CEOS Support for GEOGLAM's Essential Agriculture Variables

A rough proposal from GEOGLAM for discussion by LSI-VC

Executive Summary

This is a white paper drafted by GEOGLAM Essential Agriculture Variable (EAV) Co-Leads Alyssa Whitcraft (GEOGLAM Programme Scientist) and Sven Gilliams (GEOGLAM Director), with feedback from Symbios Team and Peter Strobl, for discussion with CEOS and the constituent space agencies to identify a strategic path forward for "implementing the EAVs" - meaning either aligning the conditions for the production of the EAVs as products or creating the products themselves. Like the Essential Climate Variables before them, the EAVs are Earth observation-based "building blocks" that in combination with one another or with other non-EO information support actionable, policy-required information on the state, change, and forecast of agricultural land use and productivity.

This white paper posits some potential areas of support from CEOS and the agencies - some of which have already begun, and which we hope to expand - and identifies a road map for GEOGLAM-side effort to provide (what we view as) the necessary effort to create EAVs in a more sustained manner toward meeting GEOGLAM's mandate from the G20 2011, and renewed each subsequent year[1].

[1] In 2023, the G20 renewed its support for GEOGLAM, "to enhance agricultural market transparency and support coordinated policy responses for food security and nutrition." They further "reaffirmed their commitment to support strengthening of AMIS and GEOGLAM for greater transparency to avoid the negative impact of food price volatility (G20 New Delhi Update, 2023)."

GEOGLAM Refresher & EAV Background

The GEOGLAM Programme is a "bottom-up, best-efforts" initiative that operates as as Agriculture Monitoring Community of Practice - composed of practitioners of remote sensing of agriculture (from R&D through operational use) - with a small secretariat that performs essential internal, cross-project coordination and assimilation into the Programme as well as outward-facing functions including fundraising, liaising with projects, communicating with the G20 and UN frameworks, releasing monthly Crop Monitor reports, and developing Earth observation acquisition, quality, and access requirements and communicating them to CEOS via the Land Surface Imaging Virtual Constellation (LSI-VC). That latter effort is co-led by Alyssa Whitcraft and Sven Gilliams, and is situated as a key cross-cutting activity within the GEOGLAM framework (**Figure 1**).

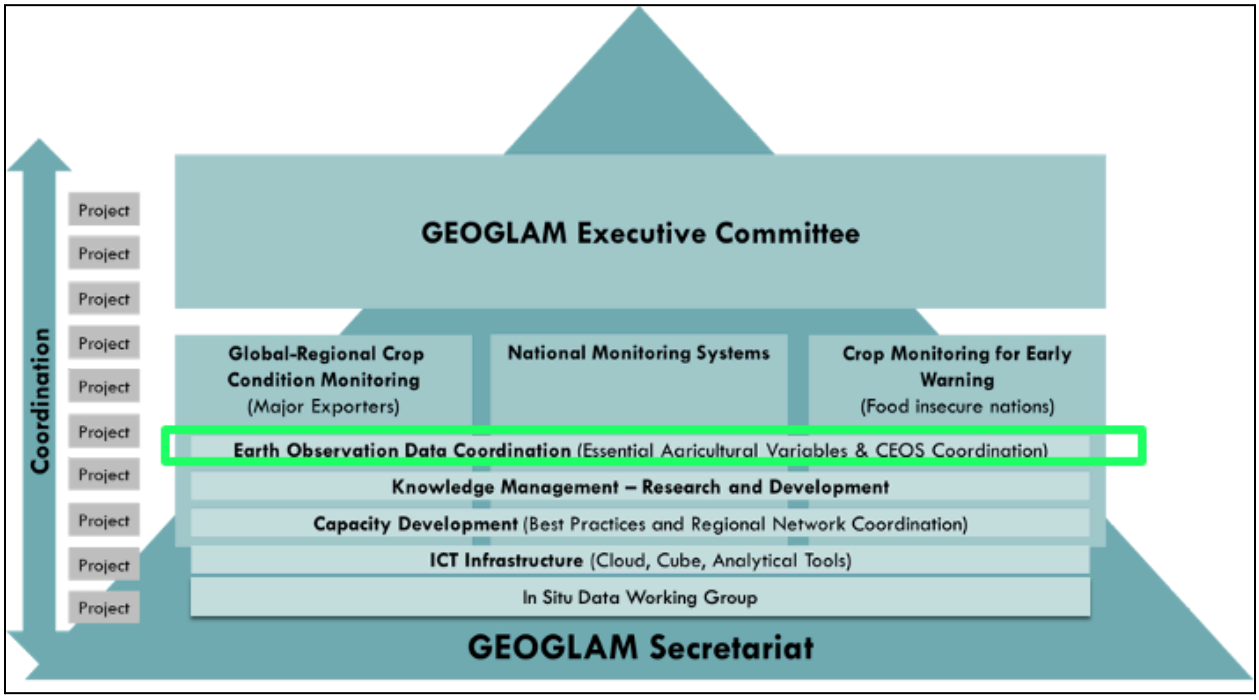

Figure 1: GEOGLAM Programme Schematic, with the EO Data Coordination Effort highlighted, within which the Essential Agriculture Variables Working Group sits.

The EAVs emerged as a priority for GEOGLAM in 2018 as a mechanism for bringing cohesion and integration from EO to impact in an increasingly complex policy environment. Learning from the Essential Climate Variables (ECVs), EAVs for GEOGLAM are Earth observation-based "building blocks" that in combination with one another or with other non-EO information support actionable, policy-required information on the state, change, and forecast of agricultural land use and productivity. . GEOGLAM covers land devoted to agriculture, which is defined as the systematic and controlled use of land and livestock to produce food, fiber, and fuel. This includes croplands, rangelands, and short-term fallow lands. The EAVs can be measured or inferred from satellite data, and are supported through field data for calibration and validation. They support the core work of GEOGLAM and its constituent communities, including supporting national and global policy frameworks (e.g. G20 Action Plan and UN Sustainable Development Goals; **Figure 2**).

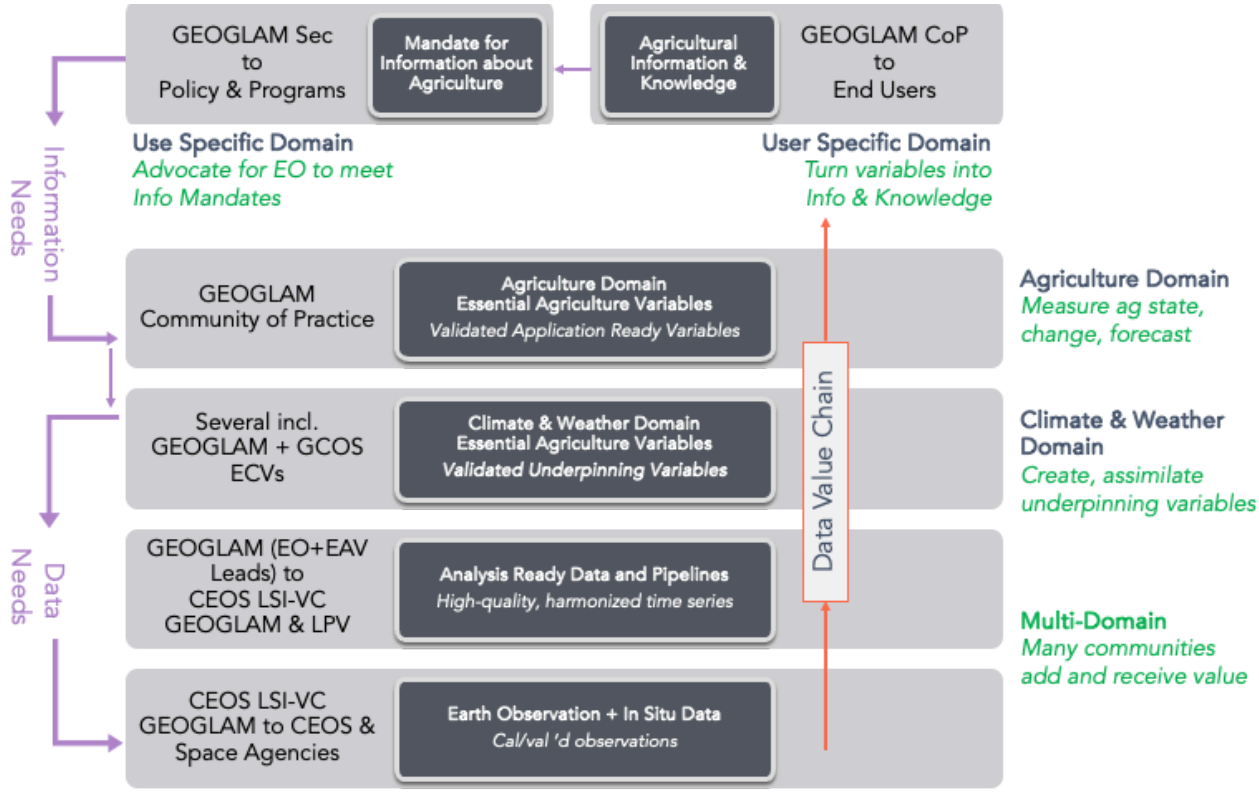

Figure 2: Actors and Activities in Operationalizing the Use of EO for Agriculture Monitoring. CEOS is an implicated actor particularly at the foundational forms of data evolution (bottom). This figure also illustrates the key role of the EAVs in both advancing the data value chain toward use, as well as in communicating the data needs (aka requirements) back to CEOS and the agencies.

The list of EAV and their specifications were developed by the GEOGLAM EAV Working Group between 2019 and 2022 under the co-leadership of Whitcraft and Gilliams. They include spatial binary land use variables ("masks"), spatial categorical variables, spatial continuous variables, and non-spatial continuous variables (e.g. area estimates; production estimates; **Figure 3**). They include both "agriculture domain" and "climate and weather domain," with the former's specifications being articulated by operational users and the latter borrowing heavily from the ECVs (**Figure 4**). They overlap *by design* so as to reduce operational burden for space agencies and scientists, and maximize the ease of harmonization with other land and atmosphere communities in efforts such as those implicated in UNFCCC Global Stocktake.

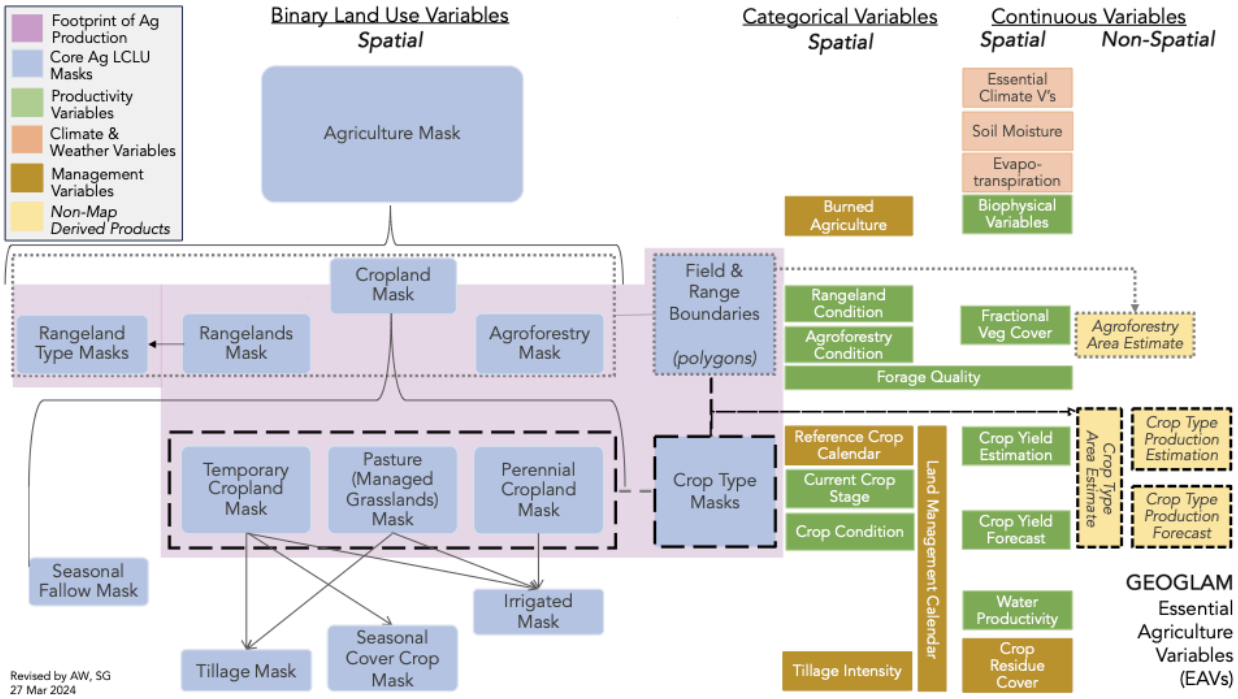

Figure 3: GEOGLAM EAVs:

They are vertically aligned as (a) Spatially explicit binary land use variables (shown in Blue), which comprise the core agriculture land use and land cover masks; (b) Spatially-explicit discrete variables related to productivity and management; (c.1) Spatially-explicit continuous variables related to productivity, land use, and climate and weather variables (many of which overlap with the Essential Climate Variables (ECVs), by design); and (c.2) Non-spatial continuous variables, namely production and area estimates for a given geographical unit.

They are further horizontally aligned as they relate to one another, e.g. we would want soil moisture, biophysical variables, ECVs, evapotranspiration, and burned agriculture all produced at the agriculture mask extent; e.g. tillage intensity need only be produced at the tillage mask extent; e.g. water productivity need only be produced at the irrigated mask extent.

There are relationships indicated by arrows and the summary swoopy shape (vertically) wherein EAVs either above subsequent EAVs or at the origin of arrows are the “sources” or extent of the below or the end of arrows.

Lastly, you will note that only 50% of “Cropland Mask” falls within the purple box, which indicates the “Footprint of agriculture under production” - this is because Seasonal Fallow Mask is not currently producing food, fiber, or fuel, but has not been removed from agriculture permanently.

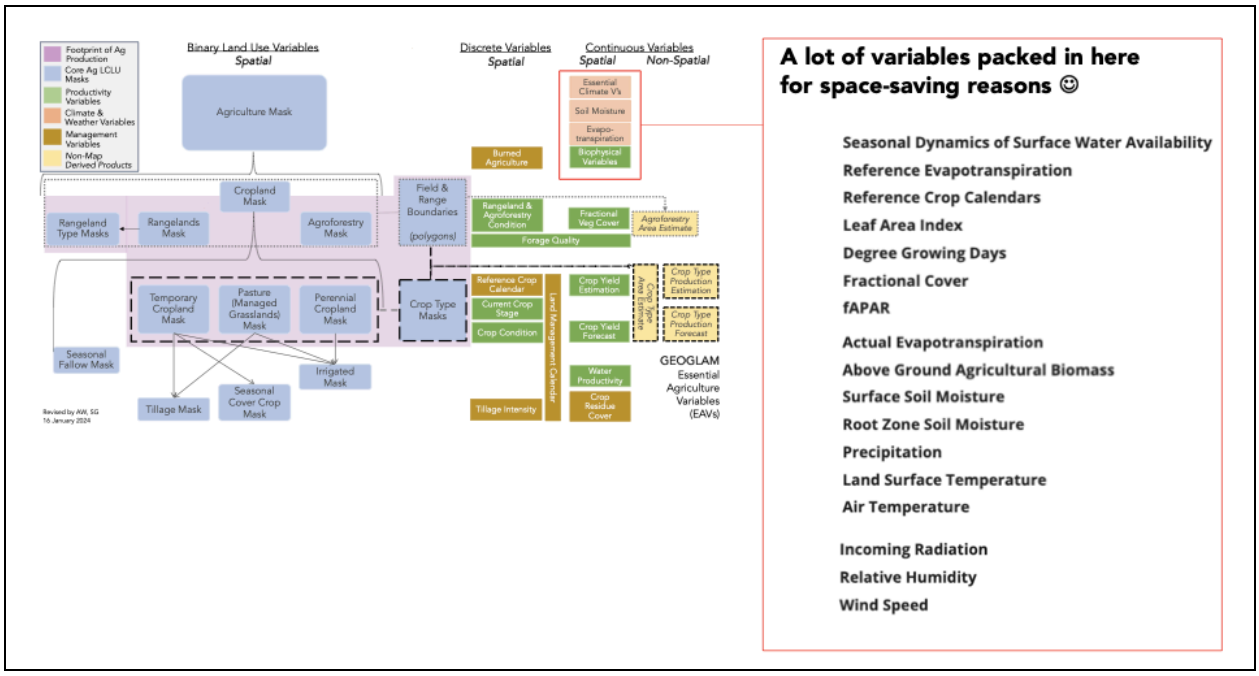

Figure 4: For space saving, many variables are nested in what is highlighted here in a red box, and expanded at right - several of which are ECVs.

Creating EAVs Products and/or Pipelines

While the variables have been articulated, there remain critical gaps in the production of the EAVs as either standard products or as "pipelines" to generate the products (e.g. open source tool-kits, user-friendly interfaces). To that end, GEOGLAM has articulated:

A. Product Specifications and Requirements - what "counts" as an EAV?
B. A gap analysis framework to identify what is missing from different user and use cases in order to fully operationalize them, a key component of which is variable assessment (**Figure 5**).
C. An identification of means to undertake the Gap Analysis (**Figure 6**).
D. Proposed realms of collaboration with CEOS to address gaps (**Figure 7**).
E. Early success with CEOS

A. EAV Product Specifications & Requirements

The GEOGLAM EAV Working Group is formulating requirements for GEOGLAM EAV Products and a transparent process for vetting/endorsing products generated by the broader GEOGLAM Community of Practice as compliant with EAV definitions and minimum ('threshold') or target specifications. While not final, the basic guidelines In order for a product, or pipeline to create a product, to be recognized as a GEOGLAM EAV:

- The product (or pipeline to create it) must meet the definition for the specified EAV, including any stated minimum accuracy requirement or "product generation notes"
- If released as a product, it must be generated at a minimum of national-scale.

- The product must have a documented accuracy assessment / error estimation / validation; or, if a pipeline, must include clear guidelines for undertaking accuracy assessment;
- The product or pipeline should be freely and publicly available (acknowledging the necessity of spatially degrading certain products due to privacy concerns around certain EAVs; a larger discussion beyond the scope of this white paper).
- The product or pipeline should have documentation in the form of a peer-reviewed paper, but at a minimum must have clear documentation.

B. EAV Gap Analysis Framework

Whitcraft and Gilliams developed a holistic "Gap Analysis Framework" that identified for a specified use case the different conditions for the production of Climate and Weather Variables (C&W Variables), the conditions for the production of Agriculture Domain Variables ("Ag Variables" which often require C&W variables), and the conditions for putting the operationally adopting EAVs in producing Agriculture Information and Knowledge (**Figure 5**, read bottom to top). Most germane to CEOS are the "Summarized Variables Conditions" and of course the individual Ag Domain and C&W Domain Variable Conditions.

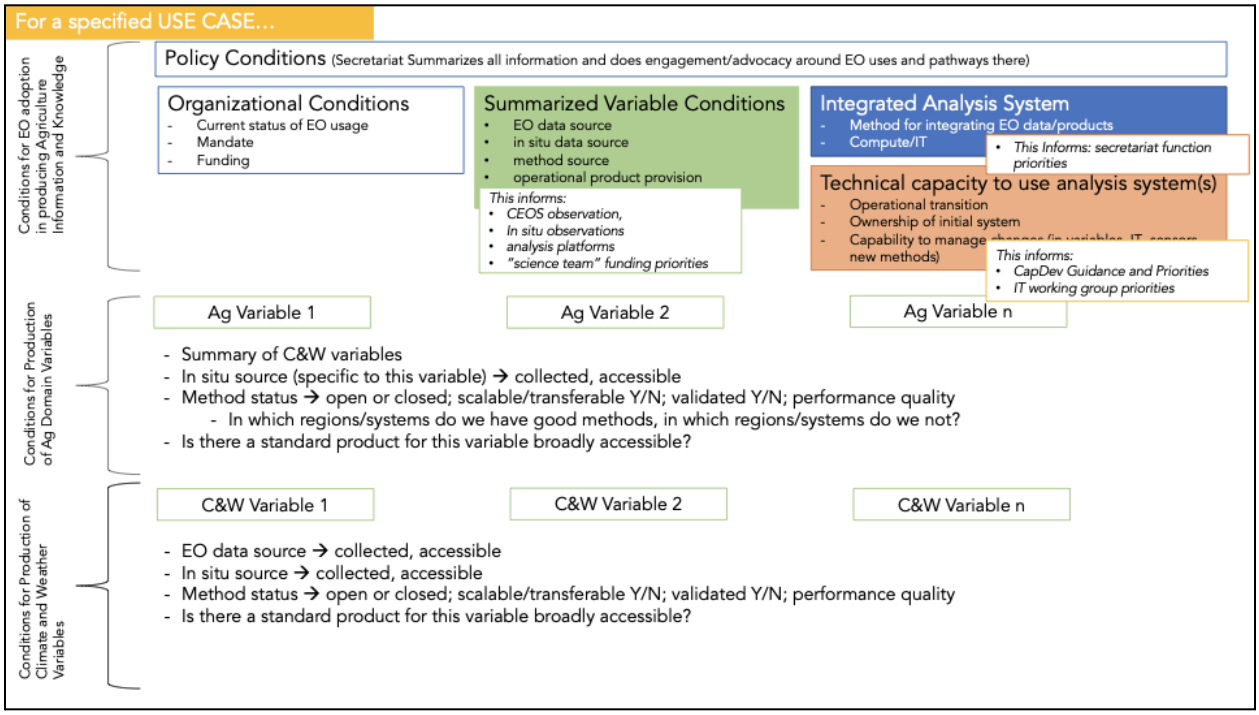

Figure 5: The GEOGLAM EAV Gap Analysis Framework that details (from bottom to top) the different conditions for the production of Climate and Weather Variables (C&W Variables), the conditions for the production of Agriculture Domain Variables ("Ag Variables" which often require C&W variables), and the conditions for putting the operationally adopting EAVs in producing Agriculture Information and Knowledge.

C. Roadmap to the Undertaking the EAV Gap Analysis

The Gap Analysis will be undertaken per use case where GEOGLAM or its constituent operational monitoring programs (national, regional, and global; Figure 1) are failing to fully implement EO in their decision or reporting process. At present, the Gap Analysis is GEOGLAM Executive Committee "approved" framework (inasmuch as GEOGLAM approves things), but there has not been a full use-case evaluated yet. However, the core work of GEOGLAM per its G20 mandate and the UNFCCC AFOLU has been suggested as potential cases.

Irrespective of the full-use case identification, however, it is possible to undertake the analysis for the individual Ag Domain and C&W Domain Variable Conditions. **Figure 6** provides a "Checklist" toward the conditions to Operationalize the EAVS. A key component to all variables is error quantification / accuracy assessment / validation - to which there are countless approaches and for which being prescriptive about required minimum accuracy is generally not appropriate (given that it will be user- or use-defined). Through a new GEOGLAM Initiative on Agriculture Product Quality, we have begun to develop reviews of current approaches to and good practices for product validation (See ***Early Successes***).

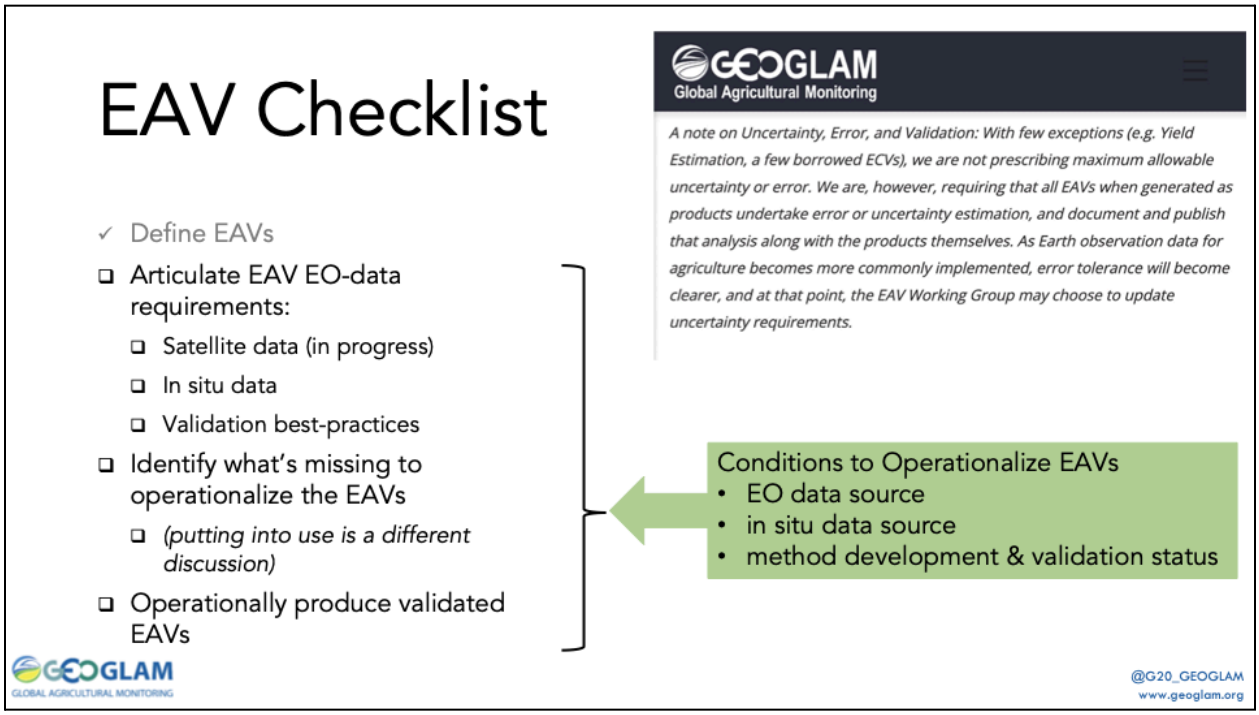

Figure 6 : EAV Checklist (as presented at the Joint Workshop in Sept 2023)
(High-level Workshop Report (link); Best Practices Publication in Prep)

D. Proposed Realms of Collaboration with CEOS to Address EAV Gaps

Broadly summarized, the proposed realms of collaboration with CEOS include:

1. Update the GEOGLAM Requirements Table with Observation Requirements (**Figure 7**)
    a. Through EAV Steward Input

   b. Then → assess missing observation capabilities with USGS RCA and CEOS MIMS?
2. Identify gaps and opportunities for easing access to and utilization of satellite data in the production of EAVs
   a. WGISS
3. Assess method status with respect to its quality and scalability/transferability.
4. Develop Validation Good Practices via the GEOGLAM Initiative on Product Quality
   a. Through Community Workshops with WG Cal-Val
5. Develop guidelines for the collecting of calibration and validation “in situ” data
   a. Through the GEOGLAM In Situ Working Group
   b. Informed by the GEOGLAM Initiative on Product Quality

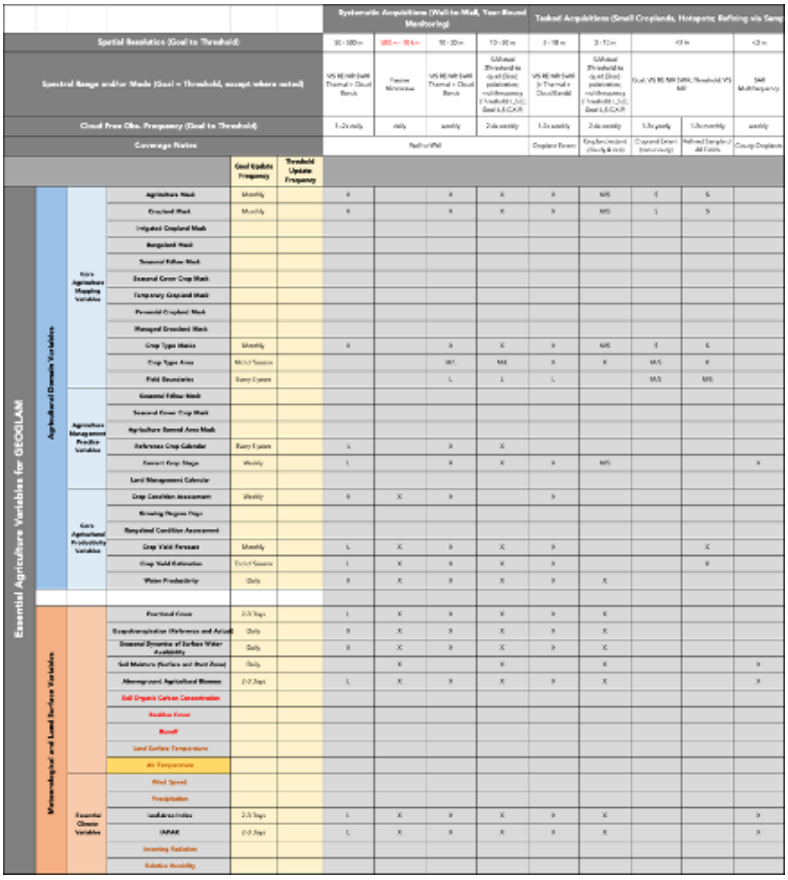

Figure 7: An outdated, incomplete, and thoroughly illegible version of the GEOGLAM Observation Requirements Table which contains rows of variables and columns of product update frequency (yellow highlight; threshold and target) and corresponding observations useful and/or necessary to create said variable. GEOGLAM will need to fill this in, and has identified a means of collecting the info.

There are multiple connections between GEOGLAM and CEOS which address the above assessment realms, which are summarized in **Figure 8**, and briefly enumerated in the above list.

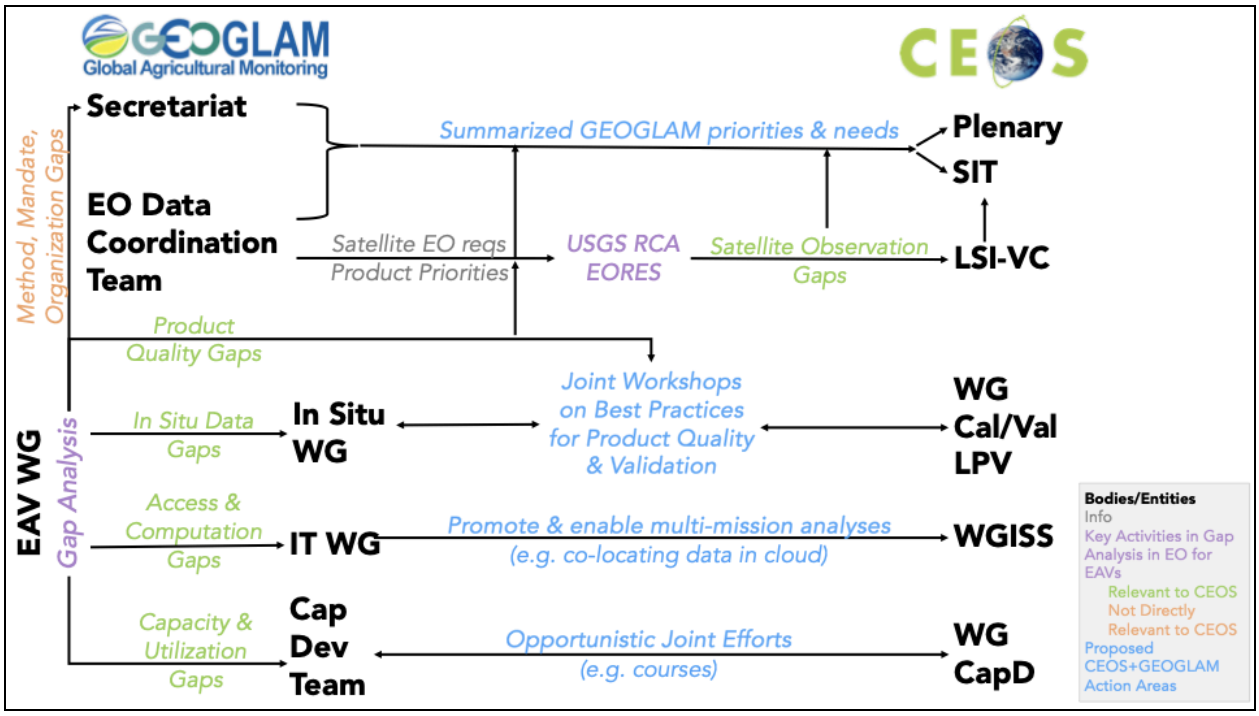

Figure 8: Realms of engagement between GEOGLAM and CEOS

E. Early Successes

With CEOS:

- CEOS LPV - GEOGLAM Joint Workshop on Product Quality / Validation Best Practices for Cropland and Crop Type Mapping
- Scoping next workshop on Evapotranspiration
  - CEOS LPV Group emerging on ET → Mike Cosh, Yun Yang
  - Working with OpenET and broader GEOGLAM ET community (e.g. Sen4ET, UN FAO) to define similar workshop
- ECVs created by various agencies

Other:

- Multiple projects which are generating EAVs already
  - GEOGLAM Crop Monitor → Crop Condition
    - Inputs from multiple national, regional, and global condition monitoring organizations
  - World Cereal → Crop Type maps for Wheat, Corn; working on Soybean and others
  - Asia-RiCE → many variables for rice
  - NASA Acres → organized around the EAV concept, focused on the US…

    Advancing Methods for Core Mapping of Essential Agriculture Variables for US Agriculture
    - Within-Season Yield Forecasting
    - Historical Yield Estimation
    - Cropland and Crop Type Mapping
    - Crop Area Estimation

    - Crop Planting/Harvest Dates
    - Field Boundaries and Sizes
    - Cover Crop Utilization and Performance
    - Crop Residue and Tillage Mapping
    - Canopy Nitrogen Content
    - Rangeland Productivity and Utilization
    - Pest & Disease Mapping
    - Soil Organic Carbon and Other Metrics of Soil Health
    - Evapotranspiration (leveraging OpenET)
  - GEOGLAM In Situ Working Group and JECAM identifying in situ datasets for model/algorithm training and accuracy assessment.
  - Copernicus Land Services (peter.strobl@ec.europa.eu want to add?)
- Many ECVs
  - Copernicus Land Services

Next Steps

This is the big question - what can we accomplish with and through CEOS?

Sub questions:

- Which agencies would produce EAVs in the medium to long-term, pending successful adoption?
  - Is the supposition that demonstration of success would lead to operational support from agencies (in one way or another) a *good* one? Or should we abandon that possibility (we don't want to set up unrealistic expectations among users).
  - Which agencies would fund the development of EAV methods?
  - Which agencies would be open to the idea of cross-mission harmonization?
- Would CEOS working groups (or contributing agencies) throw effort behind any of the "activities" in **Figure 8**?
  - How would we most successfully make that ask?
  - (*Matt's idea of using Karen/Julie presentation??*)
- What is the best way to work any of this through CEOS?
  - Sydney SIT-TW might be the time/place to make the actual ask that would then go to Plenary (*is this right??*)

Some suggestions:

- We should take stock of where we are on each EAV (gap analysis) and what is or is not working WRT to data access and products/services?
  - e.g. Peter Strobl was asking about whether the Copernicus Services was "enough" and if so, if that could be a model for others (*something like this???*)
  - I said we need to get the EAV Stewards on this, but broadening participation would be good - this might be an LSI-VC effort area
- CEOS LSI-VC could provide the platform for streamlining discussions with ECV, EBV - how do we harmonize between the requests?
  - Finding overlap, promoting middle ground
  - Interoperability discussion - creating efficiency
  - Who are the ECV PoCs for this? - maybe WG Climate

    - Who are the EBV PoCs for this? -
- We need to identify agency points of contact for the CEOS LSI-VC sub-group on GEOGLAM; Sven is working on this with the GEOGLAM Co-Chairs and we need input from CEOS as well:

Agency	**Name - Observations Side**	**Name - Products / Operations Side**	**Contact Info**
NASA		Brad Doorn	
ESA	Ben	Zolti	
JAXA		Shin-Ichi	
CSA			
INPE			
ISRO			
NOAA			
USGS			
CSIRO	Alex Held?		
GeoScience Australia			
CONAE			
DLR			
CMA? Or other Chinese			