Workshop Report

Emerging Technologies and Methods in Earth Observation for Agricultural Monitoring

February 13-15, 2018, United States Department of Agriculture, Beltsville Maryland

A joint workshop sponsored by Agriculture and Agri-Food Canada (AAFC), the United States Department of Agriculture (USDA),the NASA Earth Observations for Food Security & Agriculture Consortium (EOFSAC), and North American Tripartite Committee on Agricultural Statistics (NATCAS).

Venue: USDA National Agricultural Library in Beltsville Maryland (Washington, DC Metro Area)

Organizing Committee: Michael Cosh (USDA-ARS), Catherine Champagne (AAFC), Chris Justice (EOFSAC), Alona Bunning (EOFSAC), Robert Tetrault (USDA-FAS), Rick Mueller (USDA-NASS), Sarah Federman (USDA-OCS), Katie McGaughey (USDA-FAS), Alyssa Whitcraft (EOFSAC)

Report by Catherine Champagne (AAFC), Alona Bunning and Chris Justice (EOFSAC)

Executive Summary

This workshop brought together a number of North American and global partners interested in advancing the integration of agricultural research applications into operational monitoring systems and strengthening the institutional structures to enhance earth observation (EO) method development and utilisation. The meeting covered a broad range of advanced research in the area of crop type and crop area mapping, crop yield and crop growth stage estimation, emerging remote sensing retrieval methods (e.g., microwave soil moisture, solar induced fluorescence, rainfall estimation), new satellite missions, new techniques for downscaling, multi-sensor integration, cloud computing, field data collection and data processing. The meeting highlighted key needs to advance agricultural monitoring across a range of agricultural applications and the role of the new NASA EO for Food Security and Agriculture Consortium (EOFSAC) in developing and promoting new applications. The need for a stronger voice for agriculture in space mission planning was emphasized, and the GEO Global Agricultural Monitoring (GEOGLAM) initiative and EOFSAC may provide mechanisms to achieve this, with the upcoming NISAR mission as a near-term priority. Research priorities for global monitoring should emphasize use of EO for: yield modelling and forecasting, soil moisture estimation, synthetic aperture radar (SAR)-based monitoring, characterising crop phenology, monitoring pasture/rangeland productivity, small area crop mapping, field delineation, crop water use and stress, and assimilation in process-based models. The GEOGLAM Joint Experiment on Crop Assessment and Monitoring (JECAM) and USDA Long Term Agro-ecosystem Research (LTAR) sites provide an opportunity to establish benchmarking experiments for new data sets and methods. The Harmonised Landsat-Sentinel (HLS) project will provide pre-processed, high frequency, moderate resolution optical data and is seen as a near-term priority, with the need for multiyear time-

series and global coverage of croplands. The capacity to use newly available SAR data was seen as a gap, and an agricultural application training package will be developed through this community. Data continuity was identified as a critical requirement for operational monitoring. It was also recognized that to keep operational monitoring systems current, increased emphasis is needed to support workable pathways to more easily transition new and appropriate EO technologies and methods into the operational domain. Enhanced and more formal partnerships between agricultural monitoring agencies in North American should be explored by USDA, AAFC and SIAP, with enhanced coordination between LTAR and JECAM, through mutual participation by representatives from both communities. This partnership will continue to be built through future workshops and collaboration meetings.

Introduction

The objective of this meeting was to help advance the integration of new Earth observation (EO) technologies into operational agricultural monitoring, to develop partnerships between national agricultural agencies in Canada, the United States, Mexico, and to work collectively towards shared objectives of improving agricultural monitoring with the use of EO data. Agricultural monitoring using EO has advanced rapidly in recent years, with scientific, sensor and computational developments enabling improvements to monitoring and forecasting at national to global scales. Federal agencies in Canada and the US have collaborated on a number of these activities to work toward solutions to common scientific and operational monitoring goals. Internationally, the GEOGLAM initiative is focused on advancing the use of EO for operational agricultural monitoring at national, regional and global scales (www.geoglam.org).

The purpose of this meeting was to identify gaps and challenges for the operational user community; to share recent results from the research community relevant to operational agricultural monitoring using EO; to identify priority areas for operational research and development, as well as those approaching readiness levels suitable for transition to operational application; and to discuss plans for future collaboration towards a stronger US-Canada agricultural monitoring collaboration. The workshop also served to provide input to the USDA Emerging Technologies Team.

The first two days consisted of presentations and targeted discussion on operational user needs and recent results, emerging technologies, and methodologies, with an emphasis on those with high readiness levels for operational application in the areas of:

- Crop Land/Crop Area Mapping
- Crop Phenology and Crop Stage
- Crop Yield and Production
- New Data Inputs and Approaches
- Emerging Methods and Technologies

The third day consisted of two programmatic meetings focused on discussing and developing plans for future collaboration toward implementing a strong US-Canada agricultural monitoring research collaboration through the Joint Experiment on Crop Assessment and Monitoring (JECAM) (www.jecam.org). A separate meeting focussed on special topics for the North American Tripartite Committee on Agricultural Statistics (NATCAS) Geographic Information System and Remote Sensing Technical Committee.

The outcome of these meetings was an agreed-upon set of priorities where shared progress can be made on advancing the use of EO towards operational activities and for research and development.

Meeting Summary

<u>Opportunities and Gaps for Operational EO Monitoring of Agriculture</u>

The meeting was opened by **Seth Meyer** (Office of the Chief Economist, USDA), who emphasized the need for global information to support the World Agricultural Supply and Demand Estimates (WASDE) report, which is produced monthly in the United States for major crops globally and has a high impact on commodity prices worldwide. He emphasized the importance of EO and other information for providing objectivity in their data analysis, with the challenge that information used to inform their estimates needs to be reliable, timely and consistent. He emphasized that new technologies need to be tested over multiple seasons to determine how they can contribute to the analysis. **Chris Justice** (UMD, EOFSAC) presented the objectives of the workshop and gave programmatic overviews of the NASA Earth Observation for Food Security and Agriculture Consortium (EOFSAC) and the international GEO Global Agricultural Monitoring (GEOGLAM) Initiative. **Rick Mueller** (USDA National Agricultural Statistics Service (NASS)) identified their flagship products, including the Cropland Data Layer (CDL), the VegScape crop condition explorer, and yield forecasts of corn and soybean. He emphasized their need to: i) expand the number of crops being monitored to include small acreage crops, ii) include the use synthetic aperture radar (SAR) data in their monitoring system, iii) migrate to the cloud or cloud-like systems to enhance their data processing and analysis capacity, and iv) use EO data to monitor soil moisture. **Robert Tetrault** (USDA Foreign Agricultural Service (FAS)) outlined their monitoring of crop area, yield and production of 18 commodities in 166 countries, through a well-defined decision-making progress that allows for thorough testing of the impact of new data sets in their estimation. He emphasized the need for better understanding of the synergistic information available from multiple EO data sets and the need for historical data to provide contextual information, such as long term statistics on how conditions are changing. **Andrew Davidson** (AAFC, Agroclimate, Geomatics and Earth Observation (ACGEO) Division) highlighted their operational activities and how they are feeding user requirements into their satellite mission planning, and moving towards a collaborative hub for secure image processing in a cloud environment. **Frederic Bédard** (Statistics Canada, Agriculture Division) highlighted how as an agency they are trying to identify data sources (including EO, corporate data and insurance records) that could replace, as much as possible, the information traditionally collected through census and survey, to reduce the reporting burden from farmers. **Guillermo Martinez** (Servicio de Información Agroalimentaria y Pesquera

(SIAP) Agrifood and Fisheries Information Service) discussed EO-related activities at a range of spatial scales in Mexico, highlighting the monitoring they are doing with drones to develop livestock and fisheries statistics and the need for improved hydrometeorological information. **Glenn Bethel** (USDA FAS) highlighted the results of a US pan-agency satellite-needs working group, which showed that the most important criterion for satellite data is continuity, advocating for sensor improvements while maintaining temporal stability. This report has had an impact on future NASA mission planning.

Crop Land / Crop Area Mapping

Presentations in this session showed recent research advances on crop area estimation, field size estimation, early-season crop identification, fallow area mapping and development of cropland masks. **Matt Hansen** (University of Maryland, EOFSAC) presented a robust and scalable, statistically rigorous, global method for estimating crop area using multi-scale imagery and field-based sampling. Results were shown for the U.S., Brazil, Argentina, Pakistan and E. Africa. **Lin Yan** (South Dakota State University) showcased a generally applicable EO-based method for automated field boundary detection using time series Landsat WELD data for the U.S., the USDA CDL, and an innovative field delineation technique. **Rick Mueller** (USDA, NASS) (on behalf of Forrest Melton, NASA) presented their joint work to identify fields left fallow as a result of drought in California, which was successfully applied and used for reporting drought impacts and is now being tested in other states. **Pierre Defourny** (Université Catholique de Louvain, GEOGLAM) presented the automated ESA Sentinel-2 Agri products, which include cloud-free composites, vegetation health, cropland masks updated monthly and crop type maps. The tool used to generate these products is openly available. **David Johnson** (USDA, NASS) highlighted the importance of annual CDL crop masks for sub-setting EO data for more quantitative analysis. He noted that globally, the agricultural monitoring community has lagged in terms of providing authoritative information on where crops are present.

The discussion covered a number of topics with these key ideas receiving the most focus:

- The need for coarse resolution (250m-1km) data continuity through S-NPP and JPSS-1 VIIRS was highlighted. The relationship between MODIS and VIIRS data has been established and VIIRS is well-suited to provide dynamic data continuity. The VIIRS is currently not widely used but will need to be, as MODIS Terra and Aqua near the end of operations. VIIRS has slightly coarser spatial resolution than MODIS but pixel resolution is uniform across the scan.
- The need for science quality land products from NOAA in the JPSS-era was noted.
- The potential to rely on international data sources for coarse resolution data is limited, as Sentinel-3 was designed primarily for marine applications. However, it does provide a source of data with a morning overpass. It was noted that MODIS Aqua and both VIIRS instruments have a PM overpass.
- The existing moderate resolution data (10-60m) e.g. from Landsat do not have the temporal coverage or the global historical record to replace daily coarse resolution data. Although free access to Sentinel data and NASA's development of Harmonized Landsat and Sentinel 2 (HLS) data hold considerable promise for agricultural monitoring.
- A multi-scale approach to agricultural monitoring with EO is recommended.

Crop Growth Stage, Yield and Production

Ritvik Sahajpal (UMD, EOFSAC) described an Automated Crop Condition Assessment system that provides alerts for the GEOGLAM Crop Monitor with yield forecasts globally 2-3 months before harvest. He showed that improvements will likely come from better crop masks and the integration of other EO-derived data sets. **Mark Freidl** (Boston University) discussed methods to extract growth stage from harmonized Landsat-Sentinel 2 time series, highlighting: the difficulty in finding a stable fitting technique across all environments; the difficulty in translating remote sensing phenology to agronomic crop growth stages; and the need for field observations to further test and validate EO methods. **Nathan Torbick** (Applied GeoSolutions, EOFSAC) presented an open-access system developed for integrating Sentinel 1 data (C-Band SAR) and optical data for crop type, irrigation and crop stage mapping. **Belen Franch** (UMD, EOFSAC) presented improved within-season, crop production forecasts combining MODIS Difference Vegetation Index with growing degree day data. The model showed strong performance at national and sub-national scales for average and abnormal years. She also presented results for the historical MODIS and AVHRR record, validated for the US and Ukraine. **Sergii Skakun** (UMD, EOFSAC) discussed methods to downscale yield forecasts to the field scale using Harmonized Landsat-Sentinel 2 data that have been applied successfully to winter wheat in Ukraine and will be further developed and assessed globally. **Shibendu Ray** (Mahalanobis National Crop Forecast Centre, India and GEOGLAM) presented on high resolution crop forecasting in India the use of NDVI to develop a field sampling strategy for yield insurance index data. He highlighted the need for high resolution and microwave data to improve data coverage of small holder farms in cloudy regions. **Mutlu Ozdogan** and **Yanghui Kang** (University of Wisconsin-Madison) showed results from a study to produce in-season field level yield estimates in the US by integrating EO data into a light use efficiency model which can produce estimates three months in advance of the harvest. He emphasized the complexity in using simple models of peak vegetation growth to infer high crop yields, and the need for field level yield data to further develop and test these models.

The discussion on these sessions highlighted the following:

- The need for further evaluation of data assimilation of EO data into process-based models such as DSSAT. Traditional assimilation methods rely on remote sensing to states or fluxes, but not outcomes, such as crop yield. Yield estimates are an end product which has an estimate temporally, but only one truth per season, so the methodology for improving forecasting is more complex and further study is needed.
- The need for field level yield data for model testing and validation and the difficulty in obtaining these data was highlighted. Although such data are collected by the private sector, they often cannot be shared for privacy reasons, and data from the USDA Long Term Agro-ecosystem Research (LTAR) sites may not be representative of common agricultural landscapes and management practices. There may be more opportunity to obtain historical data. A community initiative would be needed to provide data on a less ad-hoc basis to strengthen model

development. Domestically such data are widely collected by precision agriculture applications (although calibration of the data is needed). Internationally yield data might be easier to obtain because of fewer privacy concerns for example on smallholder farms. Databases such as those of the Farmer Business Network might provide a source for field level yield data.

- Crop yield and growth stage estimation are the next major focus areas for the JECAM program, due to the complexity of scaling models from national to regional to field scale. Community leadership is needed to coordinate data collection and method inter-comparison. The question of how to engage farmers in this discussion was raised – many farmers are keen to support research and there is potential to involve them in applications with a high readiness level and in which they see benefit. The need for more robust field data on crop growth stage was also highlighted. Remote sensing of phenology methods are maturing but very little phenology work has been done on agricultural crops.

<u>New Data Sets and Approaches</u>

This session covered new sensors and data sets that are now being applied to agriculture, such as soil moisture, solar induced fluorescence, and satellite-derived precipitation, as well as new crop modelling approaches. **Dalia Kirschbaum** (NASA Goddard Space Flight Center (GSFC)) discussed the Global Precipitation Mission (GPM) and the IMERG data set which is providing global precipitation estimates, which can help inform agricultural monitoring. **Catherine Champagne** (AAFC) discussed applications of satellite soil moisture wetness index for drought risk assessment, yield forecasting and excess moisture identification. She emphasized the need for long term and real-time data sets and further development of applications. **Amy McNally** (UMD GSFC, EOFSAC) discussed the use of soil moisture from the GSFC Land Data Assimilation system (LDAS) for the FEWSNET famine early warning program, using a 30-year historical time series. **Wade Crow** (USDA ARS) discussed soil moisture data assimilation systems, highlighting the Soil Moisture Active Passive (SMAP) mission Level 4 root zone soil moisture data set and improvements in soil moisture particularly for areas with poor availability of input data for modelling. **Kaiyu Guan** (University of Illinois) discussed solar-induced fluorescence, highlighting the potential for monitoring photosynthesis. He noted the limitation of the coarse resolution from current sensors, which will improve with future geostationary satellites. **Prasad Bandaru** (UMD, EOFSAC) presented the integration of satellite-derived LAI data with the EPIC crop model and meteorological forecasts for near term (10-15 day) within-season forecasts of crop condition, crop biomass, seeding dates and crop yield.

The discussion session emphasized the following points:

- The effectiveness of assimilated soil moisture data sets was discussed. One attendee posited that assimilation models do not provide an advantage over standalone models if precipitation data have adequate spatial resolution and accuracy, which could potentially be provided by GPM.
- The need for higher resolution soil moisture data was discussed, with NISAR as a potential future source, but with the caveat that the higher spatial resolution may not provide adequate temporal

resolution. SMAP radar would have provided such information more systematically. It was suggested that there might be some value in having in-situ networks fill the data gaps.
- C-Band SAR data (Sentinel 1) are most widely available now, but models to retrieve soil moisture under vegetation canopies are still in development.
- The need to move away from pixel-based models to providing landscape level information is critical.
- The use of drones was discussed as a way of both scaling up and collecting new types of information. Challenges for broad use would include privacy concerns, but drones may be of use in a targeted way.
- The need for better information on the distribution of irrigated crop areas was noted.

Emerging Methods and Technologies

This session highlighted new missions, new techniques for field data collection, data processing and high spatial/temporal resolution data sets. **Feng Gao** (USDA ARS) discussed using a fused data set of MODIS, Landsat and Sentinel-2 for agricultural applications including yield and phenology, to helped improve the temporal coverage and in turn the estimation of the spatial variably of yield. **Jeff Masek** (NASA GSFC) presented the Harmonized Landsat-Sentinel 2 (HLS) project which is providing a seamless radiometric data set from both sensors with 2-3 day coverage. The project is generating regional data sets to meet NASA project needs, North American coverage available in 2018 and selected locations around the world including the international JECAM sites. **Chris Wasko** (National Geospatial Intelligence Agency (NGA)) discussed a field survey tool that can be used on multiple mobile platforms. **Steve Brumby** (Descartes Labs) described their monitoring system which applies machine-learning to multi-temporal data sets for global agricultural modelling for crop condition and yield estimation and can be updated in real time as imagery become available. He pointed out the challenges of working in regions with limited field data for training and validation.

Three new missions were discussed: The *ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)*, the *NASA-ISRO Synthetic Aperture Radar (NISAR)* and the *Radarsat Constellation Mission (RCM)*. **Martha Anderson** (USDA ARS) showed how ECOSTRESS will provide high resolution surface temperature, evapotranspiration and evaporative stress index products starting in 2018. The NISAR mission was presented by **Paul Siqueria** (University of Massachusetts, EOFSAC Collaborator). NISAR will provide L and S-Band SAR data and is planned for launch in 2021. **Heather McNairn** (AAFC) presented Radarsat Constellation Mission (RCM), which will provide open data with restrictions from its standard coverage, including higher temporal resolution, compact polarimetric data and HH-VV dual mode not currently available from other SAR satellites, with a launch planned for fall 2018.

The plenary discussion brought forward key ideas, including:

- The need for a global referencing system for HLS data.

- Given the high volumes of data now available, the move towards cloud-based systems that provide not just data but algorithms, models and applications is an important development. The output will need to be presented in land units that have physical or administrative meaning. This removes the burden of data processing, facilitating applications and analysis.
- The most recent advance in terms of free and open data is the European Sentinel program. This is allowing a wide variety of data brokers to provide value added information. An open data policy for Radarsat data will similarly be a major contribution. GEOGLAM will continue to make the case for open data access and sharing for those systems relevant for agricultural monitoring from other Space Agencies (e.g. India, China, Vietnam)
- The greater volume of data means that focus needs to be less on accessing data but on methods to manipulate them, and there is a need for improved and standardized processing and machine-learning techniques.
- Information that is temporally scaled to crop growth calendars and not standard annual calendars is a unique need in agriculture, and we should consider how as a community to address this.
- The need to elevate the voice of the agricultural user community in new missions is key. We are often a small player in this but need to provide clear goals and requirements, so that the community needs can be readily included in mission planning. Working with CEOS, GEOGLAM is providing a forum for agricultural EO requirements development.

Priorities for Emerging Technologies

A number of priorities were identified by the group based on the presentations and discussions:

Crop Type and Crop Area

- Accurate crop masks are key for several applications. Accurate annual crop area mapping is a critical component of operational agricultural monitoring; EO methods are now providing reliable data sets of crop area that can be used to augment operational statistical survey data.
- Automated field delineation, segmentation and field size mapping methods have been developed and tested for the U.S. These methods are ready for operational testing in other countries. Although these data are of interest for Land Use Science, it remains unclear whether there will be operational users for such data.
- EO-based crop type estimation for major commodities is working well in US and Canada and methods are being applied to other major producer countries. The development of global annual commodity crop type maps is becoming feasible. Robust identification of smaller acreage crops (greenhouses, fruit/vegetables types, pasture/grassland distinction) and global crop maps are the next challenge.
- Coarse, moderate and fine resolution data are needed for mapping in a multi-scale sampling approach. Moderate resolution (30-250m) spatial resolution data are more critical for crop type and area. Government data buys for fine resolution data are made in the US, but without a public good fine resolution satellite, the issue of broader sharing of data is often difficult to overcome.

- SAR data are needed, particularly in tropical areas where cloud cover is pervasive. Multi-frequency SAR data are key to high accuracy crop mapping for such areas. A stronger voice is needed for the agricultural monitoring community in the SAR mission planning, to push for what is needed in terms of future instrument specifications and acquisition strategies.
- Pasturelands have received relatively little attention from the agricultural monitoring community. There is the potential for EO data (including high resolution SAR) to help identify and characterize these areas.

Crop Yield, Phenology & Condition

- EO-based yield forecast models at the national to regional scale are providing information of suitable accuracy for economic forecasting. Moderate resolution products remain an area for research and development.
- Accuracy assessment of EO-based yield models is limited by the availability of field-based yield data. A community effort is needed to obtain and share such data, for example by obtaining access to historical yield data in the private sector. Access to calibrated combine harvester-collected yield data could provide such data.
- Process-based models still have a very low application readiness level for national to regional scale within-season yield forecasting. EO assimilation into these models shows considerable promise but further research is needed. The Agricultural Model Intercomparison Project (AgMIP) provides an established, international forum for evaluating process-based model methods and products.
- The phenocam network will be expanded to USDA LTAR sites, and could provide good reference data on crop development. There is a need for further evaluation to see whether these data can be usefully applied to assessing crop stage development and not just green-up.

New data sets and approaches

- A number of soil moisture products are coming on-line and efforts are being directed towards their evaluation. There is a need for a more in depth evaluation of their accuracy and utility for agricultural monitoring. There is a need for higher spatial and temporal resolution soil moisture products for data assimilation.
- Similarly, methods for mapping crop water use and stress at Landsat scales are moving toward capacity for routine production, likely using cloud computing platforms (e.g., Google Earth Engine)
- There is a need more structured research on how imagery from drones can contribute to scaling up to satellite spatial resolutions and targeted information collection.

Emerging Methods

- Moderate spatial resolution, high temporal frequency data are now becoming available but don't have a long historical record needed for some time-series applications. Multi-resolution analyses may provide an interim solution until a longer data record can be established.
- Fine resolution data analysis (automated analysis) – issue of data costs remain.

- Combining process models with satellite data (spatial) – within-season production forecasting and short term forecasts.
- Data records connected to annual growing season calendars to better target crop monitoring and compare to historical records.
- It was suggested that citizen science could play a role in ground data collection; questions of scope, incentives and data quality were raised.

What are the top priorities for each agency for improving operational monitoring?

- Harmonized Landsat-Sentinel 2 will be a game-changer for producing high resolution crop data sets; need a long term data record and to prioritize where these products will be generated globally (i.e. with a priority on croplands).
- Crop type mapping and yield estimates for non-major commodities.
- Reliable in-situ data collection (particularly in Canada).
- Improved use of SAR data particularly for cloud covered areas. Need for both data and applications training.
- Create a North American Community of Practice to move forward on these applications (potentially in the framework of GEOGLAM).

JECAM & LTAR Field Site Experiments: Accelerating Research to Operations

A session was held on the last day of the workshop to discuss mechanisms to enhance progress in research to operations through coordinated field experiments. The emphasis was on describing the current mechanisms for long term agricultural research, including the Joint Experiment on Crop Area Monitoring (JECAM), the USDA Long Term Agro-ecosystem Research (LTAR) sites, Calibration/Validation partners of the Soil Moisture Active/Passive (SMAP) mission and the potential experiments under the NASA-ISRO Synthetic Aperture Radar (NISAR).

Pierre Defourny described the current priorities under JECAM, which is a voluntary networks of sites globally to share standards, methods and data to establish guidelines and best practices for operational crop monitoring. The project has established protocols for satellite and field data collection, has conducted a number of site inter-comparison projects, with current priorities on the use of SAR for agricultural monitoring, exploiting dense optical time series from Sentinel-2, field delineation, modelling crop yield and phenology methods benchmarking. **Teferi Tsegaye** and **Alisa Coffin** from USDA discussed the LTAR network, which consists of 18 sites in the US where long term research is being conducted to enable understanding and forecasting of regional landscape capacities to provide agricultural commodities and ecosystem services under changing conditions. Each site compares "business as usual" and "aspirational" farming techniques, which push the boundaries of improving production by emphasizing genetics, environment and management practices. There are within LTAR a series of working groups to support coordination, including a Remote Sensing and Geographic Information System (GIS) working group led by Alisa Coffin, which may provide a means to develop collaboration to advance North

American or international EO research collaboration. Three LTAR sites are currently participating in JECAM.

The needs and mechanisms for integrating research into operations were discussed by **Robert Tetrault** (USDA) and **Andrew Davidson** (AAFC). The transition was defined in terms of a transfer of primary responsibility from researchers, to transition specialists to local crop analysts, with the speed of this transfer dictated by a number of factors, including the underlying science and repeatability and reliability of algorithms, but also funding, costs, latency, impact, human resources and information technology (IT) infrastructure. While USDA FAS has a much more structured transition from research to operations, AAFC has historically been more ad-hoc but is moving towards a more structured process.

The US and Canadian site leads for JECAM each presented, with representation from South Fork, Iowa (**Mike Cosh**, USDA), Gulf Atlantic Coastal Plain in Tifton, Georgia (**Mike Cosh** and **Alisa Coffin** from USDA), the Kellogg Biological Research Station in Michigan (**Guanyuan Shai**, University of Michigan and **Anita Simic**, Bowling Green State University), the Red River Manitoba site (**Heather McNairn**, AAFC) and the South Nation Ontario site (**Catherine Champagne**, AAFC). A new potential site in Massachusetts (Connecticut Valley, **Tracy Whelen**) was presented. The JECAM SAR inter-comparison study was presented, with crop type mapping comparisons using multi-temporal SAR and leaf area and biomass estimation, with current work focussed on standardizing image preprocessing for different agroecosystems. Finally, the successful efforts at site inter-comparisons from the SMAP Calibration/Validation experiment were presented by **Mike Cosh** from USDA and the potential for expanded cal/val experiments from NISAR was discussed, led by **Paul Siqueira**.

The discussion highlighted these key areas:

- The costs and investments in field data collection are large, and while it is important to leverage these to serve multiple purposes, it is important to maintain the link to the funding organization. "Branding" is important because often senior management making decisions do not fully recognize when sites are linked to other networks, and that the funding is not coming from those networks but remains internal.
- Successful site inter-comparison projects such as SMAP used mechanisms such as "data rehearsals" to ensure all data collected across sites were of the same quality and interchangeable. This proved effective in ensuring that protocols were being followed to accelerate data evaluation post-launch.
- SMAP also enabled funding of specific field site experiments through NASA and the Canadian Space Agency (CSA). These campaigns have become less expensive over time and there may be ways to conduct this research in a more cost effective way, with less emphasis on airborne flights and more resources for field data collection.
- Need to make a strong case for agricultural cal/val for upcoming missions such as NISAR to ensure resource allocation. Agriculture is just one voice at the table, but as a community we can be a louder voice.

- USDA participation in JECAM has been limited and could be increased. There would be a benefit from increased USDA participation in JECAM, potentially by leveraging the LTAR community structure.
- Several upcoming meetings will be of high value to continue this collaboration: the **NISAR Agriculture and Soil Moisture Workshop in Beltsville in June 2018**; the **Beijing Big Data workshop in August 2018**; and the **Taiwan JECAM meeting in September 2018**.

Meeting Outcomes and Actions:

- This workshop built a solid foundation for a North American agricultural monitoring community. This has in the past been ad-hoc, but there may be impetus for a more formal partnership (similar to the North American partnership on Drought which is covered under the North American Climate Services Partnership). Need to explore mechanisms to make this happen, and a partnership between North American JECAM sites and LTAR may be a good start.
- There is a high interest in expanding capacity on the use of synthetic aperture radar (SAR) but tailored training is required to build capacity. Heather McNairn (AAFC) has agreed to lead a training working group to establish this, which could also be used for training within the broader GEOGLAM initiative.
- The need for field data (particularly yield, phenology and crop type globally) was emphasized. JECAM may be a good venue to explore field based collection. There is also a potential to establish shared access to privately held data sets from precision agriculture with private sector partners. This topic should be discussed at the upcoming workshop in Taiwan.
- The partnership between JECAM and LTAR should be strengthened moving forward. Andrew Davidson and Alisa Coffin will work together to establish JECAM representation on the LTAR Remote Sensing and GIS working group.
- Research priorities for global monitoring should emphasize use of EO for yield modelling and assimilation in process based models, phenology, soil moisture, SAR, pasture/rangeland, small area crop mapping, and field delineation. This will be brought forward at the JECAM annual meeting in Taiwan in 2018.