**Project/Activity Number: S1069**

**Project/Activity Title**: Research and Extension for Unmanned Aircraft Systems (UAS) Applications in U.S. Agriculture and Natural Resources

**Start Date**: 11/01/2021

**End Date**: 9/30/2026

**Period Covered**: 01/01/2021 through 5.26.2022

**Date of This Report**: 6.30.2022

**Annual Meeting Date(s)**: May 26-27, 2022

**Participants:**

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| --- | --- |
| Name | Institution |
| Maria Balota | Virginia Tech |
| Alex Thomasson | Mississippi State University |
| Joe Mari Maja | Clemson University |
| Joshua Jackson | University of Kentucky |
| Ramesh Sahni | Washington State University |
| Jake Schrader | Washington State University |
| Gajanan Kothawade | Washington State University |
| Lav Khot | Washington State University |
| Gary Roberson | NC State University |
| Jennifer Lachowiec | Montana State University |
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| Lee Tarpley | Texas A&M AgriLife Research |
| Randy Raper | Oklahoma State University |
| Max Feldman | USDA-ARS |
| Abhilash Chandel | Virginia Tech |
| Maitiniyazi Maimaitijia | South Dakota State University |
| Alex Fremier | Washington State University |
| Ulbado Torres | Texas A&M AgriLife Research |
| Bholuram Gurjar | Texas A&M AgriLife Research |
| Joby Czarnecki | Mississippi State University |
| Seth Murray | Texas A&M AgriLife Research |
| Kristian Nelson | Pacific Northwest National Laboratory |
| Sindhuja Sankaran | Washington State University |

**Brief summary of minutes of annual meeting:**  The Washington State University (Lav Khot) hosted the annual meeting in hybrid mode. Meeting was attended by 22 researchers. On Day-1 (May 26, 2022), members received welcome remarks from Dr. Scott Hulbert (Associate Dean for Research, WSU CAHNRS) and USDA-NIFA updates from Dr. Ganesh Bora (NPL for Precision Agriculture and Data Science). Each member then shared university updates on the type of research and extension activities they have been conducting over the past 1-year. After the lunch, industry folks (MicaSense Inc., WA; Pix4D Inc., CA) provided an overview of their products such as new optical sensors, imagery mapping platforms and some application use-cases. Members also received perspectives from Mark Ledebuhr (Application Insight LLC, MI) on feasibility and future research needs on aerial chemical applications with UAS technology. Later part of the Day-1, we had a business meeting where several aspects related to renewed project scope and pertinent activities to be undertaken in 2022-23 were discussed/brainstormed. Jennifer Lachowiec from Montana State University was elected as secretary for the group and Maria Balota from Virginia Tech will be hosting the group in 2023. Day-2 (May 27, 2022) was field tours exploring WA tree fruit production systems, visit to WSU smart orchard at Prosser, WA and also the drone platform/sensors, and aerial spraying DEMOs from academia and industry.

**Accomplishments:** In 2021, this multi-state project was renewed with a new set of objectives. Members have accomplished most of the set milestones in old S1069 as can be seen in the meeting minutes and reported publications. In the annual meeting, we discussed milestones of new S1069 and formulated strategies and groups to realize those milestones. Please see the specifics as below.

(2022): Two or more multistate research teams focused on common (use-case inspired), specific, fundable research topics.

1. Plant phenomics (Team: Alex Thomasson/Seth Murray, Researchers in Nebraska are already exploring the collaboration)
2. Animal health (Team: Joe Mari Maja/Joshua Jackson, Joby Czarnecki, Lav Khot to meet and discuss)

(2022): Two or more multi state extension teams focused on common, specific, training material topics.

1. Remote Sensing for crop monitoring: (Team: Maria Balota to lead with Joshua Jackson, Abhilash Chandel)
2. Drone spraying/spreading & economics: Row, field and perennial fruit/berry crops (Team: Joshua Jackson to lead, Joby Czarnecki, Joe Mari Maja, Muthu Bagavathiannan, Lav Khot to meet and discuss)

(2022): Completed needs assessment for research based on survey of researchers and practitioners in the field of UAS in agriculture and natural resources.

1. Jennifer Lachowiec/Max Feldman to share work in Potatoes and do additional needs assessment in other crops with the team's help.

(2022): Completed needs assessment for formal classroom instruction and extension/outreach training materials based on survey of extension personnel and practitioners in the field of UAS in agriculture and natural resources.

1. Team: Maria Balota/Abhilash Chandel: Grower focused education material needs?
2. Team at Mississippi State University: High school educational material; Graduate course in Remote Sensing w/drones.

**Impacts:** UAS tools remain a novel and growing component of agriculture and agricultural research and even this multistate project is relatively new. To date, the primary impacts have been in members initiating new methods and approaches after learning about what other members have done (impact in knowledge and research direction). These new methods and approaches have also led to ideas and submissions for new funding and competitive grants (impact in funding). The members of this multistate project have given many presentations and had numerous peer reviewed publications, some of which have created additional impacts that remain unable to be documented to date. The most accepted metric of scientific impact is citations, the recent year publications related to this project have totaled 85 citations (in less than a year after publication) according to Google Scholar as of July 15, 2022. Furthermore, some of the media/industry magazine articles published by members reached thousands of readers (e.g., ASABE Resource Magazine reaches to members in more than 100 countries and to 500 libraries and other institutions).

**Publications:**

1. Aaron J DeSalvio, Alper Adak, **Seth C Murray**, Scott C Wilde, Thomas Isakeit (2022) Phenomic Data-Facilitated Rust and Senescence Prediction in Maize Using Machine Learning Algorithms. Scientific Reports 12:7571 <https://doi.org/10.1038/s41598-022-11591-0> *(0 citations)*
2. Abdulai, G., **Sama, M.P.**, **Jackson, J.J**. 2021. A Preliminary Study of the Physiological and Behavioral Response of Beef Cattle to Unmanned Aerial Vehicles (UAVs). Applied Animal Behavioral Science. Vol. 241, 105355. <https://doi.org/10.1016/j.applanim.2021.105355>.*(3 citations)*
3. Abenina, M., **Maja, J.M.**, Melgar, J.C., Cutulle, M., Liu, H. Prediction of Potassium in Peach leaves using hyperspectral imaging and multivariate analysis. MDPI AgriEngineering Special Issue: Hyperspectral Imaging Technique in Agriculture. 4(2), 400-413.<https://doi.org/10.3390/agriengineering4020027> *(0 citations)*
4. Adak, Alper, **Seth C. Murray**, Sofija Božinović, Regan Lindsey, Shakirah Nakasagga, Sumantra Chatterjee, Steven L. Anderson, and Scott Wilde. 2021. Temporal Vegetation Indices and Plant Height from Remotely Sensed Imagery Can Predict Grain Yield and Flowering Time Breeding Value in Maize via Machine Learning Regression. Remote Sensing, 13(11), 2141. <https://doi.org/10.3390/rs13112141> *(7 citations)*
5. Ahmad, A.1, **Saraswat, D.**, Gamal, A. E., & Johal, G. (2021). CD&S Dataset: Handheld Imagery Dataset Acquired Under Field Conditions for Corn Disease Identification and Severity Estimation. *arXiv preprint arXiv:2110.12084*  (1 citation)
6. Ahmad, A1, **Saraswat, D.,** Etienne, A.1, Aggarwal, V.1, & Hancock, B.3**(**2021).Performance of Deep Learning Models for Classifying and Detecting Common weeds in Corn and Soybean Production Systems. Computers and Electronics in Agriculture, 184.<https://doi.org/10.1016/j.compag.2021.106081> (21 citations)
7. Chandel, A. K., B. Molaei, **L. R. Khot**, R. T. Peters, C. O. Stöckle, and P. W. Jacoby. 2021. High-resolution spatiotemporal water use mapping of surface and direct-root-zone drip irrigated grapevines using UAS-based thermal and multispectral remote sensing. *Remote Sensing*, *13, 954.* <https://doi.org/10.3390/rs13050954> *(5 citations)*
8. Chandel, A.K., **L.R**. **Khot**, and B.C. Sallato. 2021. High resolution spectral imaging for detection and mapping of powdery mildew infestation in the apple orchards. *Scientia Horticulturae,* 287, 20110228. <https://doi.org/10.1016/j.scienta.2021.110228> *(did not find)*
9. Chandel, A.K., M.M. Moyer, M. Keller, **L.R. Khot,** and G-A. Hoheisel. 2022. Soil and climate GIS data-derived risk mapping for grape phylloxera in Washington state. *Frontiers in Plant Science (Accepted)*. <https://doi.org/10.3389/fpls.2022.827393> *(1 citation)*
10. Etienne, A.1, Ahmad, A.1, Aggarwal, V.1, & **Saraswat. D. (**2021).Deep learning-based object detection system for identifying weeds using UAS imagery. Remote Sensing, 13(24), 5182;<https://doi.org/10.3390/rs13245182> (3 citations)
11. Fernandez-Figueroa, E., A.E. Wilson, **S.R. Rogers**. 2022. Commercially available unoccupied aerial systems for monitoring harmful algal blooms: a comparative study. *Limnology and Oceanography: Methods.* <https://doi.org/10.1002/lom3.10477> *(2 citations)*
12. Lane, Holly, **Seth C. Murray**. 2021. High throughput can produce better decisions than high accuracy when phenotyping plant populations. Crop Science <https://doi.org/10.1002/csc2.20514> *(8 citations)*
13. Lee, H.-S., B.-S. Shin, **J. A. Thomasson**, T. Wang, Z. Zhang, and X. Han. 2022. Development of Multiple UAVs collaborative driving system for improving field phenotyping. Sensors (in press); <https://doi.org/10.3390/s22041423> *(0 citations)*
14. Matias, F.I.; Green, A; **Lachowiec, J**; LeBauer, D.S.; **Feldman, M**. Bison-Fly: An open-source UAV pipeline for plant breeding data collection. *The Plant Phenome Journal (Accepted)*. [https://doi.org/​​10.1002/ppj2.20048](https://doi.org/%E2%80%8B%E2%80%8B10.1002/ppj2.20048) *(did not find)*
15. Molaei, B., A. Chandel, R.T. Peters, **L.R. Khot**, and J.Q. Vargas. 2021. Investigating lodging in Spearmint with overhead sprinklers compared to drag hoses using the texture feature from low altitude RGB imagery. *Information Processing in Agriculture,* <https://doi.org/10.1016/j.inpa.2021.02.003> *(1 citation)*
16. **Prince Czarnecki, J. M.**, Samiappan, S., Zhou, M., McCraine, C. D., Wasson, L. L., 2021. Real-time automated classification of sky conditions using deep learning and edge computing. Remote Sensing 13(19):3859.<https://doi.org/10.3390/rs13193859> *(1 citation)*
17. Prior, E.M.G, C.A. AquilinaG, J.A. Czuba, T.J. Pingel, and **W.C. Hession** (2021), Estimating Floodplain vegetative roughness using drone-based laser scanning and structure from motion photogrammetry. Remote Sensing, 13, 2616. [doi/10.3390/rs13132616](https://www.mdpi.com/2072-4292/13/13/2616) (3 citations)
18. Quino, J.; **Maja, J.M.**; Robbins, J.; Fernandez, R.T.; Owen, JS Jr.; Chappell, M. RFID and Drones: The Next Generation of Plant Inventory. AgriEngineering 2021; 3(2):168-181.<https://doi.org/10.3390/agriengineering3020011> *(3 citations)*
19. Quino, J.; **Maja, J.M.**; Robbins, J.; Owen, J., Jr.; Chappell, M.; Camargo, J.N.; Fernandez, R.T. The Relationship between Drone Speed and the Number of Flights in RFID Tag Reading for Plant Inventory. Drones 2022, 6, 2.<https://doi.org/10.3390/drones6010002> *(0 citations)*
20. Resop, J.P., L. Lehmann, and **W.C. Hession** (2021), Quantifying the spatial variability of annual and seasonal changes in riverscape vegetation using drone laser scanning. Drones, 5, 91. [doi/10.3390/drones5030091](https://www.mdpi.com/2504-446X/5/3/91) (1 citations)
21. **Rogers, S.R**., K. Singh, A. Mathews, A. Cummings. 2021. Drones and Geography: who is using them and why? *The Professional Geographer*. <https://doi.org/10.1080/00330124.2021.2000446> *(0 citations)*
22. Sarkar, S., Cazenave, A-B., Oakes, J., McCall, D., Thomason, W., and **Balota, M.** 2021. Aerial high-throughput phenotyping of peanut leaf area and lateral growth. Sci. Reports (2021) 11:21661. <https://doi.org/10.1038/s41598-021-00936-w> (3 citations)
23. Sinha, R., J. Quiros Vargas, **L. R. Khot** and S. Sankaran. 2021. High resolution aerial photogrammetry based 3D mapping of fruit crop canopies for precision inputs management. *Information Processing in Agriculture,* <https://doi.org/10.1016/j.inpa.2021.01.006>. *(4 citations)*
24. Sinha, R., **Lav R. Khot**, Z. Gao, and A. K. Chandel. 2021. Sensors III. Spectral sensing and data analysis. In *Karkee & Zhang (Eds.),* Fundamentals of agricultural and field robotics, Springer Nature, Switzerland AG [https://www.springer.com/us/book/9783030703998](https://urldefense.com/v3/__https:/www.springer.com/us/book/9783030703998__;!!JmPEgBY0HMszNaDT!9Zdq5S4bomz7vvFJ0UcjD0Fwl6S0LKak5DR7RDJF9zvvAfpcQfq_aAjKbacqXi_X$). *(0 citations)*
25. Sumnall, M.J., Albaugh, T.J., Carter, D.R., Cook, R.L., **Hession, W.C.**, Campoe, O.C., Rubilar, R.A., Wynne, R.H., & Thomas, V.A. (2022), Effect of varied unmanned aerial vehicle laser scanning pulse density on accurately quantifying forest structure. International Journal of Remote Sensing, 43:2, 721-750. [doi/10.1080/01431161.2021.2023229](https://www.tandfonline.com/doi/abs/10.1080/01431161.2021.2023229) (1 citations)
26. Sumner, Z., Varco, J. J., Dhillon, J. S., Fox, A., **Czarnecki, J.**, Henry, W. B., 2021. Ground versus aerial canopy reflectance of corn: red-edge and non-red-edge vegetation indices. Agronomy Journal 113:2782–2797.<https://doi.org/10.1002/agj2.20657>*(3 citations)*
27. Wang, T., X. Mei, **J. A. Thomasson**, C. Yang, X. Han, P. K. Yadav, and Y. Shi. 2021. GIS-based volunteer cotton habitat prediction and plant-level detection with UAV remote sensing. Comput. Electron. Agric. 193(1):106629; <https://doi.org/10.1016/j.compag.2021.106629> *(2 citations)*
28. Wilber, A., McCurdy, J.D., **Prince Czarnecki, J.M.**, Stewart, B.R., Dong, H., 2022. Aerial and ground-based assessment of preemergence herbicide effects on St. Augustinegrass grow-in. International Turfgrass Society Research Journal 14(1):812-814.<https://doi.org/10.1002/its2.79> *(0 citations)*
29. Wilber, A.L., **Czarnecki, J.M.P.**, McCurdy, J.D., 2022. An ArcGIS Pro workflow to extract vegetation indices from aerial imagery of small-plot turfgrass research. Crop Science 62(1):503-511.<https://doi.org/10.1002/csc2.20669>*(1 citation)*
30. Wu, W., S. Hague, M. M. Maeda, J. A. Landivar, A. Chang, D. Jones, J. Jung, A. Ashapur, A. B. Maeda, and **J. A. Thomasson**. 2021. Cotton row spacing and unmanned aerial vehicle (UAV) sensors. Agronomy J.; <https://doi.org/10.1002/agj2.20902> *(0 citations)*
31. Young, S. et al., Robots in the air and on the water could improve shellfish farming. March/Apr 2022, Resource Magazine (ASABE) 22-23 (0 citations)
32. Young, S., J. Ore, **S. Hall**, 2022. The coming wave of aquatic robotics. Resource Magazine, Summer 2022, 13-14; <https://bt.e-ditionsbyfry.com/publication/?m=23718&i=752031&p=1&ver=html5> (0 citations)