1. Objectives/aims

With the advancements of machine learning and artificial intelligence in digital agriculture, especially the precision agriculture phenotyping sensors and tools. There is a gap between HBCU (Historically Black Colleges and Universities) education, research, outreach, and the advances in precision agriculture phenotyping technologies. Florida Agricultural and Mechanical University (FAMU) is an 1890 land-grant institution (#1 Public HBCU by U.S. News & World Report) dedicated to the advancement of knowledge, resolution of complex issues and the empowerment of citizens and communities. As the land-grant arm of FAMU, the College of Agriculture and Food Sciences (CAFS), **PI Chen**'s home college, plays a vital role in providing researched-based information and resources directly to Florida's farmers, individuals, producers, communities, and agri-businesses. FAMU CAFS Center for Viticulture and Small Fruit Research is recognized internationally for excellence in warm climate grape research and facilitator of outstanding academic programs for experiential learning and student training. Viticulture Center maintains the most extensive muscadine grape germplasm collection in the world and is serving as one of the five National Clean Plant Centers for Grapes. The Biological Systems Engineering (BSE), **PI Chen**'s home program, is a branch of engineering which integrates agricultural, biological, chemical, and engineering sciences. The BSE program is one of the two ABET (Accreditation Board for Engineering and Technology) accredited BSE programs among the nineteen 1890 HBCUs in the U.S. Currently, there is a critical need for CAFS especially BSE program to develop education, research, and extension training on precision agriculture phenotyping tools.

To address this need, this project aims to develop education, research, and extension training on precision agriculture phenotyping tools at HBCU, by coordinating and enhancing available educational resources from top R1 institutions and determine best approaches for expanding cross-disciplinary training in plant phenotyping data collection, sharing, and analysis. **We propose six objectives:**

(1) To develop educational materials focused on plants phenotyping tools applications, data collection (sensors, cameras, and smart phones), data sharing, and image processing. The educational materials will cover four modules:

Module 1 Develop image processing algorithm to estimate grapevine canopy using RGB images

Canopy cover (CC) directly relates to crop water use, yield (Westgate et al., 1997), disease, and weed development (Ma et al., 2001). Rapid canopy development in crops leads to greater biomass accumulation, greater yield potential, and the fully CC suppresses early season weed. We propose to use 4 muscadine grape (Muscadinia sp.) wine cultivars (2 red: 'Noble' and 'Floriana'; 2 white: 'Carlos' and A-27-10) at the 2 phenological stages: 'mature leaf' and 'mature berry' at Viticulture Center for students and researchers training, guided by **Co-PI Tsolova**. Sweet basil and strawberry are alternative plants to study. We will first develop image processing algorithm to estimate CC percentages. First, grape images with different growing stages will be taken using digital cameras and will be utilized for training image recognition algorithm. Image will be digitized by scanning each pixel, outputting pixel brightness, red, green, and blue color space values, green leaf areas (number of pixels), and background (e.g., soil, shadow) areas (number of pixels). After recognition by the algorithm, each image will output the percentage of leaf area, which is assumed as percentage of CC. To validate the accuracy of the algorithm, in addition to CC images, leaf area index will also be manually measured (Li-COR LAI-2000, Li-COR Inc., NE, USA) each week. Accuracies of the algorithm will then be calculated. Similarly, the grape pixels will be estimated using proposed recognition software. Similar canopy recognition software was developed by **Co-**

PI Liang (Liang et al. 2018, and Liang et al. 2021). The relationship between leaf area index, canopy cover, grape pixel numbers and grape yield will be examined.

Module 2 Website development for users to upload images from digital camera/smart phone and calculate canopy cover automatically Users, including students, researchers, growers, and so on, can upload pictures taken from their smart phones or cameras to capture progressing of canopy cover percentage using in-housed developed recognition algorithm (module 1) at reporting website (http://phrec-irrigation.com) (Figure 1). Percentage of CC and grape pixel numbers can be analyzed and displayed at website. As users upload pictures of crop canopy, it also allows extension professionals to visually examine grapevine growth and yield.

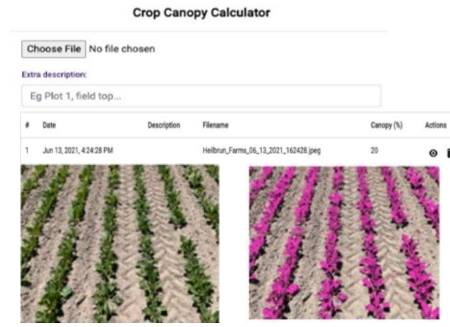

Figure 1. User uploaded a RGB image of sugar beet canopy from smart phon. Canopy cover was computed by server and canopy cover was 20%. Raw and processed images were archived in cloud server.

Module 3 Introducing hyperspectral imaging technologies for plant phenotyping Hyperspectral imaging (HSI) technology has been increasingly applied in plant phenotyping projects at different scales from plant tissues, whole plants, to canopy levels. It is mainly because HSI has great potential in measuring plant responses to various abiotic and biotic stresses at an earlier stage before being visible to human eyes. Most current HSI systems are expensive and their signal quality is compromised by various noise factors, such as the changing ambient light, leaf slopes, and so on. In 2017, the "LeafSpec" handheld hyperspectral leaf imager was developed at Purdue, leaded by **Co-PI Jin**, which overcomes most of the noise challenges (Wang et al.). The "LeafSpec" device had an enclosed imaging chamber and uniform light sources to ensure the fixed imaging distance, angle, and lighting intensity on each leaf sample. In addition, "LeafSpec" has an improved measurement quality with both high spectral (~1.5 nm) and spatial (~0.2 mm) resolutions. The high resolution of hyperspectral leaf images enables the analysis of nutrient and stress distribution at the pixel/tissue levels. We propose to demonstrate to the students and researchers that with HSI technology, how the grape leaf stressed can be potentially detected earlier. Examples of new HSI processing algorithms will also be introduced to explore the full potential of the "LeafSpec" hyperspectral imaging systems in both spectral and spatial dimensions.

Module 4 GIS server for geo-referenced imaging measurements Besides the website (module 2), we propose introducing advanced geospatial measurement data infrastructure to our students and researchers. We'll demonstrate Purdue's GeoEDF project sponsored by NSF from 2018 (Kalyanam et al.). With this facility, the imagers or smartphones can automatically upload geo-referenced and time-stamped measurement data to the server. The GeoEDF server provides automatic data management and result viewing functions. In this way the users will only need to focus on imaging and the process will not require additional efforts in data management. The server can further link the imaging measurements with other cloud data sources such as weather history and so on for further correlation analysis.

(2) To implement precision agriculture phenotyping course modules (obj. 1) for ABE 4034, Remote Sensing in Biological Systems Engineering in collaboration with cross-university experts in Fall 2022.

(3) To launch an undergraduate research training program on precision agriculture phenotyping tools and applications for Minorities in Agriculture, Natural Resources, and Related Sciences at HBCU (Cohort A in Fall 2022 and Cohort B in Spring 2023)

(4) To provide one-day activity (mini-lecture and field trip) on precision agriculture phenotyping tools topic at FAMU 4-H Youth Development Summer Camps (current target summer camp: AgriSTEM Summer Camp in July 2022 in collaboration with Ms. Newman).

(5) To organize one Field Day at Center for Viticulture and Small Fruit Research and/or FAMU greenhouse for general public especially for growers, producers to collect and analyze plant phenotyping data in Fall 2022.

(6) To adapt established educational materials and course modules as public educational resources for use by other scientific communities.

2. Furthering the aims of the AG2PI

This project seeks to establish education, research, and extension training on precision agriculture phenotyping tools at HBCU. It addresses the AG2PI priority areas including (1) identify best practices, tools, and techniques for AG2P data sharing and storage; (2) encourage cross-fertilization of existing or novel AG2P tools, data, or ideas; (3) coordinate available educational resources and determine best approaches for expanding cross-disciplinary training in AG2P data science and engineering. This project will make precision agriculture phenotyping tools and technology more accessible, particularly to those with limited resources, will engage HBCU that are currently underrepresented in AG2P, and will develop precision agriculture phenotyping tools and training activities tailored to multiple scientific communities and different career stages within AG2P. Success of this project will be measured based on the achievement of the six objectives (see section 1) and production of the tangible deliverables (see section 3)

3. Expected outcomes & deliverables

This project will produce four leading-edge precision agriculture phenotyping educational modules at HBCU: Module 1 develop image processing algorithm to estimate grapevine canopy using RGB images; Module 2 website development for users to upload images from digital camera/smart phone and calculate canopy cover automatically; Module 3 introducing hyperspectral imaging technologies for plant phenotyping; and Module 4 GIS server for geo-referenced imaging measurements. With these modules, PIs will showcase both easy-to-obtain and the most advanced imaging technologies to the audience to get people started in digital applications utilizing sensing and data infrastructure to improve the agricultural production efficiency.

Other tangible deliverables include: (1) enhanced ABE 4034 Remote Sensing in Biological Systems Engineering course with leading-edge precision agriculture phenotyping educational modules in collaboration with cross-university experts; (2) an undergraduate research training program on precision agriculture phenotyping tools and applications for Minorities in Agriculture, Natural Resources, and related sciences at HBCU; (3) Tailored public educational resources for underrepresented audiences including workshop and field day on precision agriculture phenotyping tools topic for FAMU 4-H Youth Development Summer Camp and for growers and producers to collect and analyze plant phenotyping data; (4) Publications that describe the established innovations in education, research, and extension trainings; and (5) this project will build solid foundation for future proposal development, e.g., climate-smart commodity. These again will catalyze AG2PI aims mentioned in section 2.

4. Qualifications of the project team

Dr. Jingqiu Chen (PI), Assistant Professor of Biological Systems Engineering in the College of Agriculture and Food Sciences at Florida A&M University, is the lead instructor of

ABE 4034 Remote Sensing in Biological Systems Engineering course and she is passionate about AG2P education, research, outreach, and training at all levels. She devoted herself to creating a diverse, inclusive, and equitable AG2P education at HBCU. Her expertise includes environmental and natural resources engineering, data science, and digital agriculture. **Dr. Wei-zhen Liang (Co-PI)** is a Research Assistant Professor in the Departments of Biological Systems Engineering at the University of Nebraska-Lincoln. She has a rich set of experiences related to the precision agriculture in cropping system and livestock management, including image analysis, website development, data mining and processing, and IoT in modern agriculture. **Dr. Jian Jin (Co-PI)** is an assistant professor from Agricultural and Biological Engineering Department of Purdue University, who is an expert in sensor development. Prior to joining Purdue, he conducted research at DuPont Pioneer (now Corteva), where he was most recently a Technology Leader working on automatic phenotyping and sensing and led a team for the company's hyperspectral imaging systems for automated plant screening. His major research interest at Purdue is to build the next generation automatic crop plant phenotyping systems, along with machine vision, data processing, statistics, and big data modeling. He also has interests in other areas of agricultural sensing, broadly defined, and in automation and robotics in agriculture. **Dr. Violeta M. Tsolova (Co-PI)**, Professor and Director of Center for Viticulture and Small Fruit Research in the College of Agriculture and Food Sciences at Florida A& M University, has expertise in plant genetics, plant physiology, biology, plant biotechnology, cell culture, bioinformatics, and computational biology. **Ms. Conchita Newman (Collaborator)**, Extension Agent and Program Leader of 4-H Youth Development at FAMU CAFS Cooperative Extension Program, has a proven track record of innovative cross-functional team leadership on outreach and extension activities.

5. Proposal timeline

Objective	22 6-8	22 9-12	23 1-5
Develop educational material: 4 modules			
Implement precision agriculture phenotyping modules for ABE 4034 Remote Sensing in BSE collaborating with cross-university experts			
Provide workshop and field day on precision agriculture phenotyping tools topic at FAMU 4-H Youth Development Summer Camps (promoting youth education in AG2P field)			
Launch an undergraduate research training program on precision agriculture phenotyping tools and applications for Minorities in Agriculture, Natural Resources, and Related Sciences at HBCU			
Organize one Field Day at Center for Viticulture and Small Fruit Research and/or FAMU Greenhouse for general public especially for growers, producers to collect and analyze plant phenotyping data.			
Adapt established educational materials and course modules as public educational resources for use by other scientific communities.			

6. Engaging AG2P scientific communities & underrepresented groups

The developed education materials will be directly used to train HBCU undergraduate students, K-14 students mainly from underrepresented groups, growers, producers, and so on. The training modules will be made available to anyone who will be interested in AG2PI filed.

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