Nominating Region: South

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Project or Committee Number and Title: S1069 Research and Extension for Unmanned Aircraft Systems (UAS) Applications in U.S. Agriculture and Natural Resources

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PROJECT SUMMARY

Issue, problem or situation addressed. The use of unmanned aerial systems (UAS) in agriculture and natural resources was in its infancy until this group was formed, and substantial development was needed to enable routine use in research and commercial production. Biotic and abiotic stresses are key limiting factors in crop and animal production, and in managed ecosystems. Characterizing response to environmental conditions in these focus areas is critical to maximize resilience and productivity in managed agricultural systems. Remote sensing with UAS has potential to characterize crops, animals, forests, estuaries, and their various stresses at much higher resolution than previously possible. *However, the value of UAS in agricultural systems is predicated on continued research and Extension that demonstrates reliable systems and viable workflows that provide optimum return on investment.* Scalable methods with broad applicability across multiple fields, crops, times, and regions are essential to exploiting the benefits of UAS in production agriculture. While UAS data collection is becoming more common in agronomic research, a perennial need remains for advances in the breadth, accuracy, and repeatability of measurements to enable positive economic impacts in US agriculture. These impacts will require a wider knowledge base, consistent protocols, and metadata standardization. This multistate research and Extension group leverages its strengths to address such concerns.

Objectives. (1) Determine the optimal spatial, temporal, and spectral resolution needed for actionable decisions from farmers (economic) and researchers (discovery) for the following specific applications: a) High-throughput field-based phenotyping; b) crop management; c) livestock management; d) forest management; (2) Test applications of UAS in specific real-world, production agriculture situations in multiple locations to determine: a) appropriate platforms and sensors; b) methods of calibration; c) detailed protocols for specific applications; d) appropriate data management strategies; e) benefits to researchers and end users; (3) Use UAS to detect stress and determine stressors in plants and related ecosystems to: a) develop a broader understanding of how UAS-based sensors can be used to detect biotic and abiotic stressors of plants and related ecosystems; b) develop models and calibration techniques that relate UAS-derived sensor data to the ground-truthed data; c) deliver the best measurement standards for detecting stress in plants and related ecosystems; and (4) Develop sustainable, decision-making information across geographic scales and locations.

Accomplishments. When S-1069 was conceived, university researchers had multiple challenges to acquire and utilize a UAS. Before major changes in FAA guidelines in 2016, research programs needed licensed pilots, medically certified visual observers, and government authorization permitting flight in only specified areas. Regulations were also strict regarding use of UAS for non-research applications including education, Extension, and private use. Against this backdrop, a multistate research project was created to leverage strengths that could advance this field. Since then, the members of S-1069 have met the project objectives during the five-year reporting period which ended September 30, 2021, with the following wide-reaching ***outputs***:

- Over 100 peer-reviewed publications, including 4 book chapters, on UAS to share knowledge and progress (includes 70% of the affiliated units). The breadth of publication was wide, including 45 journals targeting a variety of disciplines and audiences. Almost 20% of the articles appeared in Remote Sensing (IF > 4.0) and Frontiers in Plant Science (IF > 5.7).
- At least 30 grants with over $35M in competitive funding for research and Extension with UAS, including multi-university awards, with at least five multistate proposals, three of which were funded, resulting directly from this project (includes 50% of the affiliated units).
- A series of conferences hosted through the International Society for Optics and Photonics (SPIE) on unmanned systems for agricultural optimization and phenotyping, as well as technical sessions at meetings of the American Society of Agricultural and Biological Engineers (ASABE), the tri-societies (i.e., ASA, CSA, SSSA), the Phenome series of conferences (now NAPPN, North American Plant Phenotyping Network), and conferences hosted by the International Society for Precision Agriculture (ICPA).
- Extension programs on UAS and production of Extension materials, including multi-university led workshops on UAS, with at least one workshop held outside the US.
- Creation of digital media in the form of publicly accessible websites, training videos, tools, and datasets that build capacity for future UAS research, Extension, and education.
- Contribution to popular press articles on UAS to educate non-technical users on the status and potential of UAS for current and future applications in agriculture and natural resources.

Selected ***short-term outcomes*** that demonstrate cross-state interests and project breadth include:

- New technologies for scouting and treatment of pests in fruit and nut industries to boost production while maintaining high-quality products. Pests represent significant challenges in these industries and these challenges are exacerbated by declining labor availability, international competition, and increasing consumer demand for improved quality and reductions in chemical inputs, so UAS scouting technologies are critical. (GA and WA)
- New methods that rely on UAS for monitoring and maintaining water resources to reduce risks to humans. The risk posed by poor water quality in aquaculture can be reduced through large-scale UAS monitoring. The risk posed by flooding is addressed by higher-resolution inputs for hydrodynamic models generated from UAS data. These model outputs can also guide land managers in targeted placement of conservation practices. (NC, VA, and MS)

Selected ***medium-term outcomes*** that demonstrate a change in behavior include:

- New approaches to pastured livestock management including detection of stray herds, 3D rendering of animals to calculate market value, and forage quality assessment (KY and MS).
- New training opportunities for forest land managers to utilize UAS in operations for less labor-intensive estimation of stand and merchable value of timber (e.g., DBH). (AL and FL)

Selected ***long-term outcomes*** that demonstrate a change in condition include:

- New tools and approaches to evaluate the responses of various genotypes to associated stresses and new approaches such as phenomic selection. Breeding research programs around the country increasingly use UAS for high throughput phenotyping. A *change of condition* is evidenced by the (now common) knowledge that UAS can replace the previously laborious effort to measure plant height[1]. This change has enabled a substantial increase in the number of genotypes considered by breeders[2], leading to more accurate selections and advances in crop improvement. The resultant ***benefit*** is that improved cultivars are among the most economically and environmentally beneficial. (VA and TX)

Selected ***social benefits*** that demonstrate a contribution to the broader public include:

- Provision of UAS-collected 3D models of native American historical sites to tribal members following destruction of the site near Stephen F. Austin State University by an EF2 tornado. The 3D model serves as the basis for reconstructing the damaged property. Survivors were provided smaller 3D-printed models as a means to connect those afflicted by the event to the historical sites. (TX)
- Application of skills and knowledge to global issues such as water insecurity, as evidenced by provision of UAS training to programs such as Engineers without Borders. (AL)

Added-value and synergistic activities across mission areas. S-1069 members have varied specializations (e.g., agronomy, agricultural engineering, crop breeding, animal science, remote sensing, and computer science), a fact that has resulted in ***multi-disciplinary activities*** like developing hardware-software systems and protocols to maximize data accuracy for capturing plant and animal health attributes including canopy reflectance, plant/tree height, and plant canopy and animal temperature. ***Multi-institutional synergy*** is demonstrated in the sharing of tools between universities, for instance a 3D-printable custom UAS-payload mount for a commonly used payload, which could be printed for $12 versus $400 for the market option. ***Multi-function integration*** is demonstrated by the UAS User Log, a flexible, comprehensive, and user friendly digital log book developed for UAS operations. The multi-disciplinary expertise of members was critical to design a tool for both research and production agriculture. This multistate project has also been instrumental in assembling the human capital and expertise for UAS within and across universities, producing a network ready to respond to new challenges. Further, S-1069 members have aided in collaborative efforts with ANSI to find gaps in UAS technology standardization for crop protection and create the roadmap for new standards.

Evidence of multi-institutional and leveraged funding with examples of sources.

- *Enhancing accessibility, reliability, and validation of actionable information from unmanned aerial vehicle image data* (USDA NIFA award 2018-67021-27668, $473,430), MS/TX/IL
- *High intensity phenotyping sites: Transitioning to a nationwide plant phenotyping network* (USDA NIFA award 2020-68013-32371, $3M), MS/TX
- *RFID and Beyond: Using RFID, Drones, and BLE to improve plant inventory management* (Horticultural Research Institute, $35,000), AR/SC

These additional examples of non-funded proposals are presented to showcase the cross-university pursuits that have been made by the membership.

- *The spatial, temporal, and spectral parameters required for UAV agricultural applications* (submission to USDA NIFA), TN/LA/NC
- *Unmanned aerial systems in natural resources, toy or tool? An objective approach* (submission to USDA NIFA), MS/AL/TN/LA/AR

[1] https://doi.org/10.3390/s18124092

[2] https://doi.org/10.21203/rs.3.rs-1108535/v1, http://dx.doi.org/10.21203/rs.3.rs-954708/v1

Participating institutions and units

Auburn University (AL)
Arkansas Cooperative Extension
Cornell University (NY)
Clemson University (SC)
Louisiana State University
Mississippi State University
Montana State University
North Carolina State University
North Carolina Cooperative Extension
North Dakota Cooperative Extension
Ohio State University
Purdue University (IN)
Rutgers University (NJ)
Stephen F. Austin State University (TX)
Texas A&M AgriLife Research
University of Arkansas
University of Florida
University of Georgia
University of Illinois
University of Kentucky
University of Tennessee
Virginia Polytechnic Institute and State University
Washington State University