:** October 3, 2017
2. **School/College:** College of Agricultural and Environmental Sciences
3. **Department/Division**: Plant Pathology
4. **Certificate Title (as it will appear in the *Bulletin*)**: Agricultural Data Science
5. **Level (undergraduate or graduate):** Graduate
6. **Proposed starting date for program:** Fall 2018
7. **Abstract of the program:**

The demand for employees with "big data" expertise has risen sharply across all sectors of the U.S. economy. According to a recent Forbes Tech report, demand for many data science positions is expected to increase by between 80 and 90% over the next year. As a result, formal degree or certificate programs in data science have skyrocketed, primarily in areas related to business, consumer, and health care analytics. In contrast, there are currently no specialized training programs in Agricultural Data Science, providing an opportunity for UGA to position itself at the leading edge of this emerging field. Indeed, agriculture is viewed by many as the next frontier in big data generation and analysis, especially when considering data-intensive applications such as precision agriculture, climate and weather-based modeling, crop and livestock imaging and sensing, plant and animal phenomics, and food consumer analytics, among others.

Although many agricultural scientists receive statistical training in the analysis of field and laboratory experiments, they typically lack the integrative skills to manage, mine, and interpret big or less structured data streams. Drawing on UGA's strength in the agricultural sciences and its campus-wide Informatics Initiative, we propose to develop a Graduate Certificate in Agricultural Data Science targeted toward enrolled graduate students in the agri-food sciences and aimed at producing graduates capable of bridging the gap between the generation, analysis, and interpretation of structured and unstructured agricultural data. The Certificate is envisioned to encompass 18 credit hours in the following areas:

- Area 1: Agricultural Data Science Core (6 credits): Two required courses covering the foundations in descriptive and predictive analytics in the agri-food sciences and providing context for and integration among more specialized data science elective courses.
- Area 2: Analytical Foundations (at least 5 credits): More specialized elective courses in the foundations of data science: programming, data management, statistics, econometrics, and/or data mining.
- Area 3: Analytical Applications (at least 6 credits): Elective courses from a range of applications, including precision agriculture, geographic information science, imaging and sensing, experimental statistics, bioinformatics, and consumer analytics, among others.
- Area 4: Seminar in Agricultural Data Science (1 credit): Capstone seminar course featuring UGA and external speakers highlighting diverse applications in agricultural analytics.

II. Response to the Criteria for All Programs

The modern agri-food system generates large amounts of structured and unstructured data in areas such as precision agriculture, crop and weather-based modeling, imaging and sensing, -omics technologies, and food consumer analytics, yet current graduates often lack the integrative skills to manage, mine, and interpret the resulting data streams. The purpose of the Agricultural Data Science (ADS) certificate program is to produce graduates capable of bridging the gap between the generation, analysis, and interpretation of big data in the agricultural sector. Students with these skills will be critical for improving communication between data generators (agricultural and biological scientists) on the one hand, and data specialists (computer scientists and statisticians) on the other. Such interdisciplinary collaboration will enable the transformational innovations needed to develop solutions to meet future food and agriculture needs. As more and more companies in the agri-food sector are transforming themselves into data-driven enterprises, graduates from the Agricultural Data Science (ADS) program will be in high demand.

The ADS certificate builds upon the momentum generated by the Georgia Informatics Institutes (GII) and Informatics Across the Curriculum Program at UGA. We will utilize INFO 8000 (*Foundations of Informatics for Research and Practice)*, a currently approved graduate-level INFO course, as one of the core courses for the certificate. One additional core course, AESC 6xxx (*Applied Agricultural Data Science*), will be developed de novo following the "Specialty Core" model envisioned by GII. As such, there will be considerable potential for synergism between the ADS certificate and the GII.

The ADS certificate also addresses key long-range goals of the university, the CAES, and the Graduate School as spelled out in their respective 2020 strategic plans:

- UGA Strategic Plan – Strategic Direction II, Strategic Priority: "Provide and promote additional opportunities for interdisciplinary, dual, and joint degree experiences for graduate and professional students."
- CAES Strategic Plan – Goal 1: CAES educational programs will be at the forefront of all land-grant institutions: "Encourage the creation of interdepartmental curriculum to ensure emerging societal needs are addressed."
- Graduate School Strategic Plan –Goal 2: Enhance the culture of innovation and interdisciplinary in graduate education
    - Strategy A: "Encourage and support efforts to offer innovative and interdisciplinary research and learning opportunities for graduate students."
    - Strategy B: "Increase the number of interdisciplinary certificates, interdisciplinary degrees, and dual-degrees awarded."

B. Describe the interdisciplinary nature of the proposed program. Which school(s) or college(s) and department(s) will be involved in the development of the program? Describe the expected stage of development for this program within five years.

The ADS certificate is only open to enrolled graduate students at the University of Georgia. It will be housed in the CAES, administered by a Certificate Coordinator in the Department of Plant Pathology, and supported by a Steering Committee with faculty representatives from relevant disciplines. The curriculum will be highly interdisciplinary. Both core courses (INFO 8000 and AESC 6xxx) will integrate analytical approaches and case studies from a range of disciplines. Similarly, the capstone seminar (AESC 8xxx) will draw from intramural and invited speakers across disciplines and industries. Elective courses will be drawn from four different colleges (CAES, Franklin College of Arts and Sciences, Warnell School of Forestry and Natural Resources, and Family and Consumer Sciences) and two Institutes (GII and Institute of

Bioinformatics). At the same time, the curriculum has been designed such that prerequisites for core and elective courses will not be prohibitive for students coming from a range of different disciplines and graduate majors.

Since most of the courses that make up the curriculum of the ADS certificate are already in place, it is expected that the program will be fully developed and operational within the first 5 years.

2. *There must be a demonstrated and well-documented need for the program.*

A. Explain why this program is necessary.

Agriculture faces a "great balancing act"[1] among three critical needs: doubling food production to feed a world population of 9 billion people by 2050, while simultaneously reducing environmental impacts (agriculture currently is responsible for 24% of greenhouse gas emissions and 70% of freshwater withdrawals globally) and supporting rural economic development (agriculture directly or indirectly employs 28% of the world's population). Reconciling these conflicting needs necessitates a transition to a smarter, more efficient agri-food system that is driven by new technologies, robust decision support models, and advanced analytics to increase overall food production, optimize use of natural resources, minimize waste, and improve food access. According to a recent analysis by Rabobank, a multinational agricultural banking group, the convergence of big data, computational algorithms, and associated technologies could add $10 billion in value each year worldwide for crop farms alone[2].

The demand for employees with big data expertise has risen sharply across all sectors of the U.S. economy. According to a recent Forbes Tech report, demand for many data science positions is expected to increase by between 80 and 90% over the next year[3]. As a result, formal degree or certificate programs in data science have skyrocketed, primarily in areas related to business, consumer, and health care analytics[4] [5]. In contrast, there are currently no specialized training programs in agricultural data science, providing an opportunity for UGA to position itself at the leading edge of this emerging field. Indeed, agriculture is viewed by many as the "next frontier" in big data generation and analysis, especially when considering data-intensive applications such as precision agriculture, climate and weather-based modeling, crop and livestock imaging and sensing, plant and animal phenomics, and food consumer analytics, among others. Multinational companies such as IBM, Monsanto, and DuPont Pioneer have recognized this opportunity and are investing heavily into agricultural big data and associated analytics platforms[6] [7]. Also of note, venture capital investment into agricultural technologies in the U.S. has nearly

[1] Searchinger, T. et al. 2013. The Great Balancing Act. Working Paper, Installment 1 of Creating a Sustainable Food Future. World Resources Institute, Washington, DC.
[2] Rabobank. 2015. Building a Smarter Food System. More Productive, Connected and Sustainable, Food & Agribusiness Research and Advisory, October 2015, Utrecht, The Netherlands.
[3] Columbus, L. 2014. Where big data jobs will be in 2015. Forbes Tech 29 Dec. 2014, http://www.forbes.com/sites/louiscolumbus/2014/12/29/where-big-data-jobs-will-be-in-2015/#6de9834404af
[4] KDnuggets. 2017a. Certificates and certification in analytics, data mining, and data science. KDnuggets News, http://www.kdnuggets.com/education/analytics-data-mining-certificates.html
[5] KDnuggets. 2017b. Education in data mining, analytics, and data science in USA/Canada. KDnuggets News, http://www.kdnuggets.com/education/usa-canada.html
[6] Clancy, H. 2014. Is precision agriculture finally taking root? Forbes Tech 9 May 2014, http://www.forbes.com/sites/heatherclancy/2014/05/09/is-precision-agriculture-finally-taking-root/#1d4033363bf8
[7] Huffstutter, P.J., Gillam, C. 2015. Pivoting after failed Syngenta bid, Monsanto to build big data business. Reuters 24 Sept. 2015, http://www.reuters.com/article/us-monsanto-big-data-exclusive-idUSKCN0RO0B020150924

doubled each year since 2012 to reach an estimated total of $4.1 billion in 2015[8]; the top-four areas of investments are all in data-intensive subsectors such as food e-commerce, precision irrigation, drones and robotics, and decision support technology.

Although many agricultural scientists receive statistical training in the analysis of field and laboratory experiments, they typically lack the integrative skills to manage, mine, and interpret the more complex data generated through emerging precision agriculture, imaging and sensing, produce tracking, and food consumer analytics technologies. Training of a cadre of agri-food graduate students who are more "data-smart" and quantitative in their approach will help improve communication and collaboration between data generators (agricultural and biological scientists) on the one hand, and data specialists (computer scientists and statisticians) on the other. This type of interdisciplinary cross-talk will enable the transformational innovations needed to develop solutions to meet future food and agriculture needs.

As more and more companies in the agri-food sector are transforming themselves into data-driven enterprises, graduates from the IGC program will be in high demand. This is echoed in an industry support letter submitted on behalf of the ADS certificate (attached at the end of this document).

Finally, it is noteworthy in this context that USDA's National Institute of Food and Agriculture (NIFA), the largest funder of fundamental and applied agricultural research in the U.S., has recently launched a new initiative, Food and Agriculture Cyberinformatics and Tools (FACT), to address the increasing need for data-driven solutions to address complex agricultural problems. Building on this initiative, the FY2017 NIFA Request for Applications for its Foundational Program for the first time included funding for workshops to identify "priorities and bottlenecks in generating, managing and integrating data in the food and agricultural system." It is anticipated that this funding stream will be expanded in the near future to include research and education in agricultural data science. UGA graduate students trained in the ADS certificate will be better prepared to be competitive for these funds once they have entered the academic workforce as postdocs or independent investigators.

B. In addition, provide the following information:
    1. Semester/Year of Program Initiation: Fall 2018
    2. Semester/Year Full Implementation of Program: Fall 2019
    3. Semester/Year First Certificates will be awarded: Fall 2020
    4. Annual Number of Graduates expected (once the program is established): 12
    5. Projected Future Trends for number of students enrolled in the program: 25-40 at any one time

3. *There must be substantial evidence that student demand for the program will be sufficient to sustain reasonable enrollments in the program.*

    A. Provide documentation of the student interest in the program, and define what a reasonable level of enrollment is for a program of this type. Provide evidence that student demand will be sufficient to sustain reasonable enrollments.

An online survey was conducted among current CAES graduate students in July of 2017 to gauge interest in the ADS certificate. Among *n* = 113 respondents (49 Master's, 64 Ph.D.), 86.8% indicated that they would be interested in this program: 49.6% were "definitely interested" and 37.2% "depending on the details." Examples of student feedback received are as follows:

[8] AgFunder. 2015. AgTech Investing Report. Mid Year Report 2015. AgFunder, New York, NY.

- "This would be an AMAZING addition to any graduate student's program of study. It adds an invaluable set of skills to their "tool box" and it addresses a large gap in our knowledge and training that many graduate students have mentioned they feel they lack. A great idea."
- "I see a general need for this certificate. At the MS level, I think that students with these skills would be very marketable in the animal agriculture industry."
- "I think this program is a great idea, and would enroll now if it were available today."
- "I would definitely be interested in this. My background is in applied statistics and to have the opportunity to apply that to agricultural data would be quite useful."
- "I am trying to get this skills right now, but with a graduate certificate and an organized program of study I feel like I would be able to learn much more."
- "It is a very timely course. When might it be available?"

A reasonable level of enrollment for this type of graduate certificate program would be 25-40 students at any one time, or approximately 12 graduates per year. Based on the overwhelmingly positive feedback received during our survey, student demand should be sufficient to sustain reasonable enrollment.

B. In addition, provide the following information:

To what extent will minority student enrollments be greater than, less than, or equivalent to the proportion of minority students in the total student body?

Minority enrollment in agricultural college majors has been lagging behind that of many other disciplines because of the stigma that is often associated with "traditional" agriculture among minority populations[9]. For example, the percentage of non-white graduate and professional students in fall semester 2016 was 25.6% across UGA but only 15.9% in the CAES. The ADS certificate highlights a non-traditional, "hi-tech" approach to agricultural science that should be particularly attractive to minority students. Hence, we expect a somewhat greater proportion of minority students represented in the certificate program than across the CAES at large.

4. *The design and curriculum of the program must be consistent with appropriate disciplinary standards and accepted practice.*

Provide the following information:

A. Present a detailed curriculum outline of the program listing specific course requirements (to include programs of study, course prefix, number, and title).

Certificate Areas:

- Area 1: Agricultural Data Science Core (6 credits): Two required courses covering the foundations in descriptive and predictive analytics in the agri-food sciences and providing context for and integration among more specialized data science elective courses.
- Area 2: Analytical Foundations (at least 5 credits): More specialized elective courses in the foundations of data science: programming, data management, statistics, econometrics, and/or

[9] Wiley, Z.Z. et al. 1997. Attitude formation of ethnic minority students toward the food and agricultural sciences. J. Agric. Educ. 38:21-29.

data mining.

- Area 3: Analytical Applications (at least 6 credits): Elective courses from a range of applications, including precision agriculture, geographic information science, imaging and sensing, agricultural statistics, bioinformatics, and consumer analytics, among others.
- Area 4: Seminar in Agricultural Data Science (1 credit; new course): Capstone seminar course featuring UGA and external (industry and academia) speakers highlighting diverse applications in agricultural analytics.

AREA 1: AGRICULTURAL DATA SCIENCE CORE

Both courses are required:

INFO 8000 – Foundations of Informatics for Research and Practice (3 credits)

This interdisciplinary course provides instruction and exposure to the theory, tools, and techniques that connect data to information, knowledge, and decisions. Students will gain the knowledge and skills necessary to deeply engage in the increasingly interdisciplinary, data-driven, security-focused industrial and research enterprises as they complete practical analytical tasks and projects.

AESC 6xxx - Applied Agricultural Data Science (3 credits; new course)

This course will cover a variety of modern approaches for analyzing and interpreting data types commonly encountered in the agri-food sciences (including but not limited to variable selection and transformation, decision trees, neural networks, regression models, combination of models, and text mining).

AREA 2: ANALYTICAL FOUNDATIONS (Programming, Statistics, Data Mining, Data Management)

Take at least 5 credits:

AAEC 6610 – Quantitative Techniques in Agricultural Economics (3 hours)

Basic quantitative techniques in agricultural economic theory, emphasizing basic models used in the study of prices, marketing, and production.

AAEC 6630 or 6630E - Quantitative Tools for Agribusiness Management (3 credits)

Quantitative methods for agribusiness management focused on seven topics, including statistical tests, regression, forecasting, linear programming, non-linear optimization, multi-criteria decision making, and simulation models. These tools are introduced in lecture and then put to practical use in the computer lab using SAS and Excel.

BINF 6006 - Programming and Data Structures for Informatics (4 credits)

An intensive introduction to fundamental concepts in programming and data structures and their application to everyday use in informatics analyses. Hands-on exercises will emphasize problem-solving and writing code to collect, analyze, and present results.

CSCI 6360 - Data Science II (4 credits)

An introduction to advanced analytics techniques in data science, including random forests, semi-supervised learning, spectral analytics, randomized algorithms, and just-in-time compilers. Distributed and out-of-core processing.

CSCI 6370 – Database Management (4 Credits)

The theory and practice of database management. Topics to be covered include efficient file access techniques, the relational data model as well as other data models, query languages, database design using entity-relationship diagrams and normalization theory, query optimization, and transaction processing.

STAT 6360 - Statistical Software Programming (3 credits)

Programming techniques in modern statistical software, including SAS and R for students with some experience with computer programming. Topics include data input/output; data formats and types; data management; flow control, conditional execution, and program design; statistical graphics and exploratory data analysis; basic procedures, and functions for statistical modeling and inference.

AREA 3: ANALYTICAL APPLICATIONS

Take at least 6 credits:

AAEC 6620 - Applied Econometrics (3 credits)

Standard and advanced econometric techniques are applied to topics in agriculture and resource economics. Techniques include models for cross-section data, such as pooled regressions, limited dependent variable models, random and fixed effects models for panel data, and forecasting and volatility models for time series data. Students will conduct statistical analyses and model evaluation.

AAEC 8610 - Advanced Econometric Applications (3 hours)

Development and use of econometric techniques. Emphasis on the application of maximum likelihood estimation using MATLAB. The analysis of categorical and survival data, multiple equation regression models, simultaneous systems, and multivariate time series. The treatment of models with discrete and limited dependent variables in a panel data context.

ADSC 8000 – Statistical Genetics and Bioinformatics with Application to Animal Agriculture (3 credits)

Currently used methods and techniques in the field of molecular genetics and bioinformatics with emphasis towards applications in livestock species. It includes the evaluation of molecular markers, genetic maps construction, linkage and segregation analyses, Markers-QTL association and design and analysis of gene expression experiments.

ADSC 8120-8120L – Experimental Methods in Animal Biotechnology (3 credits)

Laboratory methods stressing RNA and protein analysis techniques. Experiments and discussions will include RT-PCR, immunocytochemistry, flow cytometry, and other related experimental approaches. Topics of discussion will also include experimental design, pitfalls, limitations and advantages of experimental techniques, and data analysis and interpretation. Students will also learn to identify unknown samples utilizing learned approaches.

BINF(MIBO)(BCMB) 8211 - Advanced Methods for Biological Data Analyses (3 credits)

Advanced strategies and methodologies for large-scale data analyses in support of genomics, transcriptomics, proteomics, and studies of biological pathways and networks. Topics include gene finding, genomic rearrangements, microarray data analyses, protein function inference, protein-protein interaction prediction, and pathway and network prediction. Major data mining

tools will be covered for each topic.

BINF 8441 - Statistical Inference for the Life Sciences (3 credits)

Introductory statistics for students in the life sciences, including probability, discrete and continuous random variables, distributions, expectations, maximum likelihood, Bayesian inference, hypothesis testing, and linear regression. These topics will be mixed with applications of the statistical concepts to biological data. Statistical inference and real data analysis are implemented.

CRSS 6050 - Improving Nutrient and Energy Efficiency with Geographic Information Systems (4 credits)

Students will apply GIS, GPS, and remote sensing principles in agricultural applications; emphasizing hands-on experience working with producers, vendors, and researchers collecting data, developing spatial databases, analyzing data, and communicating findings. Students will explore agriculture as a landscape complex and evaluate regulatory requirements, conservation opportunities, applied technologies, and market factors.

CRSS 6060-6060L - Advanced Topics in Precision Agriculture (3 credits; offered only at the Tifton Campus)

Concepts and analytical techniques used in precision agriculture to make management decisions such as geostatistics to analyze georeferenced data, development of management zones, integration of sensors with real-time control systems, and big data analytics. Lab exercises will provide experiential learning of topics covered during lectures.

CRSS(PBGG) 8010 - Research Methods and Design for Crop Science (3 credits)

Foundational methods to design and conduct effective field trials for plant research.

CSCI 6380 – Data Mining (4 credits)

A broad introduction to data mining methods and an exploration of research problems in data mining and its applications in complex real-world domains. Approaches include association and classification rule learning, tree learning, neural network and Bayesian methods, support vector machines, clustering, and ensemble learning.

CSCI 6330 - Artificial Intelligence and the Web (4 credits)

The application of artificial intelligence methodologies and algorithms to problems involving the world wide web. Introduction to problem-solving, knowledge representation, learning, and reasoning techniques and exploration of how they are applied to enable information provisioning, social networking, and service provisioning on the web.

CSCI 6850 - Biomedical Image Analysis (4 credits)

Introduction to the standard approaches to biomedical image analysis, including basic concepts of biomedical imaging, basic algorithms, principles of software systems, and their applications. Biomedical image analysis software tools will be used in hands-on projects.

FANR 6750-6750D - Experimental Methods in Forestry and Natural Resources Research (4 credits)

Statistical procedures and computer software to collect, analyze, and interpret forest resources research data.

FANR 8400 - Advanced Spatial Analysis for Natural Resources (3 credits)

Advanced theory and applications of spatial information technology and spatial analysis techniques in natural resources. Focus will be on addressing realistic problems within the field of natural resources, including in student's own research area.

FHCE 7050 - Consumer Analytics and Research Methods II (3 credits)

Advanced research methods with an emphasis on applied consumer research techniques, interpretation, and dissemination. Through the use of modern analytic tools and diverse quantitative methods, students learn to integrate design, measurement, sampling, data management, and analytic techniques found in applied consumer analytic settings such as business, government, and non-profit organizations.

FHCE 7150 - Applied Consumer Policy Analytics (3 credits)

Theoretical and empirical analysis of public and private policy-making and the implications for consumer welfare.

FORS 6760-6760L – Quantitative Models for Forest Resources Managers (3 credits)

Model forms used to simulate tree and forest stand development as well as models used to simulate the growth of various wildlife and fish species. Parameter estimation methods and model evaluation included.

FORS 7690-7690L – Applied Geographic Information Systems (GIS) for Forest Resource Management (3 credits)

Geographic Information Systems (GIS) methods and techniques to solve management problems faced by forestry professionals. Focus on the collection, organization, and analysis of spatial and tabular information with an emphasis on big data (FIA, RPA, census, Landsat) and their use in the decision-making process.

GEOG(CRSS) 6375 - GIS Applications in Agriculture (4 credits)

An exploration of the uses of Geographic Information Science (GIS) technology in agricultural applications. Basics of Global Positioning Systems (GPS) for location reference, GIS for field investigation, and remote sensing for crop and soil evaluation will be explored. Construction of GIS databases for precision farming and watershed management applications will be required.

PATH 8310-8310L – Epidemiology of Plant Diseases (3 credits)

Factors altering the course of disease epidemics in plant populations. Techniques for qualitative and quantitative measures of such factors will be emphasized.

PBIO(BINF) 6550 - Bioinformatics Applications (3 credits)

State-of-the-art computational analyses of genome, DNA, RNA, and protein sequences will be presented, including programs for analyzing these data and the underlying analysis methods. Topics include sequence and structure databases; sequence assembly; sequence alignment; evolutionary analyses; gene function prediction; genome annotation; and applications for medical, agricultural and environmental genomics.

PBIO(BINF)(FANR) 6700 - Computational Plant Science (3 credits)

Introduces computational techniques to students who are new to programming or do not regularly program using examples from plant science. In doing so, the course introduces basic

simulation techniques and imaging techniques that can be specialized and further developed in higher level graduate courses.

STAT 6230 - Applied Regression Analysis (3 credits)
Applied methods in regression analysis. Topics include univariate linear regression, techniques of multiple regression and model building, ANOVA as regression analysis, analysis of covariance, model selection and diagnostic checking techniques, nonlinear regression, and logistic regression.

STAT 8200 - Design of Experiments for Research Workers (3 credits)
Methods for constructing and analyzing designed experiments are considered. Concepts of experimental unit, randomization, blocking, replication, and orthogonal contrasts are introduced. Designs include completely randomized design, randomized complete block design, Latin squares design, split-plot design, repeated measures design, and factorial and fractional factorial designs.

STAT 8250 – Multivariate Methods (3 credits)
An introduction to the methodology of multivariate statistics for quantitatively-oriented students from various disciplines who have training in regression and analysis of variance. Topics include the multivariate normal distribution, one and two population inference on population mean vectors, MANOVA, principal component analysis, factor analysis, discrimination, classification, and canonical correlation.

AREA 4: SEMINAR IN AGRICULTURAL DATA SCIENCE
This course is required:

AESC 8xxx – Seminar in Agricultural Data Science (1 credit; new course)
Capstone seminar course featuring UGA and external speakers (industry and academia) highlighting diverse applications in agricultural analytics.

B. Identify which aspects of the proposed curriculum already exist and which constitute new courses.

Only two new courses (both required) will be needed for the proposed curriculum, AESC 6xxx (*Applied Agricultural Data Science*; 3 credits) and AESC 8xxx (*Seminar in Agricultural Data Science*; 1 credit). Brief descriptions of the two classes are included in the course listing above. Development of these two courses will commence as soon as the certificate program is approved.

AESC 6xxx and 8xxx, along with the existing INFO 8000 (*Foundations of Informatics for Research and Practice*), will play an important integrative role within the program, whereas the elective courses (all of which are already in existence) provide the flexibility to satisfy the needs and interests of diverse majors within the agri-food and allied sciences.

C. Identify model programs, accepted disciplinary standards, and accepted curricular practices against which the proposed program could be judged. Evaluate the extent to which the proposed curriculum is consistent with these external points of reference and provide a rationale for significant inconsistencies and differences that may exist.

To the best of the writers' knowledge, the ADS certificate will be the first of its kind; as such, there are no accepted disciplinary standards or curricular practices against which the proposed program can be judged directly. However, there exist numerous graduate certificate programs in general Data Science, Business Analytics, and Health Care Analytics that can serve as external points of reference[10] [11]. Most of these programs follow a similar structure as proposed here, involving a unifying and integrative core, required foundational courses in programming and data management, and a range of electives to provide flexibility for students in various majors.

D. If program accreditation is available, provide an analysis of the ability of the program to satisfy the curricular standards of such specialized accreditation.

N/A

5. *Faculty resources must be adequate to support an effective program.*

A. Define the size, experience, and specializations of the full-time faculty needed to support an effective program. Identify the extent to which such faculty resources currently exist at the institution, and what additions to the faculty will be needed to fully implement the program. Specify how many full-time faculty will provide direct instructional support to this program.

The ADS certificate involves numerous electives (and hence instructors) from four different colleges (CAES, Franklin College of Arts and Sciences, Warnell School of Forestry and Natural Resources, and Family and Consumer Sciences) and two Institutes (GII and Institute of Bioinformatics). Given the large number of electives, it is unlikely that any single one of these courses would be oversubscribed and would require additional instructor resources. The courses with the largest enrollment will be the core courses, INFO 8000 (*Foundations of Informatics for Research and Practice*) and AESC 6xxx (*Applied Agricultural Data Science*), as well as the capstone seminar, AESC 8xxx (*Seminar in Agricultural Data Science*). INFO 8000 is designed as a large survey course and is expected to be capable of accommodating the additional 12 students/year coming via the certificate. AESC 6xxx is a new course and will be developed and taught by Dr. Harald Scherm (Department of Plant Pathology and initial Coordinator of the ADS certificate program), potentially in collaboration with a new hire in computational epidemiology anticipated in his department in FY19. Responsibilities for AESC 8xxx, the seminar course, will rotate among a core group of CAES faculty with an interest in quantitative approaches and data science. As such, no new faculty resources are required.

B. In addition, for each faculty member directly involved in this program, list:

1) Name, rank, degrees, academic specialty, educational background
2) Special qualifications related to this program
3) Relevant professional and scholarly activity for past five years
4) Projected responsibility in this program and required adjustments in current assignments

[10] KDnuggets. 2017a. Certificates and certification in analytics, data mining, and data science. KDnuggets News, http://www.kdnuggets.com/education/analytics-data-mining-certificates.html
[11] KDnuggets. 2017b. Education in data mining, analytics, and data science in USA/Canada. KDnuggets News, http://www.kdnuggets.com/education/usa-canada.html

1	Harald Scherm Prof. of Plant Pathology & Department Head PhD (Plant Pathology) UC Davis, 1994	George Vellidis Prof. of Crop & Soil Sciences PhD (Agricultural Engineering) University of Florida, 1989	Romdhane Rekaya Prof. of Animal & Dairy Sciences and Adjunct Prof. of Statistics PhD (Quantitative Genetics & Animal Breeding), Polytech Univ. Madrid, 1997	Berna Karali Associate Prof. of Ag & Applied Economics PhD (Economics with Statistics minor) NCSU, 2007
2	Ecological and quantitative epidemiology	Agricultural engineering, precision agriculture	Statistical genetics, Bayesian inference, longitudinal data modeling	Applied econometrics
3	Research on temporal and spatial aspects of botanical epidemics; data synthesis techniques such as meta-analysis and text analytics; CAES Asst. Dean for Research, 2010-2017	Research on spatial and temporal patterns of soil water distribution in fields; development of data management techniques for precision agriculture; development of dynamic variable rate irrigation tools. Teaches CRSS 3030 – Introduction to Precision Agriculture and CRSS 6060 – Advanced Topics in Precision Agriculture.	Bayesian inferences and Markov Chain Monte Carlo methods; longitudinal data modeling; microarray data analysis and bioinformatics. Currently leads USDA National Needs Fellowship project on "integrated training of graduate students in quantitative and computational methods for animal breeding and genomics."	Research on financial and agricultural commodity price analysis employing multivariate and temporal econometric techniques
4[a]	Certificate Coordinator	Seminar Coordination/ Steering Committee	Seminar Coordination/ Steering Committee	Seminar Coordination/ Steering Committee

[a] No changes in current assignments of these faculty members will be needed. Seminar coordination will rotate among the seminar coordinators each year.

C. Where it is deemed necessary to add faculty in order to fully develop the program give the desired qualifications of the persons to be added.

Since the ADS certificate curriculum relies largely on existing courses, no additional faculty will be needed to fully develop the program.

6. *Library, computer, and other instructional resources must be sufficient to adequately support the program.*

A. Describe the available library resources for this program and the degree to which they are adequate to support an effective program. Identify the ways and the extent to which library resources need to be improved to adequately support this program.

Current UGA Library resources in this area are extensive, including 240,000 items (print and electronic books and journals) related to agriculture and food science, and over 200,000 in computer science, informatics, and statistics. Hence, no improvements are needed to adequately support the ADS program.

B. Likewise, document the extent to which there is sufficient computer equipment, instructional equipment, laboratory equipment, research support resources, etc. available to adequately support this program. Specify improvements needed in these support areas.

Adequate computer labs and software are available to support the program. In the CAES alone, this includes 7 instructional computer labs in Athens with 112 machines that are managed either centrally by the Office of Information Technology (OIT) or through CAES departments. Many of these labs are equipped with data science-relevant software such as R, SAS, Matlab, and ArcGIS. Access to high-performance computing and networking infrastructure is available through the Georgia Advanced Computing Resource Center (GACRC) located at UGA's Boyd Data Center, a comprehensive collection of scientific, engineering and business applications, as well as associated consulting and training services.

7. *Physical facilities necessary to fully implement the program must be available.*

   Describe the building, classroom, laboratory, and office space that will be available for this program and evaluate their adequacy to fully support an effective program. Plans for allocating, remodeling, or acquiring additional space to support the program's full implementation of the program should also be identified.

Currently available classroom and computer lab facilities are fully adequate to support this program effectively. No additional space will be needed.

8. *The expense to the institution (including personnel, operating, equipment, facilities, library, etc.) required to fully implement the program must be identified.*

   A. Detailed funding to initiate the program and subsequent annual additions required to fully implement the program are needed below. Estimates should be based upon funding needed to develop an effective and successful program and not upon the minimal investment required to mount and sustain a potentially marginal program.

	Year 1	Year 2	Year 3
Personnel			
Operating Costs	$1,500	$3,000	$3,000
Capital Outlays			
Library Acquisitions			
Total	$1,500	$3,000	$3,000

We anticipate operating costs totaling $1,500 in year 1 and $3,000 each in years 2 and 3, which will be shared between the CAES Office of Academic Affairs and the Department of Plant Pathology. Each year, $1,500 will be used to purchase software licenses and cover GACRC computing time. In years 2 and 3, $1,500/year will be used to bring in extramural speakers for the AESC 8xxx capstone seminar.

   B. Indicate the extent of student support (fellowships, assistantships, scholarships, etc.) available for this program, and evaluate the adequacy of this support. Assistantships funded from institutional (as opposed to sponsored) funds should be included in this funding analysis as well.

Students in the certificate will be funded through their regular graduate assistantships provided by their major departments or programs; thus, there will be no separate financial support line specifically for participation in the certificate. In the future, we anticipate applying for fellowship funding from the USDA-NIFA Food and Agricultural Sciences National Needs Graduate and Postgraduate Fellowship

(NNF) grants program to recruit new M.S. or Ph.D. students having an interest in pursuing the ADS certificate into existing CAES graduate majors.

9. *Commitments of financial support needed to initiate and fully develop the program must be secured.*

    A. Identify the sources of additional funds needed to support the program and the probability of their availability.

As indicated in section 8A, the CAES will provide operational funds for software licenses/computer time and to help bring to UGA extramural speakers for the AESC 8xxx capstone seminar. No additional funds will be needed to support the program.

    B. It is particularly important to include in this response the long-range plans for additional or expanded facilities necessary to support an effective program. Evaluate the timing and likelihood of such capital funding.

In the future, we anticipate applying for fellowship funding from the USDA-NIFA Food and Agricultural Sciences National Needs Graduate and Postgraduate Fellowship (NNF) grants program to recruit new M.S. or Ph.D. students having an interest in pursuing the ADS certificate into existing CAES graduate majors.

10. *Provisions must be made for appropriate administration of the program within the institution and for the admission to and retention of students in the program in keeping with accepted practice.*

    Describe and evaluate the structure for the administration of the program. Explain the degree to which that structure is in keeping with good practice and accepted standards. Similarly, explain how and by what criteria students will be admitted to and retained in the program, and how these procedures are consistent with accepted standards for effective and successful programs.

The ADS certificate will be administered by the Certificate Coordinator, Dr. Harald Scherm, who currently serves as the head of the Department of Plant Pathology and is a quantitative and ecological epidemiologist by training. He will be supported by administrative staff in his department, and advised by a Steering Committee consisting of faculty representatives from the main Colleges and Institutes that offer relevant courses and/or feed students into the program. Two additional members of the Steering Committee will be the GII Director (or his/her designee) and a representative from the agri-technology industry.

Students will be admitted to the certificate by submitting an application to the Coordinator. In order to be admitted, a student needs to be an enrolled, degree-seeking graduate student at the University of Georgia and must have the approval of his/her major adviser. The Coordinator in conjunction with administrative staff will be responsible for admitting students to the program, advising on programs of study, coordinating course offerings, maintaining student records, promoting activities, securing additional funding, and consulting with the Steering Committee regarding curriculum issues.

The semester before completing the certificate, students will be required to fill out a certificate completion form. The ADS certificate will be awarded to the student upon the completion of

her/his graduate degree. An exit survey will be conducted to determine to what degree learning outcomes have been met.

Approvals on File

Proposal: Graduate Certificate in Agricultural Data Science

College: College of Agricultural and Environmental Sciences

Department: Plant Pathology

Proposed Effective Term: Fall 2018

Department:

- Plant Pathology Department Head, Dr. Harald Scherm, 10/4/2017

College:

- College of Agricultural and Environmental Sciences Associate Dean, Dr. Josef Broder, 10/4/2017

Graduate School:

- Graduate School Dean, Dr. Suzanne Barbour, 2/8/2018