Summary of the GEOGLAM Workshop on Data and Systems Requirements for Operational Agricultural Monitoring

Hosted by the European Commission at the Joint Research Centre
17-18 April 2018

0. Executive Summary

This report outlines the outcomes from the GEOGLAM Workshop on Data and Systems Requirements for Operational Agricultural Monitoring meeting held 17-18 April 2018 at the European Commission Joint Research Centre. It lays out the context and objectives for such a meeting, followed by a high level presentation of outcomes. Included is a brief review of the state of Earth observation data acquisition, access, and use by operational entities; status and opportunities for information and computation technologies platforms within the GEOGLAM community; recommendations for enhancing GEOGLAM's role as curator of data, products, knowledge, and technology; and feedback to CEOS on potential collaborative areas for expanding EO data adoption and sustained use.

1. Context

Since 2011, the Group on Earth Observations Global Agricultural Monitoring (GEOGLAM) Initiative has had as a core activity the coordination of Earth observations data for those undertaking cropland and rangeland monitoring at national, regional, and global scales. Critical to this has been a partnership with the Committee on Earth Observation Satellites (CEOS), which has maintained an Ad Hoc Working Group on GEOGLAM since 2012, tasked with evaluating and assisting with the implementation of GEOGLAM data requirements and requests for acquisition. In 2012, this CEOS Ad Hoc Working Group on GEOGLAM convened for the first time, at the Canadian Space Agency, and concretely characterized satellite data requirements for a variety of agricultural information products in tabular format (Figure 1). This was an evolution of a previous GEO Agricultural Community of Practice effort to characterize monitoring requirements in a sensor-agnostic manner (via the "Defourny Diagram"). Between 2016 and 2017, GEOGLAM undertook a refreshment of these requirements from a "state of the

A	B	C	D	E	F	G	H	I	J	K	L	M
						Target Products						
Req #	Spatial Resolution	Spectral Range	Effective observ. frequency (cloud free)	Extent	Field Size	Crop Mask	Crop Type Area and Growing Calendar	Crop Condition Indicators	Crop Yield	Crop Biophys. Variables	Environ. Variables	Ag Practices / Cropping Systems
	Coarse Resolution Sampling (>100m)											
1	500 - 2000m	optical	Daily	Wall-to-Wall	All			X		L		
2	100-500m	optical	2 to 5 per week	Cropland extent	All	X	X	X	L	L	X	L
3	5-50 km	microwave	Daily	Cropland extent	All			X	X	X	X	
	Moderate Resolution Sampling (10 to 100m)											
4	10-70m	optical	Monthly (min 3 in season + 2 out of season); Required every 1-3 years	Cropland extent (if #5 = sample, else skip)	All	X	L/M					X
5	10-70m	optical	8 days; min. 1 per 16 days	Sample (pref. Cropland extent)	All	X	X	X	X	X	X	X
6	10-100m	SAR	8 days; min. 1 per 16 days	Cropland extent of persistantly cloudy and rice areas	All	X	X	X	X	X	X	X
	Fine Resolution Sampling (5 to 10m)											
7	5-10m	VIS NIR + SWIR	Monthly (min. 3 in season)	Cropland extent	M/S	M/S	M/S					
8	5-10m	VIS NIR + SWIR	Approx. weekly; min. 5 per season	Sample	All		M/S	X		X	X	X
9	5-10m	SAR	Monthly	Cropland extent of persistantly cloudy and rice areas	M/S	M/S	M/S					M/S
	Very Fine Resolution Sampling (<5m)											
10	< 5m	VIS NIR	3 per year (2 in season + 1 out of season); Every 3 years	Cropland extent of small fields	S	S	S					
11	< 5m	VIS NIR	1 to 2 per month	Refined Sample (Demo)	All		X		X			X

Figure 1: Version 1 of the GEOGLAM Satellite Observation Requirements (2012-2014)

science" perspective – accomplished through survey of participants in the Joint Experiment on Crop Assessment and Monitoring (JECAM) and Asia-RiCE networks. It was agreed upon – through consultation with the CEOS Ad Hoc WG on GEOGLAM during their annual meeting in September 2017 – that this R&D perspective should be complemented by an assessment of the data and service requirements from the operational user perspective. From this, the concept of an "end-to-end" assessment of operational EO data use and requirements was born.

2. Objectives and Rationale

GEOGLAM and CEOS identified that the GEOGLAM community needed to take a holistic approach to requirements in order to enhance EO data usage in operational monitoring settings, and empower decision, policy, and action towards a more food secure world– the ultimate objectives of GEOGLAM. More specifically, we needed to trace information needs to product needs to data needs, and along the way consider computational, connectivity, technical, institutional, and human capacity requirements in order to fulfill the requirements.

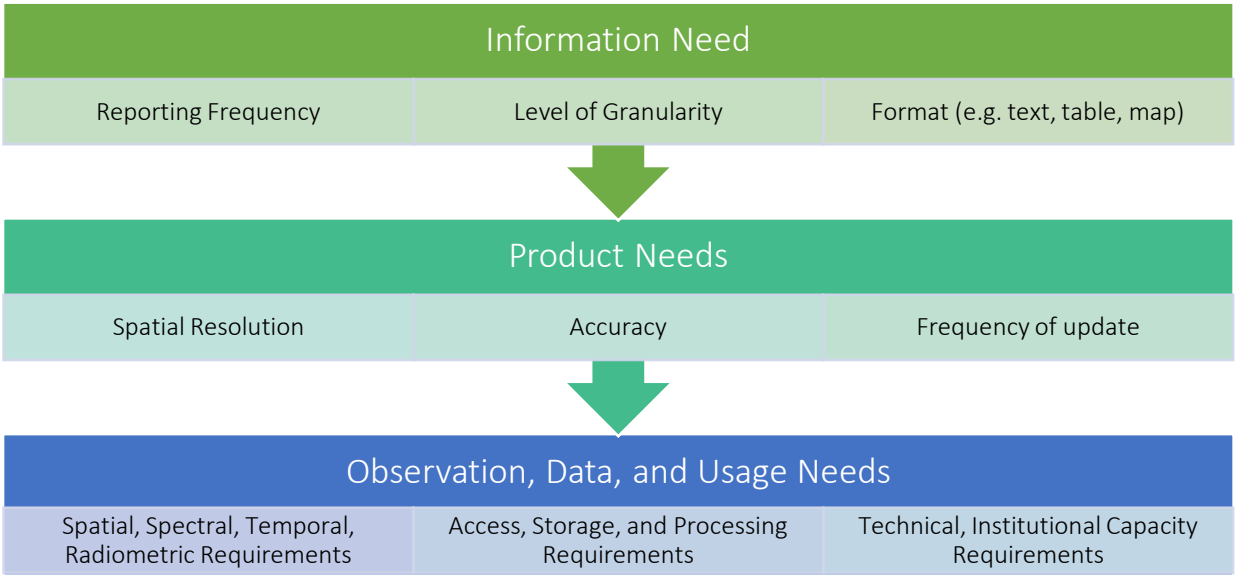

Figure 2: A diagram showing the flow from information needs through product needs and eventually data needs, as well as associated capacity requirements. This describes the holistic approach to requirements taken by this workshop, and GEOGLAM in general.

This workshop pulled together operational users of satellite data for agricultural monitoring at national, regional, and global scales. It provided an opportunity to work with CEOS representatives, including data and service providers in the context of advancing operational EO usage for agricultural monitoring. The objectives of the meeting were to:

- Characterize the state of use of EO data by operational users: identify current gaps and challenges in acquisition, access, and use of EO data, analytical tools, and ICT;
- Provide feedback to CEOS related EO data acquisition requirements, access considerations, pre-processing levels, and interactions with CEOS working groups; and,
- Better understand and implement connections across GEOGLAM Thematic Coordination Teams (TCTs), particularly in the EO Data Coordination with CEOS, information and computation technology (ICT), and Capacity Development TCTs;
    - Review priorities for GEOGLAM with respect to operational transition, and identify priority areas for Initiative action;

- Begin the process of establishing an inventory of ICT systems which have been developed to assist in data access, storage, and processing, and identify potential synergies between different ICT systems and opportunities for implementation by the operational users in attendance.

3. Agenda & Format

This was accomplished through three primary modalities:

1. Two presentation templates with targeted questions sent in advance to, 1) national, regional, and global monitoring system representatives, and 2) ICT platform/services providers.
2. A survey implemented in advance focusing on the state of, gaps in, challenges to, and priorities for use of EO for agricultural monitoring by various individuals and their organizations (remote sensing technicians; remote sensing data services developers/providers; information generators who use EO; information interpreters and decision makers), to which >50 people responded.
3. Breakout groups during the meeting focused on distilling responses and reaching consensus around six themes:
    a. Target agricultural monitoring data products and the satellite data required to generate them
    b. Operational user community priorities for data and capacity (feedback to funding agencies & CEOS)
    c. The Communication Challenge: Linking EO and end user communities
    d. State of the science, challenges, and opportunities for data access, storage, and utilization
    e. GEOGLAM's curation role for data and knowledge, and next steps in CEOS space agency data services
    f. Feedback to CEOS on satellite data preprocessing, interoperability, and "analysis ready data" requirements

The meeting was opened with a welcome from Bettina Baruth (EC JRC, Food Security Unit Head ad int.) and later by EC JRC Sustainable Resources Director Giovanni De Santi, emphasizing their long commitment to both European Agricultural Policy and Global agricultural monitoring and the significance of such a requirements gathering effort to their organization. This was followed by an overview of the history of the EO data coordination activity and requirements gathering efforts of GEOGLAM, including the rationale for and status of the requirements refresh by Alyssa Whitcraft (GEOGLAM Secretariat, EO Data Coordination Lead) and Pierre Defourny (UCL, JECAM co-lead). Inbal Becker-Reshef (GEOGLAM Secretariat, Crop Monitors Lead) and Ian Jarvis (GEOGLAM Secretariat, Programme Director) situated the meeting and our objectives with the frameworks of global policy drivers, specifically the G20 Action Plan on Food Price Volatility and Agriculture, United Nations Sustainable Development Goals, and the UN Paris Climate Accords. The remainder of Day 1 included global, regional, and national operational user presentations (see Section 5.1), followed by Breakout Groups a-c and a stimulating report-back discussion on the way forward with CEOS and funding agencies.

The morning and early afternoon of the 2nd day of the meeting saw a shift of focus to the ICT systems, with several overview presentations followed by Breakout Groups d-f. The meeting then began to wrap up via an active discussion on the Way Forward, during which many Key Outcomes and Findings (Section

5) were summarized, with a look forward to next steps toward actively advancing GEOGLAM as a whole, in addition to the EO data coordination and requirements gathering activities.

4. Participation

This meeting targeted operational agricultural monitoring actors, including ministries of agriculture, regional and global monitoring programs, and private industry. In addition it included those supporting operational monitoring, such as those acquiring data, developing data products, and delivering data services. The overarching objective was to understand and tighten the connections between those collecting, processing, and providing data, and those utilizing it to generate information. The meeting also included members of the GEOGLAM Executive Committee – composed of individuals working in each of GEOGLAM's Thematic Coordination Teams and Regional Networks.

5. Key Outcomes & Findings

5.1. State of Acquisition, Access, and Use of EO Data by Operational Entities

The arc of presentations started from the point of information needs, and traced them through product needs and onto observation, data, and usage needs (Figure 2). Information provided by these users included reports, bulletins, and publications produced, current status of EO data usage in these reports, gaps in EO data adoption and their associated drivers, comments on the original GEOGLAM data requirements table, and an opportunity for general comments related to EO data usage not covered by the previous prompts. Common themes across many presentations were:

- While there is a wide range in level of EO data usage across programs, all systems clearly communicated the importance of products, methods, and information "ownership" by their own organizations.
- *In situ* data are inconsistently available, expensive to collect, and rarely shared. Where possible facilitated sharing of these datasets would be a valuable contribution by GEOGLAM.
- Institutional, communication, and political barriers were among the most commonly articulated challenges for EO adoption, but insufficient methods, technical capacity, and computational capacity were also common.
    - There was an expressed need for assurance of long-term observations to promote institutional investment in EO-based methods, as well as higher readiness to use in terms of cloud filtering and atmospheric adjustment.
    - A consensus emerged around the need for improved communication about product and dataset quality and veracity to help users decide what datasets and products are best suited for their information needs.
    - SAR-based agricultural monitoring is a high priority, with the proliferation of freely/openly available SAR (i.e. Sentinel-1) as well as upcoming missions (Radarsat Constellation Mission) – however best practices require improvement and capacity development is critical.
    - Long-term knowledge/technology transfer relationships (both inter- and intra-nationally) are critical for developing trust and ensuring sustained transition of methods to operations – but this is often hampered by traditional funded project lengths (~3 years) so funding stability for operational implementation is required.

- There was consensus that the agricultural monitoring community needed to improve evaluations of the impact of EO data on decisions, including the development of case studies showing policy and program impact, and valuation of those decisions on society and the economy. Timely, policy-relevant information can save money and lives, "and ounce of prevention is worth a pound of cure". The community feels GEOGLAM should continue to work to identify inroads for EO based information for policies at the national to global levels.

On the final point, there were two excellent and recent examples of EO data usage in decision making with impacts on human livelihoods and food security. The first (Figure 3) was in Uganda – where EO data in 2017 were used to trigger disaster risk financing, and public works funding were directed to 31,386 households to offset losses from food production. In this case the use of EO directly resulting in a savings of USD 2.5 million from the usual amount spent on food security and had a positive impact on the lives of up to 150,000 people (presentation by Martin Owor, Commissioner, OPM Uganda).

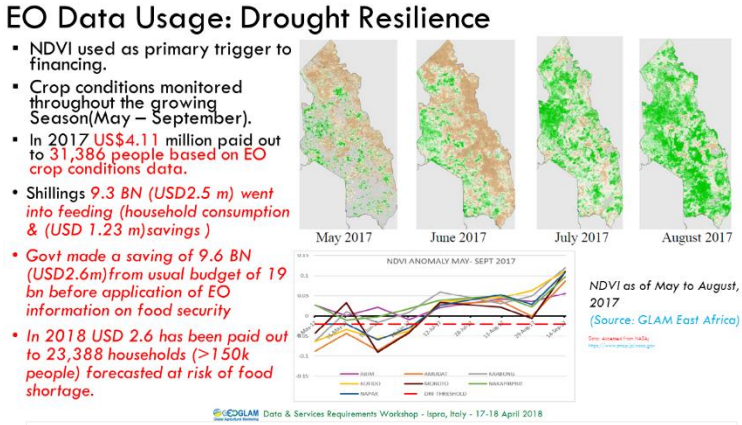

Figure 3: A slide showing the example of EO usage in decision making in Uganda (Owor, OPM).

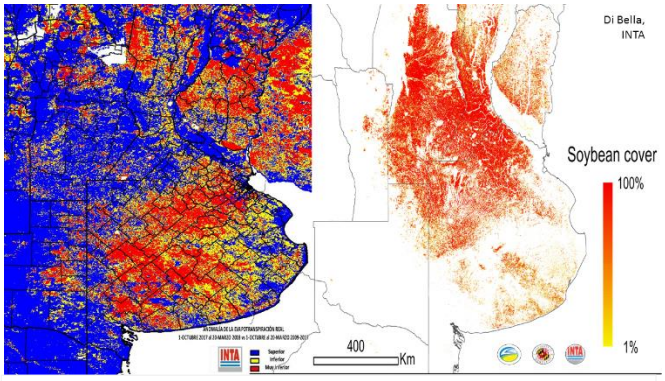

Figure 4: Evapotranspiration and a soybean crop type map were critical inputs into INTA's ability to precisely diagnose impacted farms (Di Bella, INTA).

The second example came from Argentina, where a 2018 drought "without precedence" was damaging ~80% of croplands, yet the government had been incapable of quantitatively determining which areas were impacted and necessitated the declaration of a state of emergency. Through a concerted effort on the part on INTA and their production of satellite-based evapotranspiration anomaly – realized through the physical movement of INTA remote sensing scientists into the Ministerio de Agroindustria – a state of emergency was declared and aid distributed (Figure 4). This timely response would have been impossible without the use of Earth observations (source: INTA Argentina).

Finally, at the global policy level, in February 2018 the UN Office of Humanitarian Coordination released a special food security alert for Southern Africa due to drought and pest infestations. The alert sourced the GEOGLAM Crop Monitor for Early Warning and as a result provided the international food security organizations early warning to mobilize efforts. The alert went on to suggest that monthly reporting was not timely enough when these food security hot spots are developing.

Generally, these presentations echoed survey response. Self-identified remote sensing technicians were asked to evaluate a number of statements related to their and their organization's use of EO (Figure 5).

Although confidence in individual level usage of EO products is high, there is also a consensus that more training and technical support are needed both at the individual and institutional level (Statements 1-4). This highlights the need for approaches tailored to institutional needs and situations, even if certain commonalities can be found across types of organizations. Also notable is the general preference for at least some preprocessing of EO data to be done before delivery (Statements 6&7).

#	Field	Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat disagree	Strongly disagree	Total
1	I am fully confident in my individual usage of Earth observations in my professional capacity.	40.00% 8	40.00% 8	10.00% 2	10.00% 2	0.00% 0	20
2	I would benefit from professional development or training on cutting edge EO technologies (datasets, methods, and tools).	60.00% 12	40.00% 8	0.00% 0	0.00% 0	0.00% 0	20
3	My institution's use of Earth observations is fully developed, implemented, or operational.	30.00% 6	40.00% 8	20.00% 4	10.00% 2	0.00% 0	20
4	My institution requires additional technical support to download, process, and/or utilize Earth observations.	45.00% 9	25.00% 5	10.00% 2	5.00% 1	15.00% 3	20
5	I am satisfied with my current access to satellite data and higher-level products.	25.00% 5	45.00% 9	10.00% 2	20.00% 4	0.00% 0	20
6	I prefer to perform all preprocessing of my satellite data products.	10.00% 2	15.00% 3	20.00% 4	45.00% 9	10.00% 2	20
7	I see value in being able to download and utilize higher-order data products (e.g. Surface Reflectance, NDVI, Vegetation Condition Index), in my professional context.	70.00% 14	20.00% 4	10.00% 2	0.00% 0	0.00% 0	20

Figure 5: Responses to the GEOGLAM Holistic User Requirements Survey from self-identified remote sensing technicians (those who download, preprocess, analyze, or validate EO data or data products) (Whitcraft et al.).

Similarly, self-identified individuals who use EO to produce higher-order information products for non-geospatial audiences were asked to evaluate a number of statements about EO usage in their organizations (Figure 6). Notably, while many articulated that they had a clear understanding of how EO could be used in their organizations (Statement 13), most agreed or strongly agreed that their organization would benefit from increased use of EO (Statement 10). While not particularly strong, the responses also indicated that communication between EO producers and information users about the applicability and value of EO are needed (Statements 1-3&7).

#	Field	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	Total
1	I have a clear understanding of the needs of those who use the information I generate.	55.56% 10	38.89% 7	0.00% 0	5.56% 1	0.00% 0	18
2	I have a clear understanding of how the information I provide impacts decisions.	27.78% 5	50.00% 9	16.67% 3	5.56% 1	0.00% 0	18
3	I have a relationship with users of my information.	55.56% 10	38.89% 7	0.00% 0	5.56% 1	0.00% 0	18
4	Earth observations are the primary data source I utilize in generating information.	33.33% 6	44.44% 8	16.67% 3	5.56% 1	0.00% 0	18
5	Earth observations are an important data source for me in my job.	83.33% 15	16.67% 3	0.00% 0	0.00% 0	0.00% 0	18
6	I prefer to utilize data that are already preprocessed and converted into higher-order environmental variables.	44.44% 8	27.78% 5	16.67% 3	11.11% 2	0.00% 0	18
7	Earth observations have made an impact on decisions, actions, or policies made by my organization.	38.89% 7	50.00% 9	11.11% 2	0.00% 0	0.00% 0	18
8	My organization would be worse off without Earth observations.	50.00% 9	38.89% 7	11.11% 2	0.00% 0	0.00% 0	18
9	My organization does not value Earth observations as much as other data sources.	5.56% 1	11.11% 2	11.11% 2	27.78% 5	44.44% 8	18
10	My organization would benefit from increased use of Earth observations.	33.33% 6	50.00% 9	16.67% 3	0.00% 0	0.00% 0	18
11	I am completely confident in my capacity to use Earth observations.	44.44% 8	38.89% 7	16.67% 3	0.00% 0	0.00% 0	18
12	I would benefit from professional development or training on cutting edge EO technologies (datasets, methods, and tools).	33.33% 6	33.33% 6	27.78% 5	5.56% 1	0.00% 0	18
13	I feel I have a good understanding of how EO can and should be used by my organization.	61.11% 11	33.33% 6	5.56% 1	0.00% 0	0.00% 0	18

Figure 6: Responses to the GEOGLAM Holistic User Requirements Survey from self-identified information product generators (those who utilize EO to develop higher-order information products for a non-geospatial audience) (Whitcraft et al.).

Full presentations can be found here: LINK

A full report of the survey responses will be produced and distributed at a later date.

5.2 GEOGLAM's Role as Curator of Data, Products, Knowledge, and Technology

Throughout the meeting, presenters and discussants repeatedly identified "GEOGLAM's Curation Role" as central to the Initiative's value proposition, and as a common thread through all of GEOGLAM's activities. Curation is apparent in each of the following roles and priorities the group identified for GEOGLAM, initiative wide:

5.2a. Communicating data requirements to CEOS: EO data coordination has been a core activity for GEOGLAM since its inception, and CEOS plays a critical role in ensuring agricultural observation requirements are addressed by current and planned missions. Specific recommendations related to this relationship are in Section 5.3.

5.2b. Knowledge Management System: There is a need to define and implement a Knowledge Management System to capture the intellectual productivity of GEOGLAM in a way that is meaningful

and accessible to operational monitoring entities. Such a KMS might include output products, training materials (manuals and sample data), and research compendia, among other things. All attendees were not in agreement about the scope or management of GEOGLAM's KMS, signaling the need for sub-working groups on KMS-definition, and on roles, responsibilities, and support. This will be discussed at the upcoming GEOGLAM Annual Meeting on GEOGLAM Cloud Infrastructure and Knowledge Management, 29-31 August 2018 (Sanya, China), and a concept paper will be drafted prior to Sanya to set the stage for these discussions.

5.2c. GEOGLAM Endorsement of Products and Services: One survey respondent – an end user of information – noted, *"There are more and more end user near real time EO products on the market and it is difficult to be constantly updated and have a good idea about the quality of the products."* GEOGLAM can add significant value by developing an approach to endorsing data products and services to help users parse through their recent proliferation. This will ensure the consistency and credibility of GEOGLAM outputs, while increasing EO adoption and improving the usability of EO-based information by end user communities (see 5.3a-c for related, supporting efforts). This has also been identified as a priority discussion and decision area during the upcoming Sanya meeting. In the survey, crop mask, crop type map/planted area, yield forecasting, and current year phenology were identified as top priority products. In a similar survey deployed by the Rangeland and Pasture Productivity (RAPP) group, rangeland/pasture cover and rangeland/pasture biomass were among the most highly valued products.

5.2d. Capacity Development Coordination: Even those who articulated that they were confident in their usage of EO still noted that they would benefit from professional development or training on cutting edge EO technologies. This is true in both the case of individual and institutional capacity. Regardless of the level of technical capacity, those on the receiving end of knowledge transfer and training activities clearly articulated the need for coordination across those on the delivering end. This not only ensures that end user priorities are the driving force, but also serves to maximize the efficiency and impact of activities within and outside the GEOGLAM community (see 5.3e for how this relates to GEOGLAM efforts with CEOS).

5.2e. ICT Systems and Data Services: It was clear from end user presentations that there is no appetite for a single, unified GEOGLAM data services platform. Rather than developing "in house" ICT capacity, GEOGLAM's role should be that of a federator of those ICT platforms that are focused on agricultural monitoring. As stated in 5.2c, GEOGLAM should play a proactive role in connecting and optimizing functionalities and services of ICT and cloud-computing platforms, toward enhancing user audience awareness and adoption of these services. There was general agreement across participants and survey respondents that communication across ICT platforms was a high priority, both on the supply (platform developer) and demand (data user) side. All of these topics will be addressed in the upcoming Sanya meeting.

5.2f. GEOGLAM as Communication and Collaboration Clearinghouse: Increasing communication between different levels in user organizations. This includes the development of communication tools and materials to convey the utility of EO based agricultural monitoring information to support effective policy and programs and communicate the value proposition of EO.

5.3 Feedback to CEOS: Acquisition, Access, Adoption, and Sustained Use

The relationship with CEOS around data acquisition has been effective. EO data coordination for GEOGLAM through CEOS has principally been executed in the context of the JECAM and Asia-RiCE experimental activities, allowing the state of the science to evolve at a rapid pace. Despite marked increases in data acquisition and coverage by moderate spatial resolution satellites since the CEOS Ad Hoc Working Group on GEOGLAM's (AHWG) 2012 launch, the challenge of scaling coordination to support national, regional, and global scale operational implementation persists. Where we were data limited, we are now largely constrained by issues related to data access and utilization. GEOGLAM's efforts to identify these access and utilization requirements is timely, as CEOS space agencies have increased their efforts around data services during recent months and years.

Developing a relationship around access and utilization are new frontiers in the evolution of the CEOS-GEOGLAM relationship. Specifically, there were four recommendations for interaction between CEOS and GEOGLAM:

5.3a. GEOGLAM-CEOS Coordination on Data Quality Control & Assessment: In light of the recent proliferation of data streams and associated products from CEOS agency missions, many users expressed uncertainty about which products were appropriate for their applications as well as how to gain access to them. A potential joint effort on data documentation and data quality standards would be of enormous benefit to the both the space and GEOGLAM data user communities.

- Interoperability between sensors was consistently referenced as of utmost importance.
- In the near-term, with existing missions, this might be achieved through consistent atmospheric adjustment, band pass adjustments/articulation of spectral response function, and/or GEOGLAM-CEOS development of "Analysis Ready Data" as well as "Application Ready Data" (5.3b).
- In the longer term, it was suggested that GEOGLAM should articulate "standard agricultural monitoring spectral bands" to be considered in future mission planning.

5.3b. Analysis Ready Data (ARD) and Application Ready Data (ARD+): the CEOS Analysis Ready Data for Land (CARD4L) is useful to highly-trained remote sensing technicians with adequate computational infrastructure or access to cloud-based data processing modalities (e.g. CEOS Data Cube). There was agreement with the rapidly expanding volumes of data from new missions, increased attention to data access, continuity, and quality is needed. The breakout group discussing CARD4L emphasized the following priorities of high value to the agriculture community:

- Consistent atmospheric adjustment; excellent cloud, snow, and shadow masking
- Documentation on bandwidth impacts on interoperability, and how to adjust
- Making 10-30m time series coherent with historical 100+m resolution
- A thermal infrared product family specification

Beyond this technical discussion, many users expressed a need for Application Ready derived (ARD+) products, such as NDVI anomaly or long-term vegetation index time series, in order for facilitate application and sustained use. For this, access to archival datasets is critical, and still an interest area for GEOGLAM. Looking forward, GEOGLAM will work with CEOS to better define the needs for agricultural monitoring analysis, toward the generation of "Application Ready Data" (ARD+).

5.3c. Standard Agricultural Products in Support of International Policy Drivers: Due to the proliferation of EO-based data products, the demand for policy-relevant, actionable information is only increasing. This evolving demand is coming from the perspective of market information; early warning and forecasting; climate change; Sustainable Development Goals (SDGs); and disasters. All require a more quantified approach to agricultural monitoring, as well as the ability to go beyond in-season metrics and look at state and change between season and longer term. As such, the group identified a need for consistently validated, standard agricultural products that can be leveraged alongside other data sources. The GEOGLAM focus is currently on a set of critical EO-based products that initially include cropland extent, crop type and area, yield forecast and estimation. Together these form the essential set of information required to meet the evolving needs of GEOGLAM clients. Development of requirements for a set of GEOGLAM "Essential Agriculture Variables (EAV's)" would augment the previous GCOS ECV's. Due to the fundamental nature of these variables they would support not only Paris Climate Accord metrics (adaptation, loss & damage, stocktaking) but also SDGs and the Sendai Framework for Disaster Risk Reduction.

To support the development of EAV's a coordinated effort between GEOGLAM and the CEOS Working Group Calibration/Validation's Land Product Validation (LPV) sub-group would be enormously beneficial to enable GEOGLAM to provide information support to the various users of GEOGLAM data as well as to the global policy frameworks enumerated in the previous paragraph. The GEOGLAM JECAM sites, which have the benefit of coordinated CEOS data acquisitions, would be ideally positioned to initially facilitate LPV activities associated with the EAV's. The JECAM sites could be augmented by additional sites in nations that are already doing operational monitoring (e.g. China, Canada, Ukraine, Argentina). Such a coordinated effort would inform best practices, enhance rigor, and promote clarity around the value of EO to the SDG community, which is currently led and dominated by the statistical census and field survey community. It is suggested that the joint CEOS Ad Hoc WG on GEOGLAM be tasked with developing the community requirements and outlining validation protocols for these variables.

5.3d. Data Continuity and Observation Priorities: The following data sets, products, or data characteristics were articulated as of high priority. Roughly ranked by most important to least (with operational priorities occupying slots 1-4, and research 5-6):

1. For all agricultural systems, 10-30m time series product, coherent with historical 100m+ observations
2. For smallholder systems, <10m data with high temporal resolution (cloud-free weekly to biweekly)
3. Passive microwave continuity
4. ~50m thermal observations every 2-3 days
5. In addition to Sentinel 1, access to multi-frequency SAR systems (including X and L), as well as access to upcoming C-band SAR systems (e.g. Radarsat Constellation mission)
6. Missions with bandwidths at 1.9, 2.0, 2.1 microns to target soil quality and organic content monitoring, for implications in tillage monitoring or other emerging policy frameworks (e.g. COP21's 4 pour 1000).

5.3e. Coordination on Capacity Development Activities: GEOGLAM recognizes the evolution and improvement of its monitoring activities will be guided by strengthening capacities at the national

and regional level. Generally within GEOGLAM, we have acknowledged a need for an Initiative-level approach to capacity development and operational transition of research and technologies. It is essential to coordinate efforts by multiple actors working in the same countries and regions – and to have those efforts driven by end-user needs – in order to respect national processes and priorities while maximizing the impact of training investments. Essentially our experience to date has indicated that at sub-global scales, unless there is in country or region ownership of the information development, uptake by the policy community is generally poor. Consequently GEOGLAM sees value in ensuring our Thematic Coordination Team on Capacity Development and Operational Transition is calibrated and coordinated with the CEOS Working Group on Capacity Development.

One other message was identified as highly relevant to CEOS: the lack of continuous access to *in situ* data is a critical challenge for operational uptake of Earth observations. It was noted that while it is not specifically the role of CEOS, of its constituent space agencies, or of GEOGLAM to coordinate ground observation networks, this challenge should be brought to their attention as it is completely relevant to achieving space agency objectives of enhanced and sustained use of Earth observation in decision making.

These recommendations will be reviewed alongside an updated GEOGLAM Table of Earth Observation Acquisition Requirements (cf. Figure 1) during the annual CEOS Ad Hoc Working Group on GEOGLAM meeting in September 2018, as well as in the context of the CEOS Strategic Response to GEOGLAM Requirements, which will be presented to the CEOS Plenary for endorsement in October 2018 (see Section 6).

5.4. ICT Platforms: Status and Opportunities

The following ICT systems, platforms, or tools were presented, describing their objectives, usership, data sources, cost structure, and implementation status:

ICT System	Affiliation
ESA Thematic Exploitation Platform	ESA
COPERNICUS DIAS	European Commission
Copernicus Data in German Agriculture	Julius Kuhn Institut
CAP monitoring in the EU with Copernicus	EC JRC
Digital Belt and Road (DBAR): Big Earth Data	RADI-CAS
CEOS Open Data Cube	CEOS SEO
IKI VEGA	IKI
Sen2Agri	UCL

These presentations were complemented, again, by the survey. According to survey results, data users are accessing and/or utilizing data via a variety of portals, both public - ESA Food Security Thematic Exploitation Platform, IKI VEGA, ESA SciHub, USGS Earth Explorer and GLOVIS, NASA LP DAAC, and private – Amazon Web Services, Google Earth Engine, Sentinel Hub, MDA, and Innovative Platform Testbed (IPT). Most systems required a moderate level of remote sensing expertise to utilize the system (mean=2.75 on a Likert scale where 0 = None and 5 = Extensive), and all systems were designed for universal use (i.e. a single platform to fit all users' needs), though a few were also designed to be locally tailored.

The survey had low response (n=4) for this demographic category (self-identified data services developers, testers, or providers), but nevertheless provide an interesting snapshot into future questions which must be investigated by the GEOGLAM Thematic Coordination Teams on ICT and KMS. For example, respondents were equally leveraging cloud-based and local hardware solutions, and interoperability between datasets was identified as a key challenge and priority for moving forward.

#	Field	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	Total
1	I prefer to preprocess my own satellite datasets.	0.00% 0	25.00% 1	0.00% 0	75.00% 3	0.00% 0	4
2	I have access to all the satellite data sets my users need.	25.00% 1	0.00% 0	50.00% 2	25.00% 1	0.00% 0	4
3	I would like to incorporate new functionalities into my data service.	25.00% 1	75.00% 3	0.00% 0	0.00% 0	0.00% 0	4
4	I would like to link other data services with my own.	50.00% 2	50.00% 2	0.00% 0	0.00% 0	0.00% 0	4
5	I fully understand my user audience's needs.	25.00% 1	25.00% 1	25.00% 1	25.00% 1	0.00% 0	4
6	I would like to incorporate new satellite data products into my service.	25.00% 1	75.00% 3	0.00% 0	0.00% 0	0.00% 0	4
7	I would like to have access to spatially explicit data sets about crops for use in my service (e.g. Crop Calendar, Crop Mask, Crop Type Mask), that I do not currently have.	25.00% 1	75.00% 3	0.00% 0	0.00% 0	0.00% 0	4
8	I utilize local hardware to store, process, and serve data to clients.	25.00% 1	50.00% 2	0.00% 0	25.00% 1	0.00% 0	4
9	I utilize a commercial cloud-based service (e.g. Amazon, Google Earth).	50.00% 2	25.00% 1	0.00% 0	0.00% 0	25.00% 1	4

Figure 7: Responses from self-identified data services developers to a prompt to evaluate statements as they applied to them in their roles as data services developers, testers, or providers. The sample size is small, providing ample opportunity for better understanding to be reached during the Sanya meeting.

In particular, Statement 4 identifies the topic of interoperability or inter-use of data services platforms, and highlight's again GEOGLAM's curating role in providing connections between these initiatives. This was echoed in the breakout group on the state of the science, challenges, and opportunities for data access, storage, and utilization – GEOGLAM has a large role in federating different platforms and systems including developing an inventory, supporting user access to platforms, supporting platform access to required EO (Statement 2, Figure 8), and in general providing a guide to help users navigate the proliferation of services. Relatedly, there appears to be an opportunity to better connect developers with users of their system (Statement 5), which will have been facilitated through this meeting, which brought operational users and product developers together. However, this important work must be continued through GEOGLAM in general, with opportunities coming up at future meetings (see Section 6).

6. Next Steps

The next steps can be summarized in this bulleted list:

- EVENT: GEOGLAM Annual Meeting on KMS and ICT – Sanya, China 30-31 August 2018
    - Based on the outcomes of this Requirements meeting, the Sanya meeting will require advance work on three themes in order to concretely advance the initiative:

        - 1: Cloud Infrastructure for GEOGLAM: Inventory of ICT Platforms, Standards for Platform Documentation, Interactions with other Initiatives; Anything as a service.
        - 2: GEOGLAM Knowledge Management Hub: What exists? What should GEOGLAM's KMS include? How will it be managed?
        - 3: GEOGLAM Curated Datasets: Data life-cycle management; Documentation Standards and Quality, Timeliness, Validation, etc. Requirements to Qualify as a "GEOGLAM-endorsed" product or dataset
- EVENT: Earth Observation Technologies for Crop Monitoring: a JECAM Workshop to Promote Collaborations between Rice Monitoring Sites and Asia-RiCE – Taichung, Chinese Taipei (17-20 September 2018)
    - During this meeting, a community research agenda will be established and documented, providing important feedback to funding agencies in terms of key questions that we as a community need to answer.
    - A key objective of this workshop is to develop a compendium of best practices around in-demand agricultural products. This will complement efforts to curate proliferating datasets and methods.
- REPORT: GEOGLAM Requirements Holistic Characterization – September 2018
    - While this document has provided a review of the meeting and key outcomes and recommendations, there was more specific and detailed response regarding EO data, access, and use requirements culled through the survey as well as through individual presentations. A more detailed review of this will be developed in the coming months, (e.g. building on Whitcraft, Becker-Reshef, and Justice (2015), "A Framework for Defining Spatially Explicit Earth Observation Requirements for a Global Agricultural Monitoring Initiative (GEOGLAM)").
    - This will be the primary topic of discussion during the annual CEOS Ad Hoc Working Group on GEOGLAM meeting, jointly held with the CEOS Land Surface Imaging Virtual Constellation and CEOS Space Data Coordination Group meetings (EC JRC, Ispra, Italy; 5-7 September 2018).
        - At this meeting, ARD+ and EAVs should also be discussed.
        - It would be beneficial if representatives from CEOS Working Group Cal/Val LPV group were there.
    - This will be the baseline document to which CEOS can draft its Strategic Response to GEOGLAM Requirements (CEOS Deliverable AGRI-04, due 2018 Q4). This Strategic Response is set to be endorsed by CEOS Plenary in October 2018. This should also provide feedback into the Copernicus Expansion: Sentinel 2025 effort, as well as the Copernicus 2nd Generation: Sentinel 2030 effort.
- REPORT: GEOGLAM Operationalization Agenda – TBD
    - In order to complement the GEOGLAM community research agenda, GEOGLAM also needs to articulate its operationalization priorities and needs. Funding agencies have articulated a desire to support the development and maturation of operational systems and are awaiting this clear articulation from GEOGLAM.

Notes

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