WP3 - Scientific & Technical Support Actions to improve Copernicus‘ Ability for Agriculture

D3.7 Guidelines on the improvement of future missions support for thematic applications

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Glossary

The glossary of terms used in this deliverable can be found in the public document "EO4AGRI_Glossary.pdf" available at: http://www.EO4AGRI.eu/EO4AGRI_Glossary.pdf

Definitions, Abbreviations and Acronyms

Table 1: List of Abbreviations and Acronyms

Abbreviation / acronym	Definition
Agri-App	Agricultural Applications
CAP	Common Agriculture Policy
CLMS	Copernicus Land Monitoring Service
CODA	Copernicus Online Data Access
CwRS	Controls with remote sensing
D4.1	Deliverable number 1 belonging to WP 4
DIAS	Copernicus Data and Information Services
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
EEA	European Environmental Agency
EO	Earth Observation
Fintech	Financial Technology
GEOGLAM	G20 Global Agricultural Monitoring initiative
GEOSS	Global Earth Observation System of Systems
GMES	Global Monitoring for Environment and Security
H2020	EU Research and Innovation funding programme 2014-2020.
HR	High resolution
IACS	International Association of Classification Societies
INSPIRE	Infrastructure for Spatial Information in Europe
IOCR	In-Orbit Commissioning Review
IPR	Intellectual Property Rights
JRC	Joint research centre
LPIS	Land Parcel Identification System
OTS	On the spot
PA	Public Administration
RM-ODP	Reference Model of Open Distributed Processing
SRA	Strategic Research Agenda
TEP	Thematic Exploitation Platform
UAS	Unmanned Aircraft System
VAS	Value data services
VHR	Very High Resolution

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Abbreviation / acronym	Definition
WP	Work Package

EO4AGRI Project Overview

The main objective of EO4AGRI is to catalyse the evolution of the European capacity for improving operational agriculture monitoring from local to global levels based on information derived from Copernicus satellite observation data and through exploitation of associated geospatial and socio-economic information services.

EO4AGRI assists the implementation of the EU Common Agricultural Policy (CAP) with special attention to the CAP2020 reform, to requirements of Paying Agencies, and for the Integrated Administration and Control System (IACS) processes. EO4AGRI works with farmers, farmer associations and agro-food industry on specifications of data-driven farming services with focus on increasing the utilization of EC investments into Copernicus Data and Information Services (DIAS).

EO4AGRI addresses global food security challenges coordinated within the G20 Global Agricultural Monitoring initiative (GEOGLAM) capitalizing on Copernicus Open. EO4AGRI assesses information about land-use and agricultural service needs and offers to financial investors and insurances and the potential added value of fuelling those services with Copernicus information.

The EO4AGRI team consists of 11 organizations, complementary in their roles and expertise, covering a good part of the value-chain with a significant relevant networking capital as documented in numerous project affiliations and the formal support declarations collected for EO4AGRI. All partners show large records of activities either in Copernicus RTD, governmental functions, or downstream service operations. The Coordinator of EO4AGRI is a major industrial player with proven capacities to lead H2020 projects.

The EO4AGRI project methodology is a combination of community building; service gap analysis; technology watch; strategic research agenda design and policy recommendations; dissemination (including organization of hackathons).

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Executive Summary

The main objective of the task 3.4 "**Future missions support for thematic applications**" is to analyse the opportunities for technologies not currently being deployed within the Sentinels fleet and at proposals for future missions, which could address some of the needs and gaps expressed in WP2.

The work will provide details about this analysis together with Guidelines and Recommendations that could support decision makers and institutional actors in design new missions that could benefit the agriculture sector.

To achieve the task objectives, the work performed includes the following major logical steps:

1. Review of the current EO missions relevant for the agriculture applications
2. Analysis of future already planned EO missions in the Copernicus framework and analysis on how they can improve capabilities in the agriculture domain
3. Analysis of EO existing and planned missions out of the Sentinel framework
4. Summary of the survey results in comparison with the defined requirements (results of WP2) and guidelines for future missions planning.

The workflow described starts from the analysis performed in project User requirements analysis (WP2) that provided main gaps in terms of mission parameters (payload, revisit time and spatial resolution) that affect EO applications in the agriculture domain.

Considering this information, a detailed **survey of existing and planned EO missions at institutional (Copernicus) and Commercial level** has been realised. The extensive analysis includes all the missions at worldwide level and takes into account also the current planned extension of Sentinel fleet (in this case some uncertainties in terms of planned lunch dates occurred) and new micro-satellite constellations that are revolutionizing the current EO mission paradigm. The objective of the survey is to focalise what are the missing capabilities of EO current missions and provide guidelines for future developments.

The first part of the work performed has been focussed on the survey; the next version of the present deliverable will focus on providing a critical analysis of the results obtained and related recommendations. Some initial comments especially on SAR constellations and hyperspectral satellites are already included in the present version and in particular:

SAR: the analysis performed show that operational and planned SAR missions are generally compliant with the spatial requirements and most of them provide dual polarization data, useful for agriculture applications. On the other side, the need of frequent acquisitions, that is less than 4-5 days of revisit time, is a major issue especially affecting L-band sensors. Future SAR missions should focus on the improvement of the revisit time, achievable by tuning the following parameters:

- Number of satellites

The constellations allow to improve the revisit time; solutions with new generation of satellites in cooperation with existent missions are a possible solution.

- Satellite Agility

Use of Gyro device, Right and Left Looking, electrical steering allows to improve the satellite's agility to acquire image as soon as possible.

Hyperspectral: operational and planned Hyperspectral systems are generally compliant with the spectral requirements, whereas they do not meet either the spatial resolution requirements. Since the systems are generally composed of a few number of satellites (1 or 2 in general), they also offer a limited revisit that in principle can be improved using the agility of the satellite, but not enough to reach the 3 days objective. Only use of a constellation may help on this aspect. The most challenging

objective is the improvement of the spatial resolution in the whole VNIR and SWIR, because it requires taking into account other design parameters such as spectral resolution and spectral range. Thus, to achieve high performances, a larger payload is needed.

1 Introduction

1.1 Purpose of the document

One of the key objectives of the project is to assess the contribution of current and firmly-planned EO missions supporting the Agriculture domain, to identify gaps in the fulfilment of the user needs, and to analyse new future missions that could be designed to better meet the user needs.

WP2 of the project analysed a large amount of user needs depicting the ones that are currently not satisfied by current missions and that could be the starting point for future mission design.

The present document provides a summary of on-going missions and an analysis of technologies not currently being deployed within the Sentinels fleet and at proposals for future missions, which could address some of the needs and gaps expressed in WP2 (e.g. Land thermal imaging applications, soil moisture measurements, hyperspectral imagery).

1.2 Relation to other project work

The work performed in task is strictly linked with the WP2 activities. The following schema shows the relation among the WP2 and WP3 (orange boxes) and the logic workflow followed for the present task activities (blue boxes).

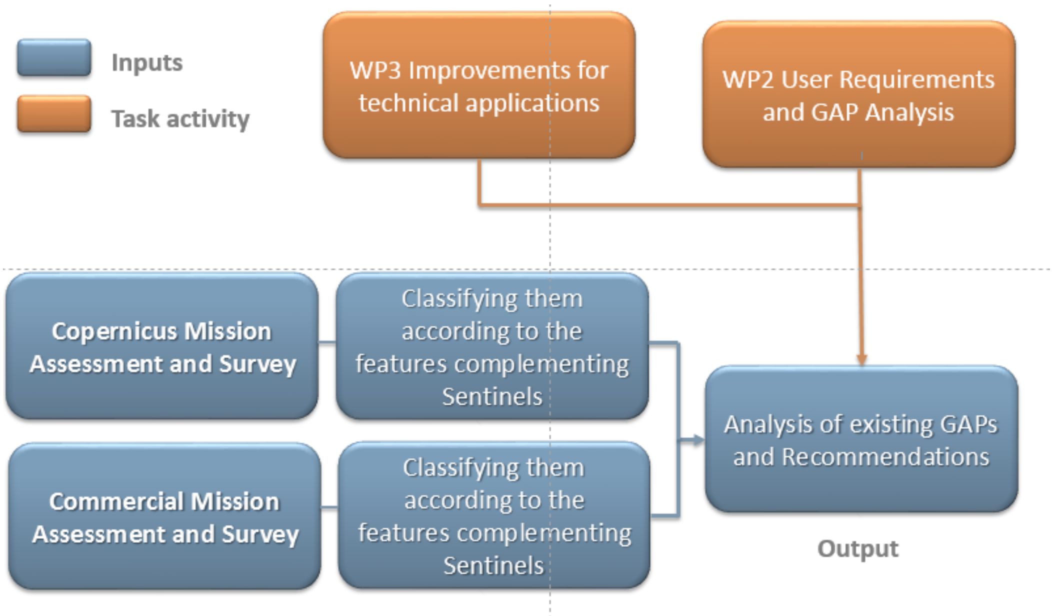

Figure 1: PERT Chart - Inter relations among EO4AGRI Work Packages

1.3 Structure of the document

The present document is structured in 7 major chapters:

- **Chapter 2** the methodology that was developed and applied in the task
- **Chapter 3** survey of EO current missions
- **Chapter 4** survey on Copernicus missions evolution
- **Chapter 5** survey on EO commercial future missions relevant for the agriculture domain
- **Chapter 6** includes the summary of survey results and recommendations and guidelines

2 Methodology and Starting Point

To achieve the task objectives, the work performed includes the following major logical steps:

1. Review of the current EO missions relevant for the agriculture applications
2. Analysis of future already planned EO missions in the Copernicus framework and analysis on how they can improve capabilities in the agriculture domain
3. Analysis of EO missions out of the Sentinel framework
4. Summary of the survey results in comparison with the defined requirements (results of WP2) and guidelines for future missions planning.

The workflow described starts from the analysis performed in project User requirements analysts (WP2) that are summarized in the following paragraph.

2.1 Analysis of baseline requirements associated to agriculture domain

EO4Agri WP2 realised a deep analysis of User requirements. These requirements have been collected and reported in terms of properties that can be referred to as Applications or Mission characteristics. Previous tasks in WP3 analysed application aspects in-depth.

The work performed in task 3.4 “Future missions support for thematic applications” started with the collection of requirements in terms of mission parameters. This was done in order to analyse the potentialities of already existing missions (Copernicus Missions and Commercial Missions), to fulfil the requested characteristics and define guidelines and suggestions for the requirements that will not be satisfied. Furthermore, the task analyzed issues related to the uncertainty associated with some of the products that is large with respect to the changes that need to be identified in the agriculture domain. The reduction of this uncertainty could drive the exploration of synergies among different missions including Sentinels and other satellite missions.

Results of this analysis can be used as recommendations for the design of future missions having the goal to effectively improve the satellite information provision in the agriculture domain.

WP2 complete material is reported in the WP2 deliverable D2.1. End User Requirements Collection and Foresight Methodology, for the sake of simplicity main requirements in terms of mission capability are reported here after:

Sensor	Spatial Resolution [m]	Revisit Time [days]	Other
L-Band SAR	5 or better	5	Dual pol System
C-Band SAR	2 or better	4	Dual pol System
X-Band SAR	1 or better	4	Dual pol System
RGB Camera	0.86 or better	7	
Multispectral	1.24 or better	3	
Hyperspectral	5 or better	3	50 bands from VNIR
Hyperspectral	10 or better	3	50 bands SWIR

Table 2: Summary of Mission Requirements from WP2

3 Relevant EO current missions review

This section presents the outcome of an extensive review of relevant operational and firmly planned EO missions, focussing on SAR and optical payloads embarked on: ESA missions (e.g. Sentinel-1, Sentinel-2 and Sentinel-3, Copernicus Expansion Sentinel missions), European national missions (e.g. COSMO-SkyMed, SPOT 6-7, Pleiades, TerraSAR, DEIMOS 1-2), other relevant non-European missions (e.g. RCM).

3.1 Synthetic Aperture radar missions

The following table presents a collection of present and firmly planned SAR missions of interest for agriculture applications, specifying for each of them the number of satellites composing the mission, significant orbital parameters, instrument properties and coverage performances.

Mission	Satellites	Orbit (Alt and Inc)	LTAN	Instrument Mode	Swath Width	Resolution	FoR	Max RT	Coverage
Sentinel-1	2	SSO 98.2º inc. 693 km alt.	dawn- dusk	Strip mode	80 km	5x5 m	20º - 46º Single look	~120 h	**Land Sea ice zone and arctic environment**
				Interferometric wide swath mode	250 km	5x20 m			
				Extra-wide swath mode	400 km	20x40 m			
				Wave mode	Sampled images of 20 x 20 km at 100 km intervals	5x5 m			
				Stripmap	30 km	3x(3-6) m			
				Spotlight	5-10 km	1.2x(1-4) m			
				ScanSAR	100 km	16x16 m			
TerraSAR-X & TanDEM-X	1+1	SSO 97.4º inc. 515 km alt.	dawn- dusk	Wide ScanSAR (only *TerraSar-X*)	200 x (194-266) km	40x(6-10) m	20º - 55º	~95 h	**Land**
				Staring Spotlight (only *TerraSar-X*)	(2.1-2.7) x (4.6-7.5) km	0.2 x 0.8/1.77 m			
				High Resolution Spotlight	5x10 km	1.4-3.5 m			
TerraSAR 2nd Genereation (TSG)	**5**	**SSO altitude = 514.8 km , inclination = 97.44º**	**dawn-dusk**	**Spotlight**	**5x5 km**	**0.25 m**	**30° - 55°**		**Global**
					20x15 km	0.5 m MAPS	30° - 55°		
					10x10 km	0.5 m	20° - 55°		
					10x10 km	1 m	20° -40°/ 45°		
					15x15 km	1 m	20° - 55°		
				Stripmap	24 km	3 m	20°-45°		
					10 km	1 m	20°-50°		

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					20 km	1 m MAPS	20°-50°		
					10 km	2 m	20°-45°		
				ScanSAR TOPS	400 km	30 m MAPS	20°-50°		
					100 km	12 m	20°-50°		
					50 km	5 m	20°-50°		
					320 km	Ship Detection	>= 40°		
COSMO-SkyMed	4	SSO 97.8º inc. 619 km alt.	dawn- dusk	Spotlight	10 km	1 m	20º - 59.5º	~12 h	**Global**
				Stripmap	40 km	3-15 m			
				ScanSAR	100-200 km	30-100 m			
				PING-PONG	30 km	15 m			
COSMO-SkyMed 2nd Generation (CSG)	2	SSO 97.8º inc. 619 km alt.	dawn- dusk	Spotlight-2A	3x8 km	0.35 x 0.48/0.55 m	20º - 59.5º	~36 h	**Global**
				Spotlight-2B	10x10 km	0.63x0.63 m			
				Stripmap	40x10 km	3x3 m			
				Pingpong	30x30 km	12x5 m			
				Quadpol	40x16 km	3x3 m			
				ScanSAR-1	100x100 km	20x4 m			
				ScanSAR-2	200x200 km	40x6 m			
RADARSAT-2	1	SSO 98.6º inc.	dawn- dusk	Fine	50 km	8 m	N/A	2-4	**Global**
				Wide Fine	150 km	8 m			
				Standard	100 km	25 m			
				Wide	150 km	25 m			
				ScanSAR Narrow	300 km	50 m			
				ScanSAR Wide	500 km	100 m			

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		798 km alt.		Extended High	75 km	25 m		days		
				Extended Lows	170 km	60 m				
				Fine Quad-Pol	25 km	12 m				
				Wide Fine Quad-Pol	50 km	12 m				
				Standard Quad-Pol	25 km	25 m				
RADARSAT Constellation Mission (RCM)	3	SSO 97.7º inc. 593 km alt.	dawn- dusk	Low Resolution	500 km	100 m	19º - 58º	~36 h	**Environment monitoring** **Disaster management** **Marine Surveillance**
				Medium Resolution	350-125-30 km	50-30-16 m			
				High Resolution	30 km	5 m			
				Very High Resolution	20 km	3 m			
				Low Noise	350 km	100 n			
				Ship Detection	350 km	variable			
				Spotlight	14 km	1 m			
				Quad- Polarization	20 km	9 m			
SeoSAR/PAZ	1	SSO 97.4º inc. 515 km alt.	dawn- dusk	Spotlight	5x5 –10x10 km	1 – 2 m	20º - 55º	~86 h	**Global**
				Stripmap	15 – 30 km	3 – 6 m			
				ScanSAR	100 km	15 m			
ALOS-2	1	SSO 97.9º inc.	Mid- day - Mid- night	Spotlight	25 km	1-3m	8°-70° 2320 km	14 days	**Land** **Disaster management**
				Stripmap	50, 50, 70 km	3, 6, 10 m			

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		628 km alt.		ScanSAR	35 km	100 m			
ALOS-4	1	SSO 97.9º inc. 628 km alt.		Spotlight	35 x 35 km	1x3 m		14 days	**Land**
				Stripmap	100 km–200 km	3 m, 6 m, 10 m			
				ScanSAR	700 km	25 m			
ASNARO-2	1	SSO 97.4° inc. 500 km alt.		Spotlight	10 km	1 m	15°-45°	14 days	**Land**
				Stripmap	12 km	2 m			
				ScanSAR	50 km	16 m			
ICEYE	18	SSO 97.69° inc. 570 km alt.	22:30 (ICEYE-X2)	Stripmap	35 km	3 m	10°-35°	3 hours	**global**
				Stripmap High	25 km	1.5 m			
				Spotlight	10 km	1 m			
				ScarSAR	120 km	20 m			
RISAT-1A/ RISAT-1B	1	SSO 97.6° incl. 536 km alt.	dawn- dusk	High Resolution Sliding Spotlight (HRS)	10 x 100 km	1 m	12° - 55°	25 days	**land**
				Fine Resolution Stripmap Mode-1 (FRS-1)	25 km	3 m			
				Fine Resolution Stripmap Mode-2 (FRS-2)	25 km	9 m			
				Medium Resolution ScaSAR mode (MRS)	115 km	25 m			
				Coarse Resolution ScanSAR mode (CRS)	223 km	50 m			
RISAT-2/ RISAT-2A/ RISAT-2B	1	Drifting orbit 41° incl. 550 km alt.		Spotlight	10 km	1 m	650 km	5 days	**land**
				Super-Stripmao	10 km	1.8 m			
				Stripmap	10 km	3 m			
				ScaSAR	50 km	8 m			
	1			Spotlight (SL)	10 x 10 km	1 m	20°-50°	29 days	**land**

GAOFEN 3		SSO 98.4° incl. 758 km alt.		Ultra-fine Strip (UFS)	30 km	3 m	20°-50°		
				Fine strip I (FSI)	50 km	5 m	19°-50°		
				Fine strip II (FSII)	100 km	10 m	19°-50°		
				Standard strip (SS)	130 km	25 m	17°-50°		
				Narrow scan (NSC)	300 km	50 m	17°-50°		
				Wide scan (WSC)	500 km	100 m	17°-50°		
				Global (GLO)	650 km	500 m	17°-53°		
KOMPSAT-5	1	SSO 97.06º inc. 550 km alt.	dawn- dusk	Spotlight	5 km	1 m	20º -45º	N/A	**Global**
				Stripmap	30 km	3 m			
				ScanSAR	100 km	20 m			
KOMPSAT-6	1	SSO 97.6 inc. 550 km alt.	dawn- dusk	High Resolution-A	5 km	0.5 m	20º -60º		
				High Resolution-B	10 km	1 m			
				Standard	30 km	3 m			
				Wide Swath	100 km	20 m			
SAOCOM-1A,1B	1+1	SSO 97.1° incl. 619.6 km	dawn- dusk	Stripmap	Single Pol: 40 km	10 m	21°-50°	8 d	**Global**
					Dual Pol: 40 km	10 m	21°-50°		
					Quad Pol: 20 km	10 m	20°-35°		
				TopSAR narrow	Single Pol: 150km	30 m	25°-45°		
					Dual Pol: 150 km	30 m	25°-45°		
					Quad Pol: 100km	50 m	25°-35°		
				TopSAR wide	Single Pol: 350km	50 m	25°-45°		
					Dual Pol: 350 km	50 m	25°-45°		
					Quad Pol: 220 km	100 m	25°-35°		
					CL-Pol: 350 km	**50 m**	**25°-45°**		

Table 3: Survey Results SAR Missions

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3.2 Optical Sensor Missions

The following table presents a collection of present and firmly planned optical missions of interest for DRR applications, specifying for each of them the number of satellites composing the mission, significant orbital parameters, instrument properties and coverage performances.

Platform	Bands	Resolution (m)	Swath Width Nadir (km)	Revisit	Inclination	Agility	status
Pleiades 1A & 1B	PAN MS (4 bands)	0.7 2.8	20	26	98.2°	± 30°	Operational
ZY-3 01	PAN MS (B,G,R,NIR)	2.1 nadir/2.3 5.8	51	5	97.49	-	Operational
KompSAT 3	PAN MS (B,G,R,NIR) IR	0.55 2.2 5	16	3.5	98.13°	± 45°	Operational
Landsat-8 LDCM	PAN MS (9 bands)	15 30	185	16	99°	-	Operational
GAOFEN-1	PAN MS (450-900 nm) WideAngle (450-900nm)	2 8 16	69 69 830	~4 (roll 25°) 4 (no roll)	98.0468°		Operational
DubaiSAT-2	PAN MS (B,G,R,NIR)	1 4	12	< 8	97.1°	± 45°	Operational
Skysat 1	PAN MS (B,G,R,NIR) Video	0.8 1 1.1	2 11 2	0.3 (with 13 satellites)	97.79°		Operational
Flock 1B	MS (B,G,R,NIR)	3 - 5		unknown	51.66°		Operational
KazEOSat 1	Pan MS (B,G,R,NIR)	1 4	20	3 (roll 35°)	98.54°	± 35°	Operational
Flock 1C	MS (B,G,R,NIR)	3 - 5			97.98°		Operational
Skysat 2	PAN MS (B,G,R,NIR) Video	1.1 2 1.1	2 8 2	0.3 (with 13 satellites)	98.8°		Operational
Deimos 2	PAN MS (B,G,R,NIR)	0.75 2	12	4 (max.)		± 45°	Operational
GAOFEN 2	PAN MS	0.8 3.2	45		98.02°		Operational
ASNARO 1	PAN MS (B,G,R,NIR)	< 0.5 < 2	10		97.4°	15°-45°	Operational
Flock 1D'	MS (B,G,R,NIR)	3 - 5			51.66°		Operational
Sentinel 2A	UV (B1) VIS, NIR (B2,B3,B4,B8 NIR (B5,B6,B6,B8A)	60 10 20 20	290	2-5			Operational

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	SWIR (B11,B12) SWIR (B9,B10)	60					
GAOFEN 8	PAN MS	0.8 3.2	45				Operational
TripleSat	PAN MS (B,G,R,NIR)	0.8 3.2	23.4			± 45°	Operational
Flock 1E	MS (B,G,R,NIR)	3 - 5			51.66°		Operational
Flock 2B	MS (B,G,R,NIR)	3 - 5			51.66°		Operational
GAOFEN-4	VIS IR	50 400	400				Operational
TeLEOS 1	Pan	1	12 (nadir)	0,4-0,5			Operational
Resurs P-3	PAN MS (B,G,R,RE,NIR) PAN MS (B,G,R,RE,NIR) PAN MS (B,G,R,RE,NIR) > 96 bands (0.4-1.1 µm)	1 3-4 12 23.8 59 118 25-30	38 38 92.7 92.7 441.7 441.7 >30	3	97.3°	± 45°	Operational
Flock 2E/2E'	MS (B,G,R,NIR)	3 - 5			51.66°		Operational
Diwata-1	MS (B,G,R,NIR) Hyper 420-700 / 650-1050	3 80 185 7000	1.9 x 1.4 52 x 39 121.9x91.4 180° x 134°		51.6°		Operational
ZY-3 02	PAN MS (B,G,R,NIR)	2.1 nadir/2.3 5.8	51	5 (1 satellite) 3 (with ZY-3 1)	97.5°	-	Operational
NuSAT 1 & 2 (Aleph-1 constellation)		1 1 30 90	5 5 150 92				Operational
Flock 2P	MS (B,G,R,NIR)	3 - 5			97.98°		Operational
Cartosat 2C	Pan MS (B,G,R,NIR)	0.65 2	9.6 10			± 45°	Operational
PerúSAT-1	Pan MS (B,G,R,NIR)	0.7 - 2.5 2 - 10					Operational
Worldview 3	PAN Multispectral (8 VNIR bands) SWIR CAVIS	0,31 cm 1,24 m 3,7 m 30 m	13,1	<1 day	98°		Operational
Skysat 3-6	PAN MS (B,G,R,NIR) Video	1.1 2 1.1	2 8 2	0.3 (with 13 satellites)			Operational

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SuperView 1&2	PAN MS (B,G,R,NIR)	0.5 2	12	2			Operationa l
Flock 3P	MS (B,G,R,NIR)	3 - 5			97.98°		Operationa l

Sentinel 2B	UV (B1)
	VIS, NIR
	(B2,B3,B4,B8
	NIR
	(B5,B6,B6,B8A)
	SWIR (B11,B12)
	SWIR (B9,B10)
		60
		10
		20
		20
		60
			290	2-5			Operationa
							l

NuSAT-3 (Aleph-1 constellation)		1 1 30 90	5 5 150 92				Operationa l
Cartosat 2E	Pan MS (B,G,R,NIR)	0.65 2	9.6 10			± 45°	Operationa l
Flock 2K	MS (B,G,R,NIR)	3 - 5			97.98°		Operationa l
Kanopus V 3&4	PSS MSS TIR (3.5-4.5; 8.4-9.4)	2 10 200	23 23 2000		97.4°		Operationa l
Flock 3m	MS (B,G,R,NIR)	3 - 5			97.98°		Operationa l
Skysat 7-12	PAN MS (B,G,R,NIR) Video	1.1 2 1.1	2 8 2				Operationa l
Jilin 1-04 **Jilin 1-05** **Jilin 1-06**	PAN MS (B,G,R,NIR) Video	0.72 4 1.13	 4.3 x 2.4				Operationa l
SuperView 3&4	PAN MS (B,G,R,NIR)	0.5 2	12	2			Operationa l
Flock 3p'	MS (B,G,R,NIR)	3 - 5			97.98°		Operationa l
Cartosat 2F	Pan MS (B,G,R,NIR)	0.65 2	9.6 10			± 45°	Operationa l
Kanopus V 3&4	Pan MS (B,G,R,NIR)	2.1 10.5	23.3 20.1	17	97.4°		Operationa l
NuSAT-4 / -5 (Aleph-1 constellation)		1 1 30 90	5 5 150 92				Operationa l
Zhuhai-1	Hyperspectral Video	10 0.9	22.5	global Covarage in 5 days			Operationa l
GAOFEN-5		<1m					Operationa l
GAOFEN-6	PAN MS (~450-900 nm) WideAngle (~450-900 nm)	2 8 16	90 90 800				Operationa l
PRSS-1	Pan MSS	1 4	> 60 km				Operationa l

GAOFEN-11		< 1	69				Operationa
NuSAT 6-8 (Aleph-1 constellation)		1 1 30 90	5 5 150 92				Operational
HySIS	55 bands Hyper (0.4 -0.9)	30					Operational
Reaktor Hello World	100's bands NIR/SWIR	20					Operational
GAOFEN-7	Hyperspectral	<1m					Planned
Kanopus V 5&6	Pan MS (B,G,R,NIR)	2.1 10.5	23.3 20.1	17	97.4°		Planned
Landmapper Constellation	R,G,B,RE,NIR RG,NIR	2.5 22	25 220				Planned
KEOSat	R,G,B,NIR	3 - 5					Planned
KhalifaSat	Pan MS (B,G,R,NIR)	0.75 2.98	12			± 45°	Operational
Flock 3R	MS (B,G,R,NIR)	3 - 5			97.98°		Planned
Flock 3S	MS (B,G,R,NIR)	3 - 5			97.98°		Planned
Flock W	MS (B,G,R,NIR)	3 - 5			97.98°		Planned
Flock X	MS (B,G,R,NIR)	3 - 5			97.98°		Planned
Zhuhai-1	Hyperspectral Video	10 0.9	22.5	global Covarage in 5 days			Operational
EgyptSat-A	Pan MS (B,G,R,NIR)	1 4					Operational
GEO-KOMPSAT-2A	B 1 Blue 0.47 B 2 Green 0.511 B 3 Red 0.64 B 4 VNIR 0.865 B 5 SWIR 1.38 B 6 SWIR 1.61 B 7 MWIR 3.83 B 8 WV 6.241 B 9 WV 6.952 B 10 WV7.344 B 11 TIR 8.592 B 12 TIR 9.625 B 13 TIR 10.403 B 14 TIR 11.212 B 15 TIR 12.364 B 16 TIR 13.31	1000 1000 500 1000 2000 2000 2000 2000 2000 2000 2000 2000 2000 2000 2000 2000			10		Planned
Scout Constellation		0.8					Planned
PRISMA		5 30	30x30 (Spot) 1800x30 (Strip)	29 (6 max. Angle)			Operational

CartoSAT 3A	Pan MSS Hyperspectral	0.25 1 12	16 16 5				Planned
Global 1-4	MS	1					Planned
ResourceSat 3S	PAN MS	1.25 2,5	60				Planned
ResourceSat 3	PAN MS Hyperpectral ATM Corr	10 20 240	925				Planned
Vivid-i	RGB	0.6 1	5.2 x 5.2	0.5 (all satellites)			Planned
EROS-C	PAN VNIR	0.4 0.8	12.5				Planned
HRSAT	Pan MSS IR	1 2 20	15 15 6				Planned
CAS 500 Series		0.5					Planned
Landsat 9	Pan MSS TIR	15 30 100	185				Planned
ResourceSat 3A	PAN MS Hyperpectral ATM Corr	10 20 240	925				Planned
ResourceSat 3SA	PAN MS	1.25 2.5	60				Planned
ALOS 3	PAN MS (B,G,R,NIR) HSUI (57 + 128 SWIR)	0.8 (1.25 BW) 2.5 30	35 75 30	60			Planned
CartoSAT 3B	Pan MSS Hyperspectral	0.25 1 12	16 16 5				Planned
EnMAP	Hyperspectral	30	30				Planned
Pleiades Neo		~0.3					Planned
KOMPSAT 7	PAN MS IR	0.3 1.2 4					Planned
Legion Constellation	PAN MS	0.3 0.5					Planned
TeLEOS 1	Pan	1	12 (nadir)	0,4-0,5			Operational
Sentinel 3C	OLCI: 21 bands from 400nm to 1020 nm SLSTR: 3 VIS, 3 SWIR, 3 MWIR-TIR, 2 FIRE	300 (OLCI) 500 1000m	1270 (OLCI) 1420 (SLSTR)	27			Planned

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Sentinel 3D	OLCI: 21 bands from 400nm to 1020 nm SLSTR: 3 VIS, 3 SWIR, 3 MWIR-TIR, 2 FIRE	300 (OLCI) 500 1000m	1270 (OLCI) 1420 (SLSTR)	27			Planned
Flock Y	MS (B,G,R,NIR)	3 - 5			97.98°		Planned
Flock Z	MS (B,G,R,NIR)	3 - 5			97.98°		Planned
CHIME							Planned
SEOSAT	PAN MS (B,G,R,NIR)	2,5 / 10					Planned

Table 4: Survey Results Optical Missions

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4 Copernicus Missions evolution: survey and assessment

The current suite of Sentinel missions is at the heart of the Copernicus program, led by the European Commission. Data from the Copernicus Sentinels, which are developed by ESA, feed into the Copernicus Services, which help address challenges such as urbanization, food security, rising sea levels, diminishing polar ice, natural disasters and, of course, climate change. Looking to the future, six high-priority candidate missions are being studied to address EU policy and gaps in Copernicus user needs, and to expand the current capabilities of the Copernicus space component.

The selected missions will face two distinct sets of expectations that have emerged from the user consultation process:

- **Stability and continuity**: while increasing the quality and quantity of CSC products and services these requirements are addressed by and Extension of the current Sentinel 1 to 6 satellite capability to enhance baseline Copernicus continuity
- **New type of observation**: they are addressed by an Expansion of the current Sentinel satellite fleet introducing new missions to answer emerging and urgent user requirements.

The expansion programme includes new High Priority Copernicus missions (HPCM). The three priorities identified are:

- **Priority 1**
  - Greenhouse gas monitoring: anthropogenic CO2 emissions for which currently no European satellite Observation are available
- **Priority 2**
  - Monitoring polar Regions: polar/Artic observations namely sea ice/floating ice concentration and surface elevation
  - Monitoring Agriculture: parameters which potentially could be addressed through thermal infrared and hyperspectral observations
- **Priority 3**
  - Mining, biodiversity, soil moisture and other parameters requiring observations in additional bands, currently not available

Here following a description of the selected missions to improve Copernicus capability and relevant for agriculture domain is presented together with a short description on how these missions are expected to support agriculture activities.

4.1 CHIME: Copernicus Hyperspectral Imaging Mission for the Environment

Hyperspectral Imaging has already supported or been used for a large range of applications (Hochberg, Roberts et al. 2015). Corresponding variables have been derived from the observed spectra, e.g. directly through distinct absorption features or indirectly, through inversion of physically based models, assimilation, spectral un-mixing, and/or (de-) correlation techniques. Based on successful airborne deployments over the last three decades and the past satellite missions along with preparatory activities of some national demonstrative satellite missions, hyperspectral imaging from satellite is now ready for operational use. The development of a spaceborne hyperspectral sensor is a logical step to complement and expand the Copernicus Space Component to serve emerging applications and services and to improve on the existing ones. In general, the application potential of a hyperspectral mission is a direct result of adding an increased number of narrow spectral (contiguous) bands with a high Signal-to-Noise Ratio (SNR) to the conventional passive optical multi-spectral remote sensing missions, such as Sentinel-2 and Landsat, thereby allowing direct and indirect identification of target compositions and quantities.

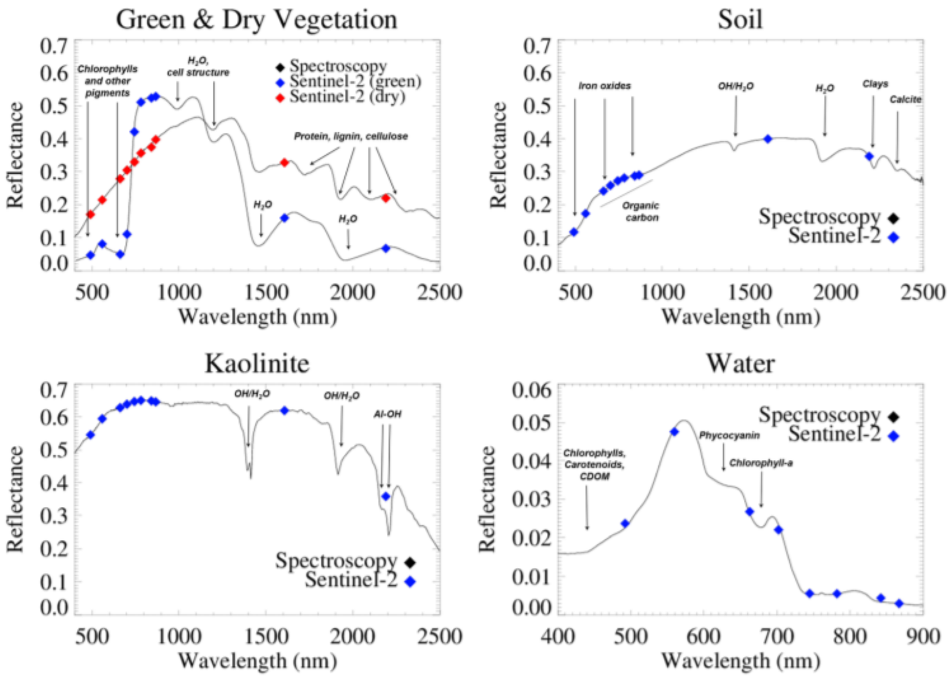

Figure 2: Reflectance spectra for different Earth surface materials at high spectral resolution and resampled to the spectral response of the multispectral instrument onboard Sentinel-2.

Considering the Sentinel missions currently operational and those being developed, a hyperspectral mission will add to- and complement the conventional passive optical multispectral remote sensing missions, such as Sentinel-2. It will support EU- and related policies for the management of natural resources, assets and benefits and, more specifically it will provide unique and major contributions in closing existing gaps in fulfilling user requirements in the domains of raw materials- and sustainable agricultural management with a focus on soil properties, sustainable raw materials development and agricultural services, including food security and biodiversity.

Improvement for Applications

In the domain of food security and agriculture, hyperspectral remote sensing has the potential to allow a more accurate determination of the main crop characteristics and their temporal change along with the derivation of soil fertility (Asner and Heidebrecht 2002). This is clearly a tool to improve farm management and field productivity (smart farming). Specific results show that with hyperspectral remote sensing it is possible to conduct a detailed phenology assessment in the developing state of crops used for a better determination of nutrient and pesticide applications, and therefore providing means to improving its application through enhanced efficiency. Further, chlorophyll content, a biochemical variable, which can be quantitatively derived from hyperspectral observations, is related to gross primary production in canopies. This main plant pigment of photosynthesis has in the past been investigated in several studies aiming to increase the understanding of assimilation rates and primary production. Hyperspectral sensors provide the unique possibility to assess chlorophyll content and photosynthesis rates at the leaf and canopy level without the restrictions of laboratory methods. As a synthesis of these assessments, innovative farm management options (smart farming) based on hyperspectral remote sensing have been proposed and initially tested, including the prediction of temporal and spatial patterns of crop productivity and yield potential. Furthermore, the quantification of crop residues after the harvesting period in the soil is an effective measure for soil functionality that relies on organic matter and important attributes as input factors. Apart from that, the estimation of photosynthesis rate and metabolism gives detailed information about primary production.

Overall, in agriculture the main advantages of a hyperspectral imager over a conventional multi-spectral imaging radiometer lie in the diagnostic capability to distinguish photosynthetically active from non-photosynthetically active vegetation, the improvement of crop type classification, the simultaneous provision of nitrogen uptake and other nutrient content, as well as information on plant disease, yield quality information and quantitative crop damage (Apan, Datt et al. 2005). Agriculture sustainability requires an assessment of the long-term viability of farming systems, ensuring that the landscape is not degrading to a point that food production is reduced. There are many components of sustainability that the proposed hyperspectral satellite can monitor. For example, these include (as mentioned above) the nitrogen (and chlorophyll) balance to ensure that the soil nutrients are not being reduced by erosion, or that excessive fertilizer applications are not polluting drinking water. In addition, maintaining the biodiversity of the agricultural landscape is a recognised proxy that the food supply chain is being managed sustainably by the farmer as well as the industries that bring the food from the field to the table. Soils are the foundation of agriculture where ninety-five per cent of food is produced from our soils. Accordingly, preserving the soils' ‘health’ is of critical importance. Soil plays a key role in the supply of clean water and resilience to floods and droughts. It is thus an important and finite resource, directly related to the ability to support plant life that has significant implications on food security, agricultural management and climate change. Therefore, monitoring of soil conditions in a quantitative way from local through to global scales is important to support farmers, land users, policy and decision makers. An important geophysical property of soils that hyperspectral imaging can provide is soil mineralogical composition. Minerals are fundamental components of all soils and are an indicator of many important soil parameters, such as pH, Redox, water/metal activities and permeability important for understanding soil chemical and physical condition. The direct derivation of mineralogical composition and abundances using hyperspectral technology has long been proven. Hyperspectral imaging has shown to be a powerful technique for the direct and indirect determination and modelling of a range of soil properties, including soil organic carbon (SOC), moisture content, textural and structural information, pH, as well as other properties assigned to a soil quality parameter (Paz-Kagan, Zaady et al. 2015), that are directly linked to crop production and fertility. In the context of food security, besides crop properties, many important soil attributes including cation exchange capacity, soil erosion, soil salinity, degradation processes, and especially organic matter which is strongly linked to the CO2 cycle, can be generated from airborne imaging spectroscopy and thus from any future space borne mission (Bartholomeus, Kooistra et al. 2011, Schmid, RodríguezRastrero et al. 2016).

Synergies with international missions

In terms of potential for synergies with other missions and especially with Sentinel-2, a hyperspectral mission would be complementary to Sentinel-2 for many fields of applications, and in particular for vegetation-related and land cover mapping applications for which Sentinel-2 is optimised. Synergies with Sentinel-2 could help slightly relax the requirements for high temporal resolution in the case of e.g. agriculture and in-land water applications, and the spatial sharpening of hyperspectral images with Sentinel-2 data could also help some of the applications requiring a high spatial resolution.

The CHIME mission will have to take full account of the achievements made by the national missions EnMAP (DE) and PRISMA (IT) and ensure exploitation of potential synergies with concurrent orbiting missions as well as airborne sub-orbital missions, such as APEX (Schaepman, Jehle et al. 2015), in order to profit from a rich and well developed legacy of existing expertise.

In terms of supporting priority missions within the Copernicus context, a hyperspectral imaging mission will provide a reliable reference for soil organic carbon (SOC), since agricultural soils are among the planet's largest reservoirs of carbon and hold potential for expanded carbon sequestration, thus providing a prospective way of mitigating the increasing atmospheric concentration of carbon dioxide. Since SOC is highly dynamic there is a need to know how much SOC is stored in the Earth's soils and monitor changes around the world, especially in vulnerable hotspots. The quantity and quality of SOC is typically difficult to map and in many cases cannot be observed by current multispectral sensor technologies.

Also, for a Copernicus Thermal Infrared (TIR) imaging mission CHIME would, through its diagnostic power, provide valuable input for separating temperature from emissivity. TIR data yields strong synergistic potential with optical hyperspectral data for a number of application domains. These include the monitoring of vegetation functioning (the photosynthetic potential characterised by hyperspectral data can be complemented by evapotranspiration derived from TIR measurements), natural hazards (wildfires and volcanic eruptions) and mineralogical composition mapping (better mineral discrimination potential by combination optical spectroscopy and emissivity at several wavelengths) including soil organic carbon, soil mineralogy, and raw material identification (non-OH bearing silicates). Such a synergy of co-located optical hyperspectral and TIR observations is the basis of the HyspIRI mission concept currently under development by NASA.

CHIME would also strongly benefit from co-located TIR data derived from a potential Copernicus TIR mission. In addition, a hyperspectral mission, such as described here will provide the necessary reference and baseline information for ensuring high quality interoperability of optical sensors not only of the Sentinel family, such as Sentinel-2, but also the missions of international partners, e.g. Landsat-8, for instance to support quantitative analysis ready data (ARD) in the Data Cube development. It would additionally provide a reference standard for high resolution multi-spectral missions, without on-board calibration, such as Urthecast daily in terms of calibration, data validation and atmospheric data correction.

4.2 LSTM: Copernicus High Spatio-Temporal Resolution Lans Surface Temperature Mission

Also, in the future agriculture will continue to be the largest user of developed water resources in most countries, often accounting for 70 per cent or more of water withdrawals from rivers, lakes and aquifers[1]. The world needs to produce an estimated 60 percent more food by 2050 to ensure global food security, and it must do so while conserving and enhancing the natural resource base. Water is a major input in the provision of food – from production in the field through all the steps in the value chain. Increasing demand for water in cities and from industries, and for environmental flows, will reduce the volume of water available for agriculture in many areas. Yet, globally, the volume of water transpired in crop and livestock production must increase between now and 2050 to keep up with increasing demand. In addition to water and agriculture application, thermal observations obtained with high spatial and temporal resolutions are essential to a number of other fields, including urban studies (heat stress monitoring, urban planning), coastal monitoring and in-land waters (thermal plumes, water temperature), polar and mountain research (glacier and permafrost monitoring, melt-water lake monitoring), emergency response to high temperature events (fires, volcanic eruptions) and others.

Surface temperature derived from thermal infrared (TIR) observations is already being obtained from spaceborne TIR sensors, however, at spatio-temporal resolutions insufficient for many applications and services including agriculture. Consequently, different actors having an international fundamental role in the EO strategy definition such as the World Bank, NASA, Asian Development Bank highlighted the importance of a future TIR satellite mission which would be able to complement the high-

[1] Copernicus High Spatio-Temporal Resolution Land Surface Temperature Mission: Mission Requirements Document Issue Date 08/03/2019 Ref ESA-EOPSM-HSTR-MRD-3276

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resolution visible (VIS) and near-infrared (NIR) observations acquired by the Sentinel-2 and Landsat satellites (World Bank 2015, Fisher et al 2017). Such a mission would provide the high temporal and spatial resolution thermal measurements needed to derive evapotranspiration at the field scale. In addition to water and agriculture application, thermal observations obtained with high spatial and temporal resolutions are essential to a number of other fields, including urban studies (heat stress monitoring, urban planning), coastal monitoring and in-land waters (thermal plumes, water temperature), polar and mountain research (glacier and permafrost monitoring, melt-water lake monitoring), emergency response to high temperature events (fires, volcanic eruptions) and others.

Mission	Number of S/C	Orbit (Alt and Inc)	LTDN	Instrument Mode	Swath Width	Resolution	FoR	Max RT	Coverage
Copernicus Expansion High Spatio- Temporal Land Surface Temperature Monitoring (LSTM) Mission	> 1	SSO Alt. in [450–800] km range (TBD) Possibly same as Sentinel-2	12:30 or 13:30 or 10:30 (FF with S2)	VNIR/SWIR	100 km 290 km for FF with S2	30 – 60 m	OZA ■ ±30º	1 d (goal) 2 d (option)	Land and in- land waters
Copernicus Expansion HyperSpectral Imaging Mission (CHIME)	1 or more	SSO Alt. in [450–800] km range (TBD)	10:30 – 11:30 or 22:30 – 23:30	HYPER-SPECTRAL	> 175 km	≤20 m (G) to ≤30 m (T)	TBD	10 d (G) / 15 d (T)	Land and Ocean

Table 5: Summary of LSTM and CHIME Missions

4.3 CIMR: Copernicus Imaging Microwave Radiometer

CIMR mission have been selected to support the Integrated EU Policy for the Arctic. In fact, the strong interest on Polar Ice and Snow missions of different Member States and User Communities led DG Grow to set up a new group of European Polar Experts Group (PEG) in 2017 to assess and report the European Commission with specific user requirements for a dedicated "Copernicus Expansion mission". Besides this specific scope the selected mission CIMR is expected to have relevance also for other domains. In particular the additional parameters that can be derived from a multi-frequency conical scanning microwave radiometer such as CIMR are:

Soil Moisture (SM)

Soil moisture is a primary state variable of hydrology and the water cycle over land either as an initial condition or boundary condition of relevant hydrologic models (NASA, 2014). Applications that require accurate maps of high-resolution soil moisture abd its spatial and temporal evolution include: weather forecasting, agricultural productivity, drought prediction, flood area mapping, water resource management. Satellite surface soil moisture up to 5 cm soil depth is recognised as an essential climate variable by the Global Climate Observing System (GCOS). The Copernicus land service provides estimates of soil moisture and soil water index. Soil moisture is a very heterogeneous variable and varies on small scale with soil properties and drainage patterns.

Microwave observations are sensitive to soil moisture because moisture affects the dielectric constant of the surface and thus the emissivity soil surface. Vegetation and roughness reduce the microwave sensitivity to soil moisture and are more pronounced as microwave frequency increases. At L-band frequency the soil moisture emissions originate from deeper in the soil (few cm) giving a more

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representative measurements of conditions below the surface crust. Measurements in C-bands are sensitive to soil moisture but in region with low vegetation.

Land Surface Temperature (LST)

The Copernicus Land Service provides estimates of LST defined as the radiative skin temperature of the land surface, as measured in the direction of the remote sensor. It is estimated from Top-of-Atmosphere brightness temperatures from the infrared spectral channels of a constellation of geostationary satellites (Meteosat Second Generation, GOES, MTSAT/Himawari). Its estimation further depends on the albedo, the vegetation cover and the soil moisture. LST is a mixture of vegetation and bare soil temperatures. Because both respond rapidly to changes in incoming solar radiation due to cloud cover and aerosol load modifications and diurnal variation of illumination, the LST displays quick variations too. In turn, the LST influences the partition of energy between ground and vegetation, and determines the surface air temperature. The Global Land Service provides the following LST-based products (see Freitas et al., 2013):

- LST: hourly LST from instantaneous observations
- LST10-DC: 10-day Land Surface Temperature with Daily Cycle
- LST10-TCI: Thermal Condition Index with a 10-day composite of Land Surface Temperature

A significant challenge for LST when retrieved from TIR measurements is the presence of clouds that preclude the retrieval. Microwave observations between 10 and 36 GHz can overcome this primary difficulty and have been successfully used to retrieve LST (e.g., Aires et al., 2001, Holmes et al., 2000, Prigent et al., 2016). The errors on these LSTs are slightly larger than for their infrared counter parts, but the estimates are available ~90% of the time (compared to less than ~40% of the time with the infrared estimates).

Precipitation Rate

Precipitation is a key hydrological and climate variable and includes both the liquid (rain) and solid (snow and ice) forms. Precipitation occurs when a particle formed by the condensation of water vapour becomes heavy enough to fall under the force of gravity. Precipitation rate estimates are a fundamental component of the water cycle characterization. The physical basis for retrieving precipitation from microwave radiometer measurements depends on distinguishing the radiation from Earth's surface from the radiation emitted from precipitation (e.g. Hilburton and Wentz, 2008). Microwave emission from the ocean surface is strongly polarized, while the emission from rain drops is un-polarized. Thus, precipitation can be accurately distinguished from the underlying ocean surface using measurements of the vertically and horizontally polarized radiation. CIMR will be able to provide estimates of precipitation rate, although further algorithm development is required, in particular to exploit forward and backwards views together.

4.4 ROSE – L L Band Synthetic Aperture Radar

ROSE-L would carry an L-band SAR. Since the longer L-band signal can penetrate through many natural materials such as vegetation, dry snow and ice, the mission would provide additional information that cannot be gathered by the Copernicus Sentinel-1 C-band radar mission. It would be used in support of forest management, to monitor subsidence and soil moisture and to discriminate crop types for precision farming and food security. In addition, the mission would contribute to the monitoring of polar ice sheets and ice caps, sea-ice extent in the polar region, and of seasonal snow.

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Mission	Number of S/C	Orbit (Alt and Inc)	LTAN	Instrument Mode	Swath Width	Resolution	FoR	Max RT	Coverage
Copernicus Expansion L-Band SAR (LSAR)	1 or more	SSO Possibly same as Sentinel-1	dawn-dusk	Single-pass and repeat- pass interferometry	260 km	5x5 m	20º - 45º	6 days	Global

Table 6: Summary LSAR Mission

4.5 FSSCat- Towards Federated EO Systems

FSSCat is an innovative mission concept consisting of two federated 6U Cubesats in support of the Copernicus Land and Marine Environment services. They carry a dual microwave payload (a GNSS Reflectometer and a L-band radiometer with interference detection/mitigation), and a multi-spectral optical payload to measure soil moisture, ice extent, and ice thickness, and to detect melting ponds over ice. It also includes a radio/optical inter-satellite link and an Iridium intersatellite link to test some of the techniques and technologies for upcoming satellite federations. FSSCat will be the precursor of a constellation of federated small satellites for Earth observation achieving high temporal resolution and moderate spatial resolution in a cost-effective manner. Small satellites are a cost-effective way to test new concepts for Earth observation. The constellation of federated satellite systems will offer the highest investment return, improved revisit time, scalable approach, and graceful performance degradation at the end of the satellites' life.

5 EO commercial existing and future missions: survey and assessment

According to Satellite Applications Catapult analysis [22], 328 small satellites were launched in 2017, and the 2018 forecast for microsatellite launches across the globe falls between 263 and 413. Those 328 small satellites referred to satellites of mass up to 500kg, but according to the Satellite Applications Catapult, some 89 percent of these were less than 10kg (nanosatellites). Two thirds of these spacecraft were orbited to deliver Earth imaging/observation applications enlarging dramatically the EO based application to be developed. In this dynamic market, the EO4Agri activity analysed the missions that can impact the agriculture domain and reported, in the following table, the critical parameters that affect the current analysis.

		ORBIT	SATELLITE MASS	PAYLOAD	RESOLUTION	REVISIT	KEY FEATURE	LIFESPAN
planet	FLOCK	LEO	5kg	Optical	3-5 m	1,5hrs	RGB/ Multispectral	2-3 yrs
spire	LEMUR	LEO	4kg	AIS/ RO/ ADS-B	-	1,5hrs	-	2 yrs
SATELLOGIC	ALEPH	LEO	37kg	Optical/ Video	1 m	1,2HRS	Multispectral	3 yrs
BLACKSKY	GLOBAL	LEO	56kg	Optical	1 m	3hrs	Multispectral	3 yrs
exactEarth	EXACTVIEW	LEO	Payload mounted on Iridium NEXT	AIS	-	n.a.	-	Depending on bus
Capella Space	CAPELLA 36	LEO	40kg	SAR	0,5 m	1hr	-X-Band	2 yrs
ASTRO DIGITAL	LANDMAPPER	LEO	11kg (20kg)	Optical	22 m (2,5m)	1 day	Multispectral	5 yrs
GeoOptics	CICERO	LEO	10kg	RO	-	n.a.	-	2 yrs
planet	SKYSAT	LEO	120kg	Optical/ Video	37 cm	12hrs	Multispectral	6 yrs
ICEYE	ICEYE	LEO	80kg	SAR	3 m	1 hr	X-Band	2-3 yrs
urthecast	OPTISAR	LEO	670 kg + 1400 kg	Optical/ Video/ SAR/ AIS	50 cm + 5 m	n.a.	Multispectral + L/ X Band	n.a.
	VIVID - I	LEO	100 kg	Optical	60cm	12hrs	Multispectral	5 yrs
AXELSPACE	AXELGLOBE	LEO	80kg	Optical	2,5 m	1 day	Multispectral	5 yrs
HERA	1HOPSAT	LEO	22kg	Optical/ Video	1 m	n.a.	n.a.	3-5 yrs
urthecast	URTHEDAILY	LEO	340kg	Optical	5m	1 day	Multispectral	10 yrs
HYPERSAT	HYPERSAT	LEO	n.a.	Optical	<10m	n.a.	Hyperspectral	n.a.
MAXAR	WV LEGION	LEO	700kg	Optical	30 cm	3hrs	Multispectral	n.a.
MAXAR	WV SCOUT	LEO	<50kg.	Optical	80 cm	3hrs	Multispectral	n.a.
AIRBUS	PLÉIADES NEO	LEO	700kg	Optical	30 cm	12hrs	Multispectral	5 yrs

Table 7: Survey of Commercial EO current and future missions

6 Recommendations and conclusions

In the following tables a direct analysis of potential gaps identified in WP2 are reported listing the missions that presents characteristics closer to those required. This straight comparison allows a direct definition of critical parameters/gaps that can drive recommendations for future mission design.

L- Band SAR	<= 5 m Spatial Resolution	<= 5 days Revisit Time	Dual pol System	Country	Operational/ Planned
ALOS-2	OK	NO	OK	Japan	Operational
ALOS-4	OK	NO	OK	Japan	Planned
SAOCOM-1A	NO	NO	OK	Argentina	Operational
SAOCOM-1B	NO	NO	OK	Argentina	Planned
ROSE-L	OK	NO	OK	EU	Planned

Table 8: LBand SAR comparison between existing missions and required performances

C-Band SAR	<= 2 m Spatial Resolution	<= 4 days Revisit Time	Dual pol System	Country	Operational/ Planned
Sentinel-1	NO	OK	OK	EU	Operational
RADARSAT-2	NO	OK	OK	Canada	Operational
RCM	**OK**	**OK**	**OK**	Canada	Planned
RISAT-1A/1B	OK	NO	OK	India	Planned
GAOFEN 3	OK	NO	OK	China	Operational

Table 9: CBand SAR comparison between existing missions and required performances

X-Band SAR	<= 1 m Spatial Resolution	<= 4 days Revisit Time	Dual pol System	Country	Operational/ Planned
TerraSAR-X/ TanDEMX	**OK**	**OK**	**OK**	Germany	Operational
TSG	OK	NO	OK	Germany	Planned
Cosmo-SkyMed	OK	OK	NO	Italy	Operational
CSG	**OK**	**OK**	**OK**	Italy	Planned
SeoSAR/PAZ	**OK**	**OK**	**OK**	Spain	Operational
ASNARO 2	OK	NO	NO	Japan	Operational
ICEYE	NO	OK	NO	Finalnd	Planned
RISAT 2	NO	NO	OK	India	Operational
Kompsat-5	OK	NO	OK	Korea	Operational
Kompsat-6	OK	NO	OK	Korea	Planned

Table 10: XBand SAR comparison between existing missions and required performances

Currently operational and planned SAR missions are generally compliant with the spatial requirements and most of them provide dual polarization data, useful for agriculture applications. On the other side, the need of frequent acquisitions, that is less than 4-5 days of revisit time, is a major issue especially affecting L-band sensors. Future SAR missions should focus on the improvement of the revisit time, achievable by tuning the following parameters:

- Number of satellites

The constellations allow to improve the revisit time; solutions with new generation of satellites in cooperation with existent missions are a possible solution.

- Satellite Agility

Use of Gyro device, Right and Left Looking, electrical steering allows to improve the satellite's agility to acquire image as soon as possible.

Hyperspectral	**<= 5 m Spatial Resolution**	**<= 3 days Revisit Time**	**50 bands VNIR**	**Country**	**Operational/ Planned**
PRISMA	**NO**	**NO**	OK	Italy	Operational
EnMAP	NO	NO	OK	Germany	Planned
ALOS 3	NO	NO	OK	Japan	Planned
Reaktor Hello World	**NO**	**NO**	OK	Finland	Operational

Table 11: Hyperspecral 1 comparison between existing missions and required performances

Hyperspectral	**<= 10 m Spatial Resolution**	**<= 3 days Revisit Time**	**50 bands SWIR**	**Country**	**Operational/ Planned**
PRISMA	**NO**	**NO**	OK	Italy	Operational
EnMAP	NO	NO	OK	Germany	Planned
ALOS 3	NO	NO	OK	Japan	Planned
Reaktor Hello World	**NO**	NO	OK	Finland	Operational

Table 12: Hyperspecral 1 comparison between existing missions and required performances

Currently operational and planned Hyperspectral systems are generally compliant with the spectral requirements, whereas they do not meet either the spatial resolution requirements. Since the systems are generally composed of a few number of satellites (1 or 2 in general), they also offer a limited revisit that in principle can be improved using the agility of the satellite, but not enough to reach the 3 days objective. Only use of a constellation may help on this aspect. The most challenging objective is the improvement of the spatial resolution in the whole VNIR and SWIR, because it requires taking into account other design parameters such as spectral resolution and spectral range. Thus, to achieve high performances, a larger payload is needed.

Besides the previous conclusions and recommendations, other elements could be considered such as:

- Lower Cost: modular approach (miniaturisation, digitisation of interfaces)
- Architectural evolution: Integration with other missions, (de-)centralised intelligence
- Opening up to constellations or virtual constellations (Space 4.0)
- Standardisation (e-I/Fs + form factor) of modules for multi-suppliers

Other possible improvements for agriculture applications improvements are related to:

- LPIS availability as open and free data
- Meteorological data harmonization and integration

These concepts, preliminary listed in the present document, will be analysed in deep during the task activities and reported in the V2 of the present deliverable.

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