**Respondents**

AB = Anju Biswas

AH = Atena Haghighattalab

AT = Alison Thompson

JL/MB = Juan Landivar and Mathendra Bhandari

KS = Keshav Singh

LK = Lav Khot

SM = Seth Murray

PG = Paco Gonzalez

MB = Matthew Blua

RP = Rolf Peters

IG = Ishai Gottlieb

**What are the largest bottlenecks to adoption?**

1. Multidisciplinary team is needed to run effective program. Lots of skills needed. Each person needs to get credit for the work they have performed. (AH, AB, SM, AT, JL/MB, PG)
   1. Drone pilot (PG, AB, AH, JL/MB)
      1. Pilot needs license
      2. Knowledge of data collection best practices
   2. Data analysis (AT, SM, AB, JL/MB, AH, LK)
      1. R and/or Python skills
      2. Statistics knowledge (spatial and temporal)
   3. IT/Data storage/Metadata (SM, JL/MB, AH)
      1. Huge amount of data is generated each flight, week, year, etc.
      2. What metadata to include for multi-year, multi-site, multi-program studies
2. Lack of affordable and easy to use equipment. Sensor integration challenges. (KS, LK, JL, PG, AT, RP)
   1. Drone and sensor integration. Mission planning software, etc. (KS, LK, RP)
   2. Cost of drone and sensor (AT, PG, AB)
   3. Lack of standard protocols for diverse sensor and drone combinations (KS, LK, JL/MB, RP)
3. Uncertainty about perceived value. (AT, PG)

**What are the most promising applications of drones in agriculture?**

1. Precision agriculture applications. (LK, PG, AT, JL/MB, AB, RP, MB, IG)
   1. Field scouting (PG, JL/MB, AT, RP, MB)
   2. Decision support tools (AT, LK, JL/MB, AB, KS, RP, MB, IG)
      1. Water, nutrient use/stress
      2. Crop management (pest/pathogen control, growth regulator application)
      3. Crop insurance estimates (hail damage, lodging, etc.)
   3. Spot application of pesticides/small molecules (LK, JL/MB, MB)
2. Crop phenotyping/Plant breeding (AB, LK, JL/MB, AH, KS, SM)
   1. Measure plant traits: plant emergence, vigor, maturity, height, above ground biomass, growth curve data, senescence, light canopy interception (KS, AH, JL/MB, AB)
3. Crop modeling/yield prediction (KS, SM, AH, JL/MB, LK, AT)
   1. Yield prediction (AH, SM, KS, JL/MB)
   2. Identify cause of plant stress (KS, AH)
   3. Resource use efficiency (KS, JL/MB, AT)

**What are the least promising applications?**

1. Complete automation of data collection we already perform well (AH, SM)
2. Still a lot to be proven in regards to genetic gain in plant breeding for some crops and estimation of accurate physiological parameters (AT).

**What are some things you wish you would have known before you began using a UAS?**

1. Use of ground control points (GCP) to denote field boundaries (LK, AT, KS, JL/MB)
   1. Best practices is generally 4 corners of the field with sometimes a 5th GCP in the middle. Folks who have RTK still use GCPs. (AT, KS, JL/MB)
2. Calibration for multispectral/hyperspectral sensors (AT, LK, KS, PG, AB, JL/MB)
   1. In some cases sensors are sold with calibration panels, in some cases they are not. In this cases calibration needs to be done in the lab (KS)
   2. In some cases can use a downwelling light sensor (DLS) to adjust for sun irradiance (KS)
3. Flight parameters for different sensor types (AB, LK)
   1. Time of day is important. Does not need to be solar noon but needs to be consistent (KS, AB)
   2. Flight speed, overlap, capture rate, altitude change by sensor type (AB)
   3. Can reduce data capture rate for thermal images (LK)
4. Learning to write computer scripts in a new language to communicate with colleagues (AH)
   1. Needed to learn to script in R and Python to communicate with breeding colleagues (AH)
5. Build a support team. Don’t try to do everything yourself (SM, AT, AH, JL/MB)

**What educational resources have you found most useful when developing your own skillset with UAS-based imaging?**

1. Hands on training with an experienced user. Find a collaborator with an incentive to work with you. Identify areas where unique skills apply to the same problem and apply knowledge (LK, SM, AH, AT, AB)
2. Technical documents and text books (LK, PG, AT, KS)
   1. Federal Aviation Administration resources, particularly Part 107 chapters 11 and 14 for flight basics (LK)
   2. Product manuals (LK, PG, AT)
   3. Text books and current literature (AB)
      1. “Introductory Digital Image Processing: A Remote Sensing Perspective” by John Jensen
3. Working groups, workshops, and conferences (SM, LK, AT, AH, AB)
   1. North American Plant Phenotyping Network (SM, AB, AH)
   2. International Plant Phenotyping Network (SM, AH)
   3. PhenomeForce workshop series (AB, SM, AH)
   4. S1069 Multi-state project (LK)
   5. Maricopa Phenomics workshop (AT)
   6. Australian Plant Phenotyping Facility (AH)
   7. Open Drone Data Processing Interest Group (SM)
   8. USDA SCINet Geospatial Research Working Group (AT)
4. Dedicated private courses (LK, PG, AT)
   1. University courses (LK)
   2. Coursera and LinkedIn for learning python and/or data processing (AT)
   3. FAA Part 107 certification training (PG)
5. Google for answers, code examples, YouTube (PG, AT)