GEOGLAM GLOBAL AGRICULTURAL MONITORING USER REQUIREMENTS

1. Introduction

This document is the outcome of a working group meeting held at the Canadian Space Agency in Montreal, Canada, on July 10 and 11, 2012, to define the User Requirements for CEOS. Since that meeting, the requirements have been refined. These requirements are designed to meet the needs of the GEOGLAM program, which will be phased over six years. Meteorological parameters are not identified in this document and will be addressed in another forum. It was recognized that there is a need at a subsequent stage for the development of a global sampling strategy concerning very high resolution data acquisitions.

The objective of this exercise was to provide CEOS with an understanding of the agricultural monitoring observation requirements for GEOGLAM and initiate a process by which those requirements can be translated into operational data acquisition. The desired outcome was a document that could be subsequently used by the CEOS space agencies to identify specific EO sensors and data acquisition requirements to address GEOGLAM EO-related observation and information needs.

The agenda was structured to answer the following questions:

1. WHAT thematic information is needed? (crop type, yield estimates, soil moisture, others),
2. WHERE should the measurements be taken and at what level of detail? (spatial issues like geographical areas, minimum mapping units), and
3. WHEN should the measurements be taken? (temporal issues like crop calendar, frequency of acquisition).

2. Required Observations

Table 1 shows the range of observations that were identified. The observations were classified by spatial, spectral and temporal resolution, effective observation frequency (cloud-free), swath and sample/ refined or wall-to-wall. For each category of observations, the information products that could be derived using this observation were identified. Some of the table entries depend on field size, where large /medium /small field size is defined in the table notes. Region specific acquisitions were addressed, specifically rice crop monitoring. Spatial resolution requirements are generated relative to field size; this is preliminary and could be refined/improved with a consideration of landscape heterogeneity and spatial pattern.

OBSERVATION & SENSOR TYPE			REGIONAL CHARACTERISTICS & GEOGRAPHICAL EXTENT						DERIVED PRODUCTS & MONITORING APPLICATONS							
SPATIAL RES.	SPECTRAL RES.	TEMPORAL RES.	WHERE? (+ cropland mask & sampling scheme)				WHEN?									
Spatial resolution	Spectral range	Effective observ. frequency (cloud free)*	Swath / Extent	Sample (s), Refined (rs) or Wall -to-Wall (w2w)	Large, Medium, Small fields	Crop types diversity	Calendar/ Multiple cropping	Cloud coverage	Use (Primary or Secondary Source)	Croplands mask	Crop type area	Crop cond. indicators	Crop bioph. var.	Env. variables (reservoir, water, soil moisture)	Ag. Practices / Cropping systems	Crop yield
2000 - 500 m	thermal IR + optical	few per day	global	w2w					NRT products (PS)			x	x (L)			
100-300m	optical + SWIR	2 to 5 per week	global	w2w	L/M/S		*		NRT products (PS)	x	x	x	x (L)		x (L)	x (L)
1-15km	passive microwave	daily	global	w2w					NRT products (PS)					x		
50-150 m	SAR dual pol. (X,C,L) ****	5 per season	main crops	s	L/M/S	rice area	entire growing season	high cloud cov.	NRT products (SS/PS)*	x	x	x	x (L)	x	x (L)	
5-20m	SAR dual pol. (X,C,L) ****	5 per season	main crops	s	L/M/S	rice area		high cloud cov.	NRT products (SS/PS)*		x	x	x	x	x	
Footprint	RADAR Altimetry	weekly		s					NRT products (PS)					x		
50-100m	thermal	daily ?	main crops	s	L/M/S		entire growing season		NRT products (PS)			x				
20-70m	optical + SWIR	1 per month (if possible same sensor) (min 2 out of season + 3 in season)	croplands	w2w	all M/S		year-round, focus on growing season		annual products (PS)	M/S	M					
20-70m	optical+SWIR	1 per week (min. 1 per 2 weeks)	main crops	s	country specific (see phasing) L/M/S		entire growing season		NRT products (PS)	L/M/S	M/S	x	x	x	x	
5-10 m	optical (+SWIR)***	1 per month (if possible same sensor) (min 2 out of season + 3 in season)	croplands	rs	L/M/S (focus on S)		year-round, focus on growing season		annual products (PS)	L/M/S	L/M/S					
5-10 m	optical (+SWIR)***	1 per week (min. 1 per 2 weeks)	main crops	rs2	country specific (see phasing) S		entire growing season		NRT products (PS)			x	x	x	x	
< 5 m	optical	1 to 2 per month	croplands	rs3	demo. case (2 - 5% of croplands L/M/S)		2 - 4 coverages per year		annual products (PS)		x				x	x

* PS in regions with frequent cloud cover, valid observation frequency expected during the agricultural season in cloudy regions

** according to agro-systems constraints (2° by 2° DB)

*** SWIR is the goal, recognizing that only SPOT-5 has these spatial and spectral resolutions

**** X band SAR is powerful for estimating rice crop area but X-SAR may not be suitable for rice crop growth status because it saturates under heavy cloud / rainy conditions, which are common in rice growing regions of Asia.

x = yes

L = large field (>15 ha)

M = medium field (2.5 ha-15 ha)

S = small field (<2.5ha)

w2s= wall to wall

s= sample

rs= refined sample (subset of larger sample)

NRT : Near-Real Time in the context of monitoring crop conditions and stages means that the goal is to make data accessible to users within 48 hours

Phases for GEOGLAM

(1) = Tentatively 3 producer countries (Argentina, Australia & Ukraine) & 1 at-risk country (Uganda); Nov 2012 - Nov 2014 (TBC in Feb 2013)

(2) = Adding 5 more countries; improved sampling for main producers & possibly at-risk countries (Mar 2014 - Nov 2015) - Preliminary Design Phase

(3) = All major producers & 5 at-risk countries (completed by Nov 2017) - Critical Design Phase

Table 1: Required Observations

Main crops typically refer to wheat, rice, maize, and soybeans; for at-risk countries, this will vary. Meteorological parameters (snow cover, temp., rainfall, etc.) are not included in this table and will be addressed in another forum. Sample size will vary according to field size; samples need to be coordinated and nested- the more frequent the temporal resolution requirements, the fewer the sample sites.

Information type	Requirement priority			*Relevant satellite EO products*
	Timeliness	Consistency over time	Accuracy	
Monitoring and early "warning" systems				
Rainfed planted area outlook	+++	++	±	*Cultivated crop type/crop cluster map*
Irrigated crop outlook	+++	++	±	*Water availability (incl. reservoir height)*
Early acreage estimate	+++	++	±	*Early Crop Acreage statistics*
Crop condition (anomalies, stress indicator)	+++	+++	±	*Index (VI, etc), Crop variables (LAI, ET, etc)*
Yield forecast	+++	++	+	*Index (VI, etc), Crop variables (LAI, ET, etc)*
Early production estimate	+++	++	+	*Yield forecast & Early Crop Acreage stat.*
Precision Agriculture				
Parcel variability (for different growing stages)	++	+++	++	*Index (VI, etc), Crop variables (LAI, ET, etc)*
Nutrients status	++	+++	++	*Index (VI, etc), Crop variables (LAI, ET, etc)*
Weeds and pest	++	+++	++	*Pest control product*
Water status	++	+++	++	*Water stress /drought*
Control				
Damages indicator (insurance)	++	+++	++	*Index (VI, etc), Crop variables (LAI, ET, etc)*
Illegal crop detection (poppies, etc)	+++	±	+	*Cultivated crop type/crop cluster map*
Crop and management compliance (e.g. EU CAP)	+++	±	+	*Cultivated crop type/crop cluster map*
Cropping practices control (tillage, residue, etc)	+++	±	+	*Cultivated crop type/crop cluster map*
Statistics systems				
Cropland area and change	+	+++	+++	*Cultivated crop type/crop cluster map*
Yield estimate	+	+++	+++	*Index (VI, etc), Crop variables (LAI, ET, etc)*
Crop acreage statistics	+	+++	+++	*Crop Acreage statistics*
Crop production statistics	+	+++	+++	*Yield estimate & Crop Acreage statistics*
Irrigated crop statistics	+	+++	+++	*Cultivated crop type/crop cluster map*

Table 2: Relevant Satellite EO Products for Various Required Information

Table 2 shows how EO derived products from Table 1 will contribute to answer agricultural information needs, and what are the corresponding requirement priorities in terms of timeliness, continuity / consistency over time, and accuracy. Information types are ordered following the seasonal chronology. GEOGLAM priorities will focus on "Monitoring and early warning systems" and "Statistics systems" while "precision agriculture" and "control" can be relevant either for methodology development (R&D) or national capacity development. The level of priority increases with the number of "+"; "±" relates to anomaly detection and change detection.

Agricultural landscapes	Coverage	Large fields - low to high crop diversity	Small fields (< 2ha) - no crop diversity	Small fields (< 2ha) - high crop diversity	Precision farming - sub-parcel level
Satellite EO products		spatial resolution and valid observation frequency			
Near real time to 'Weekly' products					
7-day (10-d) monitoring products					
Index (NDVI & other VI, WSI)	global croplands	100-250 m / daily	100-250 m / daily	100-250 m / daily & 5-10 m / weekly	1-10 m / weekly
Crop variables (LAI, fAPAR, , ET, biomass, DMP)	global croplands	100-250 m / daily	100-250 m / daily	100-250 m / daily & 5-10 m / weekly	1-10 m / weekly
Water availability (incl. reservoir height)	irrig. croplands	Lidar ? / SAR ?	Lidar ? / SAR ?	Lidar ? / SAR ?	Lidar ? / SAR ?
Hazard products					
Crop damage area (disease, winter kill, storm,etc)	regional focus	100-250 m / daily	100-250 m / daily & 10-30m/weekly	5-10 m / weekly	1-10 m / weekly
Water stress /drought	regional focus	100-250 m / daily	100-250 m / daily & 10-30m/weekly	10-30m / weekly (incl. SAR)	10-30m / weekly (incl. SAR)
Pest control (e.g. locust) product	regional focus	100-250 m / daily	100-250 m / daily & 10-30m/weekly	10-30m/weekly	1-10 m / weekly
Flooding extent	regional focus	10-30m/every 3 days (mainly SAR)	10-30m/every 3 days (mainly SAR)	10-30m/every 3 days (mainly SAR)	10-30m/every 3 days (mainly SAR)
Annual products					
Early Crop Acreage statistics	global croplands or area frame sampling	100-250 m / daily & 10-30m / biweekly	100-250 m / daily & 10-30m/weekly	5-10 m / biweekly	n.a.
Cultivated crop type/crop cluster map	global croplands or area frame sampling	10-30m / biweekly (+ SAR time series)	10-30m/ biweekly (+ SAR time series)	10-30m/ biweekly (+ SAR time series)	n.a.
Crop Acreage statistics	global croplands or area frame sampling	10-30m / biweekly	10-30m / biweekly	5-10m/biweekly	n.a.
Multi-annual products					
Global cropland mask	global	10-30m/biweekly	5-10m/biweekly	5-10m/biweekly	n.a.
Global irrigated map	global	10-30m/ biweekly (incl. SAR)	5-10m/ biweekly (incl. SAR)	5-10m/ biweekly (incl. SAR)	n.a.
Global cropping intensity map (cycles)	global croplands	100-250 m / daily & 10-30m / biweekly	100-250 m / daily & 10-30m/biweekly	100-250 m / daily & 5-10m/biweekly	n.a.
Global cropping systems map (field size, crop diversi	global croplands	10-30m/ biweekly	5-10m/biweekly	5-10m/biweekly	n.a.

	100-250m	10-30m	5-10m	1-10m
daily	X			
3 days		X		
weekly		X	X	X
bi-weekly		X	X	

Table 3: Spatial Resolution and Observation Frequency for Various Satellite EO Products

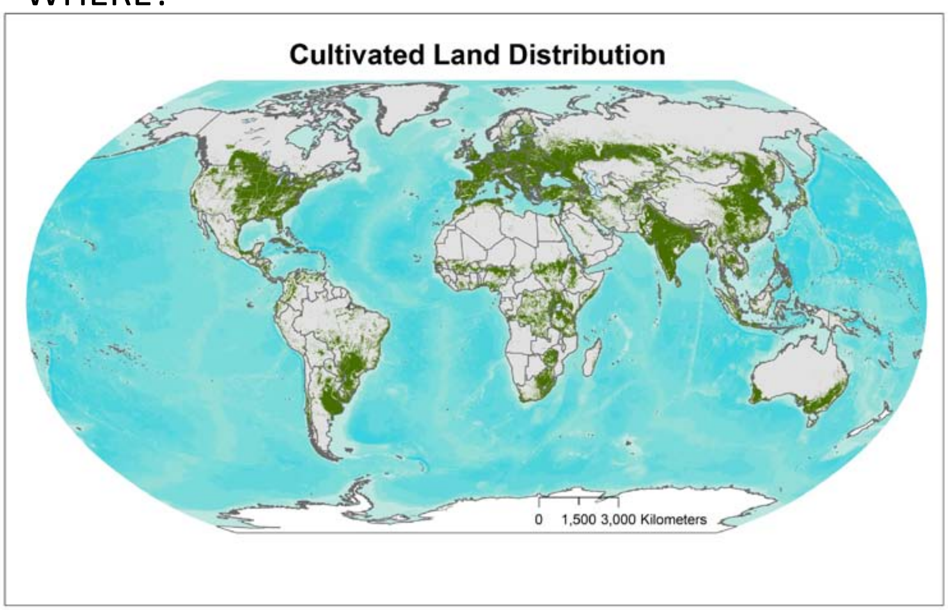
Table 3 shows the spatial resolution and observation frequency requirements for various satellite EO derived products (Table 1) depending on the agricultural production systems (crop diversity and field size). This table details Table 1 by taking into account specifities in the type of agriculture. Satellite EO products are ordered in intra-seasonal, annual and multi-annual. Major requirement constraints (5-10m weekly) appear for regions with high crop diversity and small fields. Very high resolution (1-10m) would be dedicated to pilot areas. The monitoring of water availability (soil moisture, river and reservoir level) will mobilize SAR, interferometry, and in a longer term Lidar.

3. Spatial and Timing Components

This section contains the spatial and timing components required to qualify, characterize and develop a multi-scale/stratified observation scenario. It includes a series of multi-scale shape files (maps) and related crop calendars for the various cropping regions identified in the table. Specific area coverage maps and crop calendar information is provided at global and regional scales. Cloud cover maps are included, as are area maps and crop calendars specific to rice cultivation.

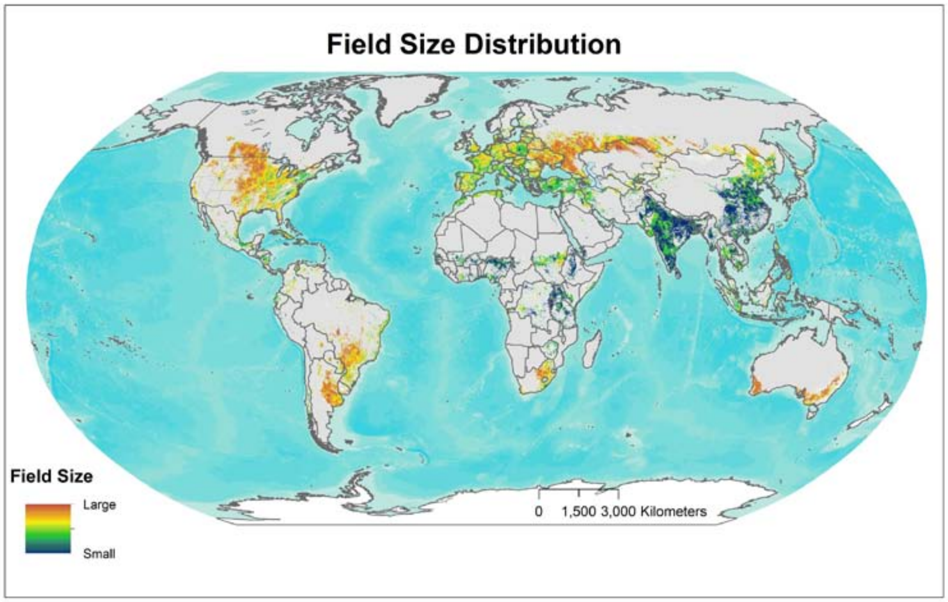
It is very important to note that the maps below are very much preliminary products compiled and created by individual groups contributing to GEOGLAM and have not yet been vetted by the community. These can serve as a good guideline to complement the requirements table and show progress on the part of GEOGLAM but by no means are these final GEOGLAM products.

WHERE?



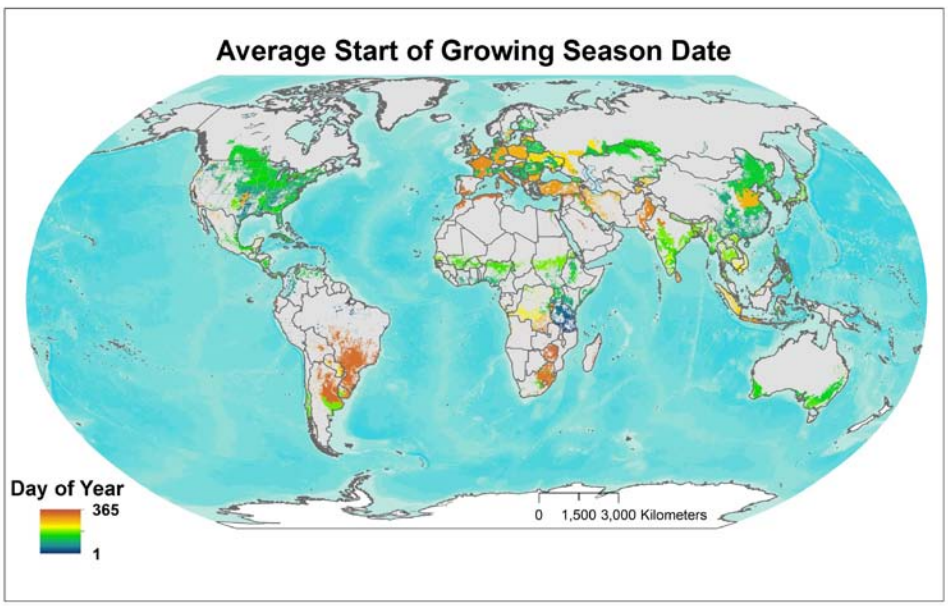
Cropmask Sources: USGS NLCD (USA), CORINE (Europe), Africover (Africa), South Africa, Zimbabwe (national products), MODIS UMD MCD12q1 (rest of world). compiled by UMD

AT WHAT LEVEL OF DETAIL(SPATIAL RESOLUTION)?



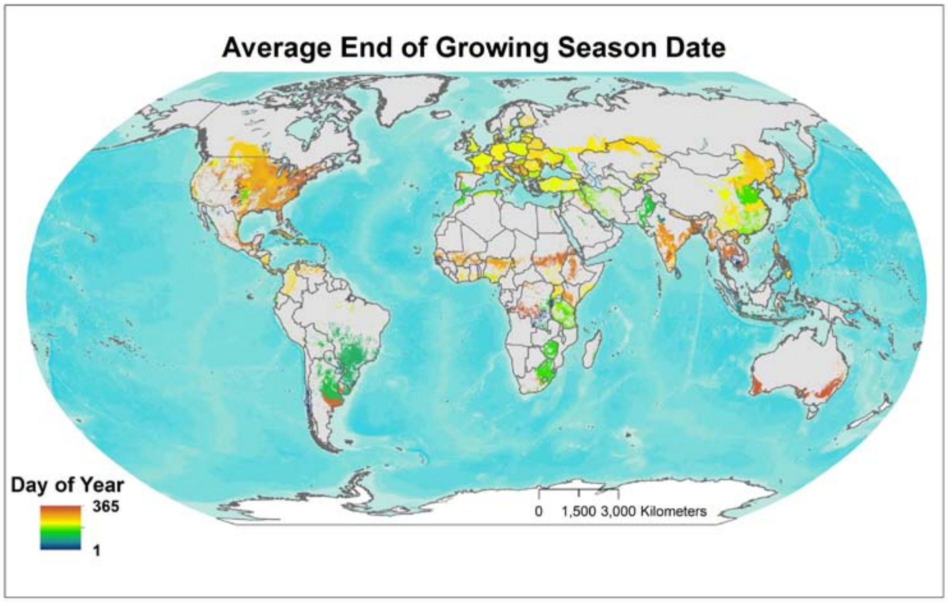
Data Source: IIASA, Ecosystems Services & Management, based on interpolation of 50,000 IIASA GEOWIKI collected validation points

WHEN?



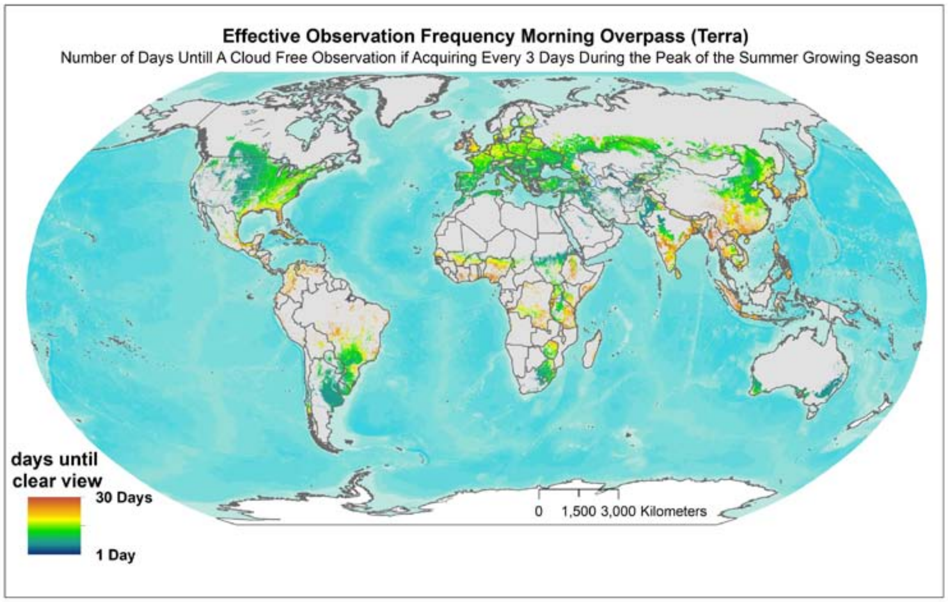
Data source: UMD crop calendar (USA), SAGE crop calendar (rest of world)

WHEN?



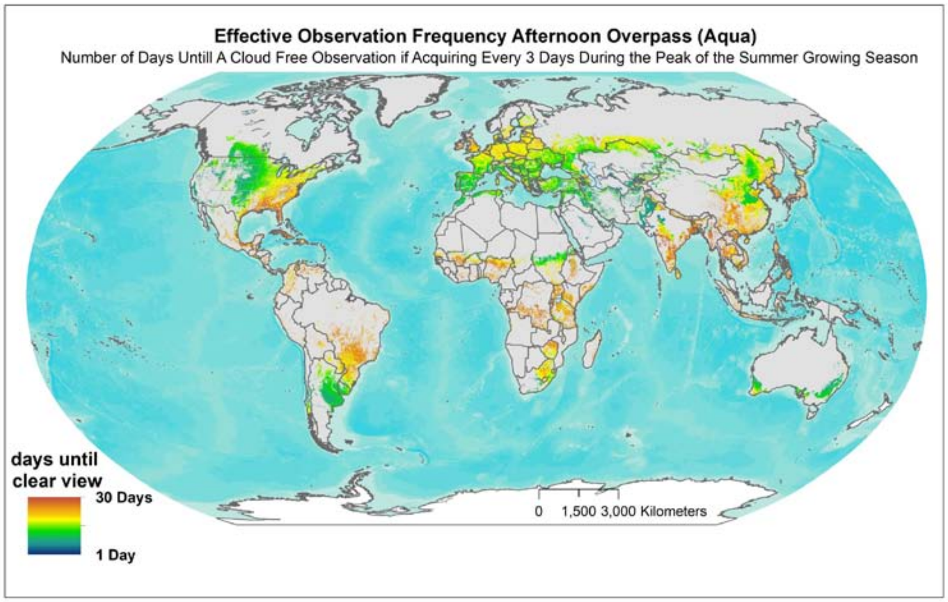
Data source: UMD crop calendar (USA), SAGE crop calendar (rest of world)

HOW OFTEN?



Data source: UMD, based on MODIS Terra data from 2000-2011

HOW OFTEN?



Data source: UMD, based on MODIS Terra data from 2000-2011

4. Operational Considerations

Operational considerations such as data latency, data quality, need for high-level products, interoperability, etc. are addressed in this section.

Agricultural monitoring in the context of GEOGLAM covers a range of interdependent tasks including: mapping croplands and agricultural land use change and characterizing cropping systems and their changes, estimating area planted and crop type, monitoring crop growth and crop stage, forecasting and estimating crop production. While each of these monitoring tasks requires satellite observations, the spatial resolution and observation frequency are in part dictated by the field size and spatial complexity of the agricultural landscape as presented in table 3. The tasks associated with monitoring crop growth and production are time-sensitive and the goal for data delivery is for near real-time data.

As the GEOGLAM initiative is targeted at operational users, there is a preference for delivery of useful information products rather than raw data. As the satellite data are increasingly used for quantitative analysis, it is essential that the underlying data are calibrated and geo-located with the appropriate documentation needed to use the data. Removing the burden of data pre-processing from the end-user facilitates data use and in this context, ortho-rectification and atmospheric correction for optical data are highly desirable for end users.

As no single sensing system can provide all the data that are needed, those undertaking monitoring will be dependent on data from multiple systems. This creates a number of challenges for users who have to ingest diverse data into their analysis and decision support systems. Data inter-use is an important aspect of utilizing a system of systems. Standard formats have been an elusive goal of CEOS for many years yet would help the user community. While the broader remote sensing community is moving towards generating standard data products for climate change studies (i.e. ECV's), there has yet to be a similar initiative with an agricultural monitoring focus. The procedures for ordering data and data delivery need to facilitate data access and use. For operational monitoring at national to global scales, large volumes of data will be generated, and so procedures for automatic download need to be made available. Procedures will be needed for accessing and processing high volume data for example from both Very High Resolution (VHR) and Microwave systems. Special consideration is needed for the provision of data to monitoring groups in developing countries which may not have the benefit of high speed internet. Any steps that CEOS can make towards facilitating data inter-use in terms of formats, tools and functionality of delivery systems will enhance the utility of the data and reduce obstacles to the uptake of use of the data. In terms of data analysis, vendors are encouraged to provide the capability to ingest data from different sensing systems and data analysis tools which can be run on multiple sensors at different resolutions.

GEOGLAM recognizes that in responding to GEO data needs, CEOS is moving into a new endeavor and that while the first priority will be to make sure the required data are acquired for a given area at the appropriate time, ease of data access and timely delivery will also be critical to effective use of the data. However, rather than specifying stringent requirements on the CEOS ground segment, the approach adopted by GEOGLAM is to work in partnership with CEOS to establish the procedures necessary to make this agricultural monitoring program successful. In this sense, GEOGLAM provides CEOS with an opportunity to explore approaches to improving coordination on data acquisition, access and inter-use with the GEO Agricultural Monitoring Community of Practice.