Cornell Initiative for Digital Agriculture (CIDA)

3rd Annual Cornell Initiative for Digital Agriculture Workshop

3rd Annual Cornell Initiative for Digital Agriculture Workshop

Table of Contents:

Agenda……pg. 2
Welcome Letter……pg. 3
Keynote Speakers: ……pg. 4
Charlie Messina……pg. 4
Noah Snavely……pg. 4
Panels: ……pg. 5
Ag Analytics/Industry Panel - The connected farm: Opportunities and challenges of improving productivity through connectivity……pg. 5
Moderator:
José Martinez, Professor, College of Engineering……pg. 5
Panelists:
Ponsi Trivisvavet, M.B.A. '99, Chief Executive Officer, Inari……pg. 5
Elizabeth Bruce, Director, University Relations, Microsoft……pg. 6
Dan Wolfson, Director/CTO, Data & Analytics, Watson Media & Weather at IBM……pg. 6
Abe Hughes, General Manager, Trimble……pg. 7
Lawrence Wang, Director, Digital Strategy Development, Cargill……pg. 8
Food Industry/Grower's Panel - Improving food production efficiency through tech innovations: opportunities and barriers……pg. 9
Moderator:
Renata Ivanek, Associate Professor, College of Veterinary Medicine……pg. 9
Panelists:
Emily Reiss, Ph.D. '18, Principal Technical Specialist, Kreher Family Farms……pg. 10
Jim Brennan, B.S. '76, M.Eng. '77, President of SmartWash Solutions, Taylor Farms……pg. 10
Richard Stup, Agricultural Workforce Specialist, Cornell University……pg. 11
Savanna Crossman, Research Coordinator, Advanced Ag Alliance……pg. 11
Research Abstracts: ……pg. 12
2017 Digital Agriculture USDA Hatch Grant Recipients……pg. 12
2019 CIDA Research Innovation Fund and USDA Hatch Grant Recipients……pg. 18
2019 CIDA Research Innovation Fund Summer Stipend Recipients……pg. 25

3rd Annual Cornell Initiative for Digital Agriculture Workshop

7:30	**Breakfast and Poster Presentations**
8:30-9:00	**Welcome and Introductions Around the Room** Tim Vanini, B.S. '91, CIDA Managing Director
9:00-10:00	**Keynote Speaker** Charlie Messina, Senior Scientist, Corteva
10:00-10:40	**Networking, Refreshments and Poster Viewing**
10:40-11:00	**CIDA Update** Susan McCouch, Ph.D. '90, Professor, College of Agricultural and Life Sciences Faculty Director, CIDA
11:00-11:40	**Digital Agriculture USDA Hatch Grant Awardees (August 2017)**
11:40-11:50	**Break**
11:50-12:30	**CIDA Research Innovation Fund and USDA Hatch Grant Awardees (June 2019)**
12:30-12:45	**CIDA Research Innovation Fund Summer Stipend Awardees (May 2019)**
12:45-2:00	**Networking, Lunch and Poster Viewing** – sponsored by **Microsoft**
2:00-2:50	**Ag Analytics/Industry Panel – The Past, The Present, and The Future of Digital Ag Technology** Moderator: José Martinez, Professor, College of Engineering Panelists: Ponsi Trivisvavet, M.B.A. '99, Chief Executive Officer, Inari Elizabeth Bruce, Director, University Relations, Microsoft Dan Wolfson, Director/CTO, Data & Analytics, Watson Media & Weather at IBM Abe Hughes, General Manager, Trimble Lawrence Wang, Director, Digital Strategy Development, Cargill
2:50-3:00	**Break**
3:00-3:50	**Food Industry/Grower's Panel – Improving Food Production Efficiency Through Tech Innovations: Opportunities and Barriers** Moderator: Renata Ivanek, Associate Professor, College of Veterinary Medicine Panelists: Emily Reiss, Ph.D. '18, Principal Technical Specialist, Kreher Family Farms Jim Brennan, B.S. '76, M.Eng. '77, President of SmartWash Solutions, Taylor Farms/SmartWash Solutions Richard Stup, Agricultural Workforce Specialist, Cornell University Savanna Crossman, Research Coordinator, Advanced Ag Alliance
3:50-4:00	**Break**
4:00-5:00	**Keynote Speaker** Noah Snavely, Associate Professor, Computing and Information Science at Cornell Tech **Closing Comments**
5:15-7:15	**Networking and Refreshments** Park Atrium, Statler Hall

Sponsored by:

Microsoft Trimble

3rd Annual Cornell Initiative for Digital Agriculture Workshop

To all,

Welcome to the 3rd Annual Cornell Initiative for Digital Agriculture Workshop!

We are so happy that you are here to join us in Ithaca. You couldn't have arrived at a better time with fall colors in full hue. We are looking forward to engaging research presentations by our faculty and graduate students on their latest findings and upcoming projects. Furthermore, we encourage you to take the opportunity to view posters, listen to two diverse panels on Ag-Analytics and Food Industry and network with faculty, staff, students and other external stakeholders.

In your Welcome Packet, you should have access to abstracts of the presentations, bios of the keynote speakers, moderators and panelists, and a full agenda for the workshop. In addition, we will provide CVs from Cornell graduate students and post-docs who are have expressed interest in potential internships or jobs with your respective entity. We encourage you to reach out to them with your interests.

Again, we are grateful for your participation in our workshop, and hope you have a wonderful time at the event, The Statler Hotel and Cornell University.

Please feel free to contact me or Gabriela during the workshop if you have any questions.

Sincerely,

Tim Vanini
Managing Director, CIDA

Gabriela Cestero
Administrative Assistant, CIDA

3rd Annual Cornell Initiative for Digital Agriculture Workshop

Keynote Speakers:

Title: “Predictive Agriculture: Transforming Breeding and Agronomy”
Charlie Messina, Senior Scientist, Corteva

Charlie Messina is a Research Fellow with Corteva, located in Johnston Iowa since 2004. He has Agronomy and MSc degrees from the University of Buenos Aires and a PhD in Ag and Biological Engineering from the University of Florida. His major research interests include: a) fusion of biological models and statistical learning methodologies; b) physiology and genetics in maize; c) development and application of mathematical models to enable design in agricultural systems. In his current role, he leads the Agricultural Systems initiative and modeling team. During his tenure at Corteva he contributed to the development and launch of AQUAmax, the development of Encirca® N product, and advanced prediction methodologies. He represents Corteva in International research consortiums and lead collaborations with leading institutions in Agriculture. He represents the Industry sector as elected representative of the Crop Science Society of America, and the North America Plant Phenotyping Network. He is strong advocate for equal opportunity, diversity and inclusion; he led a diversity network at Corteva in 2007 and 2008.

Title: “Reconstructing the 3D World from Images of Everything”
Noah Snavely, Associate Professor, Computer Science at Cornell Tech, Cornell University

Noah Snavely is an associate professor in the Computer Science Department at Cornell University and Cornell Tech, working in the Cornell Graphics and Vision Group. Noah also works as a researcher at Google Research. Noah's research interests are in computer vision and graphics, in particular in recovering structure from large photo collections for use in understanding and visualizing the world around us. Noah is the recipient of a PECASE, a Microsoft New Faculty Fellowship, an Alfred P. Sloan Fellowship, and a SIGGRAPH Significant New Researcher Award.

3rd Annual Cornell Initiative for Digital Agriculture Workshop

Ag Analytics/Industry Panel - The connected farm: Opportunities and challenges of improving productivity through connectivity

Moderator:

Jose Martinez, Professor, College of Engineering

José Martínez is Professor and Associate Director of Electrical and Computer Engineering, faculty member of the graduate fields of Computer Science and Systems Engineering, and Faculty Fellow of the Atkinson Center for a Sustainable Future. He is co-founder and part of the Executive Committee of Cornell's Initiative for Digital Agriculture (CIDA); and he is also the Associate Director of the DARPA/SRC Center for Research in Intelligent Storage and Processing in Memory (CRISP).

Panelists:

Ponsi Trivisvavet, M.B.A. '99, Chief Executive Officer, Inari

Ponsi Trivisvavet is CEO and Director of Inari, a company that seeks a winning food system with its industry-disrupting process that taps natural diversity of plants in the context of climate change and respect for the environment. Ms. Trivisvavet has broad expertise in global agriculture as well as extensive management skill in seeds business. Prior to joining Inari, she held a number of leadership roles at Syngenta, most recently as president of Syngenta Seeds North America. Before Syngenta, she held positions with McKinsey & Company. Ms. Trivisvavet holds an MBA from Cornell University.

3rd Annual Cornell Initiative for Digital Agriculture Workshop

Elizabeth Bruce, Director, University Relations, Microsoft

Elizabeth is a University Relations Director in the Technology and Corporate Responsibility group at Microsoft that works across divisions, from research to product teams, providing cross-company direction on strategic university engagements and public-private partnerships. Elizabeth is passionate about Open Data for research and strengthening Microsoft's relationships with key universities. Prior to Microsoft, Elizabeth spent over a decade at MIT working with faculty to lead research initiatives and strategic partnerships with industry and government, in data science, big data, privacy, cloud computing, biomedical, and communications. Elizabeth served as Executive Director at the Institute for Data, Systems, and Society (IDSS) and co-founded the MIT Big Data Initiative at the Computer Science and AI Lab (CSAIL). She holds a Joint Program Master's degree from MIT and Woods Hole Oceanographic Institute in Ocean Engineering and a BS in Electrical Engineering from the University of Washington, Seattle, WA.

Dan Wolfson, Director/CTO, Data & Analytics, Watson Media & Weather at IBM

Dan is an IBM Distinguished Engineer and Director/CTO of Data & Analytics for The Weather Company division of IBM where he leads the Decision Platform products covering areas such as Weather Signals, Vegetation Management for Utilities, Agribusiness, Geopatial Data/Analytics & Video Recognition. In addition he and his team support the data engineering, analytics and data governance operations of The Weather Company. He is responsible for technical leadership, product development and operations in this rapidly growing area with particular interest in the delivery of insight into analytical and operational solutions and the curation and management of information. Current focus areas include Weather based Analytics, Remote Sensing and GeoSpatial Data Management. Previously he was the chief architect/CTO for the Insights as a Service unit of the IBM Analytics Group.

Dan has over 30 years of experience in research and commercial distributed computing, covering a broad range of topics including transaction and object-oriented systems, software fault tolerance, messaging, information integration, analytics, master data management, business integration, metadata management, data governance and database systems. He has written numerous papers, blogs, and is the co-author of three books about information management: “Enterprise Master Data Management: An SOA Approach to Managing Core Business Information”and “Beyond Big Data: Using Social MDM to Drive Deep Customer Insight”, and "Common Information Models for an Open, Analytical, and Agile World". Dan is a member of the IBM Academy of Technology and an IBM Master Inventor with over 45 patents issued. In 2010, the Association of Computing Machinery (ACM) recognized Dan as an ACM Distinguished Engineer.

Abe Hughes, General Manager, Trimble

General Manager of the Agriculture Division of Trimble Inc., a $3 billion high tech pioneer in global positioning, connectivity, mapping and data analytics transforming the way we work in agriculture and other industries. Abe served as Vice President North America for New Holland Agriculture and Construction, a world leader in tractors, combines and hay equipment. New Holland is a division of CNH Industrial/Fiat Group, where Abe was responsible for leading the successful turnaround, doubling revenues from $1 billion to $2 billion and returning the division to profitability. He has over 25 years of corporate and entrepreneurial experience in a wide array of manufacturing, retailing and service industries in the U.S., Europe, Asia, Africa and Latin America.

Abe received his MBA from the Harvard Business School and his BA from Cornell University and is fluent in Portuguese, Spanish and English.

3rd Annual Cornell Initiative for Digital Agriculture Workshop

Lawrence Wang, Director, Digital Strategy Development, Cargill

Lawrence Wang, Cargill is Director of Digital Strategy Development for Cargill. He leads a global team that is catalyzing the digital transformation for Cargill. His team has engaged internal and eternal stakeholder to drive digital innovation into the food and ag industry, including execution of the Farm To Fork Accelerator in partnership with Techstars. Lawrence has spent his career in technology and has worked across industries including retail, financial services, medical device, and food and agriculture at companies such as IBM, Accenture, Target, and Medtronic.

3rd Annual Cornell Initiative for Digital Agriculture Workshop

Food Industry/Grower's Panel - Improving food production efficiency through tech innovations: opportunities and barriers

Moderator:

Renata Ivanek, Associate Professor, College of Veterinary Medicine

Dr. Renata Ivanek is an Associate Professor of Epidemiology in the Department of Population Medicine and Diagnostic Sciences, College of Veterinary Medicine. She joined the Department in 2015 after being on the epidemiology faculty at Texas A&M University.

Dr. Ivanek holds a Doctor of Veterinary Medicine degree from the Faculty of Veterinary Medicine, University of Zagreb in Croatia; an MS in Veterinary Epidemiology jointly granted by the London School of Hygiene & Tropical Medicine and the Royal Veterinary College in United Kingdom; and a PhD in Comparative Biomedical Sciences from Cornell University.

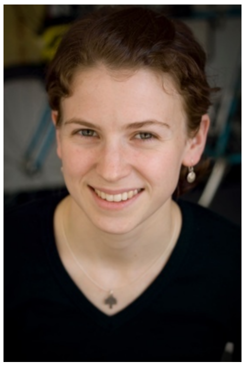
The overarching goal of Dr. Ivanek's research is to advance *One Health* -- the interconnected health of people, animals, plants and their shared environment. Her computer lab develops new and sustainable data- and model-driven approaches for improving food safety, controlling infectious diseases and optimizing food production systems.

Most recent projects in Dr, Ivanek's lab include studies of antibiotic use and resistance in animal agriculture. She develops decision support tools to reduce food waste and prevent pathogen spread in food and veterinary environments. Also, she conducts controlled intervention trials on farms to reduce contamination of foods with foodborne pathogens and determine how weather conditions affect food safety.

3rd Annual Cornell Initiative for Digital Agriculture Workshop

Panelists:

Emily Reiss, Ph.D. '18, Principal Technical Specialist, Kreher Family Farms



Emily Reiss grew up in New Jersey, and attended the University of Rochester for her undergraduate education. She received her B.S. in Environmental Science with minors in Biology and Spanish in 2008. After working in the international education and energy efficiency fields in New York City, she returned to Upstate New York in 2011 to pursue her PhD in the Field of Horticulture at Cornell University. Her doctoral research focused on biodiversity in agroecosystems and how farmers can manage cover crops to maximize their benefits. In 2017 she moved to Rochester to join Kreher Family Farm and serves as the Principal Technical Specialist for the Crop Division.

Jim Brennan, B.S. '76, M.Eng. '77, President of SmartWash Solutions, Taylor Farms/SmartWash Solutions

Jim has over 30 years' experience in the food, beverage and produce industries and has held executive positions in R&D, Engineering, and Operations. Jim specializes in the development and commercialization of new businesses and technologies which enable new businesses. He has successfully guided international joint ventures in the fruit and vegetable sector. He has established long-term joint development efforts in bioengineering focused on alternative disease and pest control. Equally as important are his efforts to integrate microprocessor control technology into everyday agricultural practices and processing, leading to significant reductions in disease and pest control costs as well as positively impacting food safety in products. In his current position he has guided the development and commercialization of a novel processing approaches for the prevention of water mediated microbial cross-contamination in food and agricultural wash systems. He has also been instrumental in the advancement of GAPs in produce items ranging from tropical fruits to tree nuts to a broad spectrum of vegetables.

3rd Annual Cornell Initiative for Digital Agriculture Workshop

Richard Stup, Agricultural Workforce Specialist, Cornell University

Dr. Richard Stup is the Agricultural Workforce Specialist with Cornell University's College of Agriculture and Life Sciences. He leads educational programs in human resource management and conducts applied research into labor challenges facing the agricultural industry. His focus is on leadership development and regulatory compliance at the farm level. Before joining Cornell, Richard practiced as an organization development consultant, served as a senior leader in Farm Credit, was an extension specialist with Penn State, and worked in the feed industry. He earned his doctorate from Penn State in the field of Workforce Education and Development, including research into human resource management on employee organizational commitment.

Savanna Crossman, Research Coordinator, Advanced Ag Alliance

Savanna Crossman has served as the Research Coordinator since 2014 and has taken the position of Secretary within the AAA. Savanna is a native of Northwest Vermont where she has worked extensively with crop and dairy farmers. She graduated from the University of Vermont with a Bachelor's Degree in Agronomy and Soils and she has earned her CCA through the American Society of Agronomy. She is currently pursuing her Master's Degree in Agronomy at Kansas State University.

2017 Digital Agriculture USDA Hatch Grant Recipients:

A New Foundation for Digital Irrigation Scheduling in Apple Orchards

Lailiang Cheng, Professor, CALS, SIPS; Alan Lakso, Professor Emeritus, CALS, SIPS; and Abraham Stroock, '95, Professor, COE, Chemical and Biomolecular Engineering (CBE).

New York State (NYS) is the second largest producer of apples in the US. With an annual value of $322 million, apples are the state's fifth most valuable agricultural commodity **(NYS** Report 7-2013). Nationally, apples represent a $3.1 billion annual value. The yield, quality, and susceptibility to disease of apples are influenced by water availability through the growing season.

Recent trends toward more frequent and severe mid-summer drought and the move toward higher density cultivation strategies have driven the adoption of irrigation by an increasing number of NYS orchards; orchards in western states (notably Washington) have long depended on irrigation. While research over the past decades has elucidated the importance of controlling water status in experimental contexts, the translation of this knowledge into commercial practice has been hindered by the lack of tools with which to access the relevant measure of water stress (stem water potential) and couple this data stream with physiologically informed models to provide precise control of irrigation. This project will leverage a newly developed Cornell technology, the microtensiometer, to develop a framework of measurements and Cornell apple water-use models to provide feedback control of water stress for use in apple orchards. The project will produce a demonstration prototype of this system in a sector of the Cornell orchard, and serve as a foundation for next generation precision techniques for the control of water use in apple and other high value horticultural crops.

E-synch: A Tool to Automate and Optimize Cattle Reproductive Management

David Erickson, Professor, College of Engineering (COE), Mechanical and Aerospace Engineering (MAE); and Julio Giordano, Associate Professor, CALS, Animal Science (ANSC).

We will develop **the E-synch device, an easy to use, automated, and reusable tool for cattle reproductive management.** E-synch (Electronic synchronization) will combine (1) an electronically-controlled intravaginal drug delivery device to enable the synchronization of

ovulation with (2) sensing technology to monitor physiological parameters. E-synch will drastically reduce the need for labor-demanding, costly, and cow-disruptive injectable treatments. Physiological monitoring through sensors will allow individual cow-level, real time customization of protocols. Ultimately, E-synch will reduce the hassle of reproductive management promoting adoption and optimization of programs for artificial insemination (AI) which will help optimize the productivity and health of millions of cows around the world.

The PDs teams' have an excellent track record of collaboration focusing on developing biomedical devices to improve cattle management. First, we will develop a prototype device and controlling software. Thereafter, we will test the prototype device under field conditions. This research will complement current efforts in Dr. Giordano's lab to optimize the response to intravaginal delivery of reproductive hormones in cattle and prior efforts by Dr. Erickson in engineering biomedical systems including controlled release drug delivery devices.

Ultimately, E-synch will increase farm sustainability by reducing labor needs and improving cow welfare through better reproductive performance and reduced cow manipulation.

Development of a High-resolution Weather Forecast Database for Digital Agriculture Research and Outreach Applications

Arthur DeGaetano, Professor, CALS, Earth and Atmospheric Sciences (EAS); and Madeleine Udell, Assistant Professor, CIS, Statistics and Data Science (DSDS).

Weather forecasts provide the foundation for many operational agriculture decisions. Both formal stakeholder surveys and more casual conversations with producers highlight the need for timely, high-spatial-resolution weather forecasts. In fact, nearly all agricultural decision tools developed and maintained by the Northeast Regional Climate Center incorporate some form of forecast information. Nonetheless there are three significant gaps in our and our collaborator's abilities to exploit the full potential of forecast information in these tools. Through this work we propose to narrow these gaps by developing a database of past weather forecasts. This will allow both researchers and users to assess past forecast skill. A related component will focus on forecast resolution. Here we plan to run a weather forecasting model at a very high resolution over a focused domain, like the Finger Lakes, with the goal of assessing the value (and veracity) of this computationally expensive approach. A final goal will address data retrieval. The webservice API developed by the NRCC to access gridded data resources is not as responsive as we would like for some interactive web applications. Exploring and implementing more efficient data storage formats and retrieval algorithms for these forecast datasets will enhance user experience with existing and future agricultural tools. Three objectives will define this project. The overarching goal is to develop and provide the digital agriculture community with access to a continually updated weather forecast database.

1. **Develop a forecast data archive.** The availability of only the most recent NDFD forecast prevents us from evaluating the uncertainty in these forecasts. We assume that incorporation of the forecast will lead to a better-informed management decision compared to past practice or farmer experience. The existence of such an archive will serve as a resource for research and also allow recent forecast skill to be incorporated into operational decision tools.
2. **Evaluate of high-resolution weather forecasts.** Using a meteorologically interesting and agriculturally important subregion, such as the Finger Lakes, we will establish a cloud-based environment in which we will operationally run the

Weather Research and Forecast model (WRF) at high and moderate spatial resolutions.

3. **Improve our forecast data webservice response.** The standard approach to serving weather forecasts and data does not scale to extremely high-resolution values using standard data structures: the scale of the data is too large to store in memory or to execute these lookups efficiently. Working with CIS, we propose a fundamentally different approach that integrates a predictive model with a lookup table. This approach allows for arbitrarily high-resolution forecasts without demanding that computer hardware grow proportionally.

Improving Vineyard Management Using Touch-Sensitive Soft Robots

Kirstin Petersen, Assistant Professor, COE, Electrical and Computer Engineering (ECE); and Justine Vanden Heuvel, Associate Professor, CALS, SIPS.

Despite the promise of sensor networks and computer vision, technological advances have yet to deliver a reliable, accurate method for estimating grapevine yield prior to harvest. This project proposes to apply inexpensive robots that can touch, sense, and carefully manipulate fragile agricultural products to the problem of estimating grape yield while quantifying additional cluster characteristics that impact grower decisions in the vineyard. Novel high-resolution ultrasonic multi-modal sensor arrays incorporated into a pneumatic chamber guided by a stereo-vision camera will sense - through touch - cluster and berry size to calculate growth rate, cluster temperature, integrity, and potentially the early signs of fungal infection. Data will be collected, processed, and reported via a user-friendly interface. We envision a series of inexpensive platforms in the vineyard that will communicate to a base station providing the grower with real-time cluster data to facilitate decisions about canopy management, crop control, potentially pest management, harvest, and streaming in the winery.

Advancing Digital Agriculture and Conservation Through Data-Driven Decision and Policy-Making

Fengqi You, Professor, COE, BCE; and Matt Ryan, Assistant Professor, CALS, SIPS

The U.S. plants over 170 million acres of corn and soybeans a year, more than any country in the world. The U.S. agriculture sector is subsidized primarily via federal crop insurance. The U.S. crop insurance market is also the largest in the world, with over $100 billion in liabilities annually. Despite its size, the governments' pricing of the insurance risk as it relates to soil and practice types is fairly crude. For example, they do not reflect how conservation practices can improve soil health over time. On the other hand, adoption of conservation-oriented practices remains somewhat low. For example, USDA estimates that only 3 to 7 percent of farms use cover crops, amounting to only 1 percent of cropland.

An important departure point for addressing conservation in the context of Digital Agriculture is to tackle the inherently complex agricultural systems with a Systems Engineering approach by creating new knowledge and analytics tools for data-driven decision- and policy-making. Data-driven cyberinfrastructure and computational tools can seamlessly integrate the raw and/or processed agricultural data with prediction models (e.g., crop, soil, water and weather) to derive reliable, multi-resolution, and spatially connected crop yield distributions under various practice, environmental, and technology scenarios. At the farm level, data analytics and data-driven optimization would inform the growers with respect to input and crop management needs (e.g. seed, fertilizers, pesticides, soil amendments, cultivation, and harvest), in order to optimize crop yield, reduce unnecessary applications of fertilizers and pesticides in conservation-oriented practices, preserve natural resources, and contend with impending weather events. At the policy level, these computing and systems engineering tools could be used for optimizing crop insurance policy design under various soils, weather, and conservation practices, including cover crops, crop rotation and diversification, no-till farming, reforestation, skip-row, and others. The creation of such tools evidences the need for continuous, solid and reliable production of agriculture-related data; the design of analytics that translate such data into useful information; and the ability to synthesize and deliver the right information in time and space to growers and policy makers to promote conservation.

This proposal aims to combine and adopt data-driven optimization and advanced machine learning techniques with Digital Agriculture data to inform conservation decision-making at both the farm level and the policy level. Building upon the state-of-the-art computational tools on data-driven decision making under uncertainty pioneered by the PI You, this research will

leverage the expertise of co-PI Ryan on conservation agriculture and cover crops, to solve questions of interest. Namely, these will include investigation of cover crop adoption (at scale, and in dynamic contexts), as well as other priority areas identified.

2019 CIDA Research Innovation Fund and USDA Hatch Grant Recipients:

Improving strawberry yield through native and robotic pollinators

Kirstin Petersen, Assistant Professor, College of Engineering (COE), Electrical and Computer Engineering (ECE); and Scott McArt, Assistant Professor, College of Agriculture and Life Sciences (CALS), Entomology.

Approximately 75% of all agricultural crops require pollination, an ecosystem service valued at ~$170B in worldwide annual revenue [1]. Global reliance on pollination is expanding, yet farmers in many parts of the world suffer from increasingly unpredictable yields stemming from dwindling populations of wild pollinators and unsustainable losses of managed bees. The proposed work will integrate automated monitoring of wild and managed pollinators with cutting-edge robotic pollination, laying the groundwork for a bio-hybrid system capable of observing, predicting, and improving yield in pollen-limited crops. Specific innovations include durable, low power insect camera traps, mobile end-effectors for local electrostatic pollination, rapid cross-pollination by quadcopters, and growth models conveyed to the farmer through an online app. These technologies will be validated with strawberry plants over several bloom cycles in the greenhouse, and through field experiments in a commercial farm. Short term, these technologies can be seamlessly integrated into current farm practices. Long term, they may be managed by automated schedulers to ensure optimal yield long before harvest. In a broader sense, this research opens a new frontier in precision agriculture, where robots not only have the intelligence to overcome the challenges of field deployment, but can operate as part of the natural ecosystem around crop plants.

New soil robotics and sensing for soil-root phenotyping of water-use effectiveness
Taryn Bauerle, Associate Professor, CALS, School of Integrative Plant Science (SIPS); Robert Shepherd, Associate Professor, COE, Mechanical and Aerospace Engineering (MAE); Mike Gore, Ph.D. '09, Associate Professor, CALS, SIPS; Johannes Lehmann, Professor, CALS, SIPS; and Abraham Stroock '95, Professor, COE, Chemical and Biomolecular Engineering (CBE).

Soil, the microbiome, and plant roots represent a critical frontier in agricultural science and practice. The opacity, heterogeneity, and dynamic nature of soils have severely limited in situ studies, phenotyping, and precise interventions as part of soil and crop management. This project brings together expertise in soil science (Lehmann), root biology (Bauerle), phenotyping and genetics (Gore) with engineering expertise in robotics (Shepherd) and sensing (Stroock) to develop a suite of technologies that will provide dynamic access to the rhizosphere (root-soil interface). In this seed project, we focus on water relations – a critical aspect of rhizosphere biology; the project will also build toward a platform technology for in situ measurements in soils. The availability and flow of water in the rhizosphere represents important yet inaccessible targets for measurement in phenotyping and management of irrigation and fertigation. We will develop two innovations to provide access to these characteristics in the field: 1) a sensing strategy to provide sub-millimeter resolution of water relations (potential, content, and conductance) within the rhizosphere, in situ; and 2) a soil-swimming robot to provide semi-autonomous exploration of the root zone with multiple sensing modalities. We will pursue experiments with our emerging capabilities guided by scientific questions about roots and rhizosphere to drive new approaches to phenotyping.

Microbiome-informed computational models and decision support tools to predict fresh produce spoilage: spinach as a model system
Martin Wiedmann, Ph.D. '97, Professor, CALS, Food Science (FS); and Renata Ivanek Miojevic, Ph.D. '08, Associate Professor, College of Veterinary Medicine (CVM), Population Medicine and Diagnostic Sciences.

Food waste is a significant global challenge; construction of computational models and decision support tools to predict shelf life creates opportunities to reduce food waste caused by microbial food spoilage. Existing methods for shelf life prediction of food typically use culture-dependent microbial count data rather than relative levels of microbial populations determined using culture-independent methods. The overall goal of the project is to develop a computational model of microbiome interactions and perturbations during processing,

transportation and retail for predicting product shelf life. This will serve as a basis to later develop and pilot transformational strategies to reduce food waste through more accurate shelf life prediction. This project will focus on fresh produce, using spinach as a model system. Specific objectives are (i) collection of spinach at farms and processing facilities; classical microbiological testing and 16S metagenomics; descriptive and inferential statistics on microbial and microbiome data; (ii) shelf life studies with spinach collected in Obj. 1 to track changes in microbiome and measure timing and extent of spinach spoilage under laboratory conditions that simulate typical environmental and management conditions at retail; (iii) development of a computational model of microbial dynamics over shelf life to serve as a decision support tool that allows for spinach spoilage prediction and assessment of different spoilage control strategies.

Accelerated and automated stress diagnostics in apple orchards

Awais Khan, Associate Professor, CALS, SIPS at Cornell AgriTech; Serge Belongie, Professor, Computing and Information Science (CIS), Computer Science (CS) at Cornell Tech; and Noah Snavely, Associate Professor, CIS, CS at Cornell Tech.

Apple orchards suffer from large numbers of diseases that can incur serious damage to trees, fruits, and the industry. Effective chemical and/or biological control methods rely on accurate early diagnostics to implement successful and environmentally-sound management. As disease symptoms vary widely due to age of infected tissues, genetic variations, and light conditions within trees, it is challenging for computer vision models to accurately distinguish between the many symptoms of many diseases. International competitions are held at the Fine Grained Visual Classification (FGVC) workshop at Computer Vision and Pattern Recognition (CVPR) conference to find novel solutions to major challenges in computer vision. For the first time, a plant disease challenge, 'iCassava', is a priority in 2019 to develop models to distinguish four plant diseases. As single-leaf images with few disease symptoms do not reflect conditions in an orchard, we assembled a team with expertise in plant pathology, phenotyping, and computer vision to address a complex and multi-dimensional system of stresses in apple orchards. The following goals will be pursued: 1) Create expert-annotated disease datasets of high-quality RGB images of multiple apple stresses; and 2) Develop automated image-based stress classification and quantification and lead a global challenge competition at CVPR2020. Open-source code developed for stress diagnosis in apple orchards will be made available.

Carbon farming: Combining machine intelligence, big data and process models to support this emerging sector

Dominic Woolf, Senior Research Associate, CALS, SIPS; Johannes Lehmann, Professor, CALS, SIPS; and Fengqi You, Professor, COE, CBE.

Restoration of soil organic carbon (SOC) plays a critical role in addressing climate change while improving agricultural efficiency, and reversing land degradation. However, scaling up of soil carbon sequestration is impeded by the high cost of monitoring, and by high levels of uncertainty in SOC predictions. This project aims to create a step change in accurate prediction of SOC, by combining Cornell's state-of-the-art soil modeling with machine learning, deep learning, and spatially-explicit big data to create a grey-box digital twin. This will provide a platform to drive evidence-based policy and support massive scaling up of optimized investment in soil health and climate-change mitigation.

Function-targeted high-resolution phenotyping platform to deduce genetics-functions relationships in rhizomicrobiome for promoting plant nutrients utilization

April Gu, Professor, COE, Civil and Environmental Engineering (CEE); Jenny Kao-Kniffin, Associate Professor, CALS, SIPS; and Kilian Weinberger, Associate Professor, CIS, CS.

This study aims to contribute to CIDA's ability in predictive and function-targeted agricultural phenotyping via leveraging innovative single cell Raman microspectroscopy (SCRM) technology and computational science. Rhizomicrobiome research is only in its infancy and holds the key to a better understanding of plant-microbe interactions and improving plant health and productivity. Current genomics approaches have greatly advanced our understanding of the rhizomicrobiome. However, critical limitations exist in cost and scalability of genomics data acquisition and data interpretation due to the lack of reference genomes, and inability in gene-function relationship deduction, particularly for highly diverse and poorly characterized soil rhizosphere. These hampers our ability to provide timely, relevant information to various stakeholders. The proposed a novel and integrated phenotyping-genotyping technology platform will circumvent some of the above limitations and enable us to build a world-class agricultural phenotyping facility at Cornell to discover, profile new and in situ function-relevant microorganisms, such as polyphosphate accumulating organisms (PAOs) contributing to P utilization, carbon (PHB, glycogen)-accumulating organisms (CAOs) involved in nitrogen

fixation, other novel organisms based on their phenotypes, and to establish gene-function relationships by correlating phenotypic with genotypic profiles.

Scalable digital sensors of the skies and soils: An internet of things approach to improve farm-scale weather forecasts of extreme heat, drought and rainfall

Toby Ault, Assistant Professor, COE, Earth and Atmospheric Sciences (EAS); and Max Zhang, Associate Professor, COE, MAE.

Extreme weather is a serious threat to agriculture, economic vitality, human safety, and physical infrastructure in farming communities throughout the world. Climate change is likely to increase the risk of severe weather, particularly heat waves, droughts, and floods. To flourish in spite of these hazards, farmers, growers, agro-business, and food producers require a toolkit of political, infrastructural, and technological resources to manage the risk of extremes. Numerical models of weather and climate will be among the most important of these tools because they empower decision makers with information to anticipate and prepare for consequential events. Large national research labs have made formidable progress developing open source tools for numerical weather and climate prediction (e.g., 1,2,3). Yet weather predictions on even relatively short (1-7 day) timescales frequently miss key hazards to agriculture during the warm season when extreme rainfall, heatwaves, and droughts can exact severe crop losses. The proposed research will leverage an existing wireless "Internet of Things" (IoT) to monitor and forecast key variables for predicting extreme weather at State, County, and Farm scales in the Northeast. It will further position the project team and cross-campus collaborators to work on a major bid to the USDA to develop a new model designed to capitalize on heterogeneous data sources for real-time tracking and prediction of extreme weather hazards to agriculture.

Development of predictive models to accurately detect subclinical and clinical mastitis in dairy cows milked with automated milking systems

Rick Watters, Director, Quality Milk Production Services Western Laboratory and Senior Extension Associate, CVM; and Kristan Reed, Assistant Professor, CALS, Animal Science.

Inflammation of dairy cow mammary glands, or mastitis, is one of the most important diseases in dairy production. Costs related to veterinary service, labor, loss of saleable milk, reduced milk production, and culling make it one of the most costly dairy diseases. In conventional milking systems, detection of clinical mastitis (CM) is straight forward by identification of abnormal milk or a swollen quarter, but subclinical mastitis (SCM) is only identified by a somatic cell count (SCC) ≥ 200,000 cells/mL. Accurate and timely detection of SCM has the potential to improve milk quality and farm economics. Automated milking systems (AMS), also called robotic milking, harvest milk at the quarter level and provide hundreds of data points from each cow at milking. Quarter level data points, such as milk yield, milking time, duration between milking visits, kick-offs, incomplete milkings, and conductivity are some of the values that could be used to develop an algorithm for accurate identification of cows at the onset of CM and SCM. We propose to develop predictive models to accurately detect CM and SCM in dairy cows milked with AMS. In 2018 there were 76 farms and 279 AMS units installed or approved for installation in New York State. At present, there are 17,000 cows or 3% of the dairy cows in New York State milked with AMS. Automated milking systems are installed on a growing number of dairy farms with a projected annual increase of 20 to 30% AMS units in the coming years.

Remote-sensing based framework for farm-scale in-season crop yield forecast

Ying Sun, Assistant Professor, CALS, SIPS; Carla P. Gomes, Professor, CIS, CS; Ariel Ortiz-Bobea, Assistant Professor, SC Johnson College of Business (JCB), Dyson School of Applied Economics and Management (Dyson).

Despite decades of efforts for crop yields estimation using remote sensing techniques, reliable yield forecast that can resolve within field variability at sufficient lead time (before harvest), which is critical for crop management, risk management in light of climate shocks, and insurance
decisions, has yet to be established. Rapid advances in sensing technologies from ground to satellite, machine learning algorithms, cloud computing capability offers opportunities for

tackling this challenge. This proposal aims to develop scalable, field-scale, in-season forecast approaches for crop yield at low cost by synergistically integrating these new technological advances, including UAV/satellite remote sensing of Solar-Induced Chlorophyll Fluorescence (SIF) and hyperspectral reflectance, the state-of-art mechanistic crop growth models, and machine learning techniques. We propose to develop both process- and statistics-based approaches for yield forecast and examine their complementary strengths for large-scale operational application. We will finally build a Google Earth Engine based web portal to report yield forecast on weekly basis to inform farmers, agribusinesses, and extension agents in nearreal
time. We will seek input and feedbacks of our developed framework from local farmers via Cornell Cooperative Extension and New York Corn and Soybean Grower Association during the course of the project.

2019 CIDA Research Innovation Fund Summer Stipend Recipients:

Digital Tools for Systems Analysis and Data Analytics of Biomass Pyrolysis in Agriculture
Ning Zhao (PhD candidate), COE
Primary Advisor – Fengqi You, COE; Secondary Advisor – Johannes Lehman, CALS

Biomass is a promising source of renewable energy with eco-friendly characteristic receiving great attention especially in Digital Agriculture communities. Biomass pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen. Depending on the final temperature and reaction time, pyrolysis technologies can be classified into two types: slow pyrolysis and fast pyrolysis. The yields as well as the physical and chemical characteristics of the products vary considerably according to the types of pyrolysis technologies. This research project is to study the environmental impact of spatial analysis of biomass processing considering specific pyrolysis technologies under economic and environmental criteria. By performance life cycle and techno-economic analysis/optimization biomass supply chains, we leverage data science and systems engineering methods with agricultural systems. We adopt life cycle optimization method to balance both the techno-economic and life cycle environmental impact objectives. Two major activities of my work are life cycle assessment and systems modeling. In life cycle assessment, we evaluate the global warming potential (GWP) of different pyrolysis technologies using existing technology data and Ecoinvent V3.5. In problem modeling, a bi-objective optimization model is formulated in order to balance the economic and environmental objectives.

Internet of Dirt
Jennifer Liu (PhD candidate), CIS, A&S
Primary Advisor – Steve Jackson, CIS; Secondary Advisor – Phoebe Sengers, A&S

Abstract: In recent years, Internet of Things (IoT) infrastructures have expanded into the field of agriculture. Some of the applications for IoT in this context includes precision agriculture, livestock monitoring, and smart greenhouses. While these systems are designed in specific ways to fit their environment, they may degrade and fail in unexpected ways that require replacement and repair. In this research, I will study the maintenance of IoT infrastructures in the context of agriculture through 1.) conducting ethnographic field work and 2.) generating design implications for future IoT systems for agriculture. Over the course of the summer, I will examine the interactions between farmers, technicians, IoT infrastructures, and the

environment as a way to understand how these systems are maintained across different field sites. These field sites will build upon existing collaborations with CIDA, and will include farms that have implemented IoT systems. The fieldwork methods will include participant observation, semi-structured interviews, and design probes as a way of gaining key insights on how these IoT systems are maintained. I will then generate design implications by identifying mismatches between practices at the field sites and current design directions as a way suggest how systems could better meet the needs of the farms. These design implications will support the development of future development of IoT systems for agriculture at local, regional, and global scales.

ReproPhone and e-Synch: Novel Tools to Automate and Optimize Cattle Reproductive Management

Magdalena Masello Souza (PhD candidate), CALS
Primary Advisor – Julio Giordano, CALS; Secondary Advisor – David Erickson, COE

Abstract: Main goals are to develop; 1) e-Synch; an intravaginal reusable device to automate synchronization of ovulation and monitor physiology of cows and 2) ReproPhone; a user-friendly, rapid, low-cost tool to determine pregnancy and ovarian status of cows on-farm. The e-Synch consists of an electronically controlled device loaded with products to synchronize ovulation and sensors to monitor cow activity and temperature. Briefly, user inserts e-Synch and selects desired treatment with a mobile app. Next, e-Synch automatically delivers hormones required for the selected protocol. Once protocol is completed, e-Synch is removed and the cow is inseminated. On the other hand, ReproPhone consists of a lateral flow immunoassay (LFIA) to quantify circulating reproductive hormones coupled with a portable imaging device connected to a mobile app. Specific activities: 1) Evaluate efficacy of e-Synch. Conduct field trials to evaluate the ability of current prototype to deliver hormones used for synchronization of ovulation. Based on initial tests we will work with Dr. Erickson's group to improve the design and function of the device. 2) Optimize current LFIA. Currently our LFIA and reading system is designed to test plasma samples, which is not ideal for on-farm implementation, as samples need to be processed before testing. Therefore, I will work on modifying current format to measure hormones in unprocessed whole blood samples. Activities include laboratory experiments and on-farm testing.

Plant Vein Detection through Machine Learning and Computer Vision

Hannah Thomas (PhD candidate), CALS
Primary Advisor – Margaret Frank, CALS; Secondary Advisor – Bharath Hariharan, CIS

Abstract: Advances in computer science have led to programs capable of identifying plant parts (e.g. flowers and fruit). This project will utilize these advances to tackle the challenge of using computer vision and machine learning to identify leaf venation in plants. In addition to moving water and sugars through the plant, veins transport macromolecules (RNAs and proteins). My thesis is to visualize this movement; this project will focus on imaging this process. Aim 1) To analyze the shape of venation in the leaf, a water-mobile dye will be added to the roots, taken up by the xylem and carried into the leaves. In a healthy plant, this happens very quickly. The resulting leaves are then imaged under a fluorescent microscope. Analyzing the results are difficult due to a high amount of noise in the images. Traditional segmentation fails to quantify the amount of fluorescence in the leaves. Aim 2) To solve this problem, we will create an automated imaging pipeline for detection of fluorescence in leaves. I will develop a computer vision approach with Professor Bharath Hariharan (CS). This will require the generation of a training set (produced in aim 1) that teaches the computer how to "see" veins. After training, the program performance will be tested against human annotated images. A successfully trained program will be able to automatically detect the presence of fluorescence within dynamic plant veins. This tool will be made publicly available at http://www.plant-image-analysis.org/