IMPLEMENTING MULTI-SCALE AGRICULTURAL INDICATORS EXPLOITING SENTINELS

GUIDELINES FOR A FIELD CAMPAIGN

ISSUE I1.00

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1. BACKGROUND OF THE DOCUMENT

1.1. Scope and Objectives

This document aims to present the main elements for performing a field campaign, including guidelines for ground data acquisitions and reporting in agreement with the methods proposed by CEOS LPV and VALERI project. This guideline follows the one recently proposed for a ground campaign in the European Space Agency (Baret, 2012).

1.2. Content of the Document

Chapter 2 provides an overview of Imagines

Chapter 3 provides an introduction to the direct validation strategy

Chapter 4 details criteria for site selection

Chapter 5 provides comments on satellite acquisitions

Chapter 6 gives recommendations for sampling the site

Chapter 7 provides guidelines for reporting

2. IMAGINES OVERVIEW

2.1. Executive Summary

The GMES Land Service has been built in the framework of the FP7 geoland2 project, which has set up pre-operational infrastructures. IMAGINES intends to ensure the continuity of the innovation and development activities of geoland2 to support the operations of the global land component of the GMES Initial Operation (GIO) phase. In particular, the use of the future Sentinel data in an operational context will be prepared. Moreover, IMAGINES will favor the emergence of new downstream activities dedicated to the monitoring of crop and fodder production.

The main objectives of IMAGINES are to (i) improve the retrieval of basic biophysical variables, mainly LAI, FAPAR and the surface albedo, identified as Terrestrial Essential Climate Variables, by merging the information coming from different Sentinel sensors and other GMES contributing missions; (ii) develop qualified software able to process multi-sensor data at the global scale on a fully automatic basis; (iii) propose an original agriculture service relying upon a new method to assess the biomass, based on the assimilation of satellite products in a Land Data Assimilation System (LDAS) in order to monitor the crop/fodder biomass production together with the carbon and water fluxes; (iv) demonstrate the added value of this agriculture service for a community of users acting at global, European, national, and regional scales.

2.2. Portfolio

The ImagineS portfolio contains global and regional biophysical variables derived from multi-sensor satellite data, at different spatial resolutions, together with agricultural indicators, including the above-ground biomass, the carbon and water fluxes, and drought indices resulting from the assimilation of the biophysical variables in the Land Data Assimilation System (LDAS) (Table 1).

The ambition of the project is to provide a full coverage of the globe, at a frequency of 10 days, merging Sentinel-3 and Proba-V data. The demonstration of high resolution (10m) products (Sentinel-2 + Sentinel-3 + PROBA-V) will be done over 11 demonstration sites of cropland and grassland in contrasting climatic and environmental conditions (

ID	Name	Description	Location
1	South-West, France	Flat cropland with a rotation of wheat, maize, sunflower. Some fields are irrigated.	43° 29' N, 1° 16' E
2	Hegyhatsal, Hungary	Flat cropland where small parcel-based agricultural management is typical of the whole country	46° 57' N, 16° 39' E

ID	Name	Description	Location
3	Las tiesas Farm, Barrax, Spain	Flat cropland of 65% dry land (barley, wheat) and 35% irrigated crops with large pivots (onion, garlic, sugarbeets, potatoes, maize, alfalfa, sunflower).	39° 02’ N, 2° 04’ W
4	Tula, Russia	Typical field size is near 100 hectares. Crop types are winter wheat, spring barley, potatoes, maize, rape seeds, and winter rye.	53° 05’ N, 37° 14’ E
5	Pandamatenga, Botswana	Flat extensive grassland savanna	18° 30’ S, 25° 32’ E
6	Merguellil, Tunisia	Flat plain with fields of cereals, vegetables and olive trees, dry and irrigated	35° 45’ N, 10° 5’ E
7	Free State Province, South Africa	Agriculture and grasslands. Site located in the major grain producing province of South Africa.	28° 25’ S 27°4’ E
8	Greenbelt Farm, Ottawa, Canada	Agriculture in this region of eastern Canada mainly consists of corn, soybean and spring wheat annual crops adapted to short-season, perennial forage and livestock pasture.	45° 18’ N, 75° 45’ W
9	Requínoa, VI Region of Chile, Chile	Flat cropland area covered by annual crops such as maize, wheat, alfalfa, sunflowers.	34° 19’ S, 70° 50’ W
10	25 Mayo, La Pampa, Argentina	Pastures (pampas)	37° 54’ S, 67° 44’ W
11	Yanco area, Murrumbidgee River catchment, Australia	A gently sloping area containing irrigated croplands and natural rangelands.	34° 45’ S, 146° 04’ E
12	Comunidad de regantes del Campo de Cartagena, Spain	50.000 ha irrigated crops with drip irrigation (vegetables and citrus trees).	37º 48’ N, 1º 03’ W
13	Cordoba, Spain	Flat cropland area	37º 48’ N 4º 44’ W
14	Lambayeque, Peru	Flat cropland area monitored for drought and desertification analysis	6° 47’ S, 79° 46° W

Table 2).

France and Hungary are the main areas of interest as the regional LDAS can run at 8 km resolution over these countries.

The feasibility of the crop map merging Sentinel-1, Sentinel-2, and Sentinel-3 will be demonstrated over two areas of about 300km x 300km around Tula (Russia) and in the Free State Province (South Africa). Both areas are demonstration sites of the JECAM initiative, developed in the framework of GEO Global Agricultural Monitoring, which enables to share experiment data on proposed sites where regularly field campaigns are organized.

ID	Name	EO sensor	Temporal resolution	Spatial resolution	Spatial coverage
01	LAI, FAPAR, FCover	S3 + PROBA-V	10 days	300 m	Global
02	Albedo	S3 + PROBA-V	10 days	300 m	Global
03	Biomass	S3 + PROBA-V	10 days	16 km (8 km)	Global (Fr,Hu)
04	Drought indicators	S3 + PROBA-V + ASCAT	10 days	16 km (8 km)	Global (Fr,Hu)
05	Carbon fluxes (GPP, RE, NEE) and evapotranspiration	N/A	10 days	16 km (8 km)	Global (Fr,Hu)
06	FAPAR per class	S3 + PROBA-V	10 days	16 km (8 km)	Demo sites
07	Surface reflectance	S2	Instantaneous[1]	10 m	Demo sites
08	FAPAR	S2 + S3 + PROBA-V	10 days	10 m	Demo sites
09	Biomass	S2 + S3 + PROBA-V	10 days	Local simulations	Demo sites
10	Crop map	S1 + S2 + S3	Continuous update [2]	10 m	Demo sites

Table 1: Detailed IMAGINES products. [1]: for each Sentinel-2 image; [2]: when a new acquisition is available.

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1	South-West, France	Flat cropland with a rotation of wheat, maize, sunflower. Some fields are irrigated.	43° 29' N, 1° 16' E
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	Hungary	country	16° 39' E
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Table 2: IMAGINES demonstration site characteristics

3. INTRODUCTION

The content of this document is designed to be compliant with validation guidelines (CEOS LPV, VALERI, ESA) where recommendations are given for running and exploiting a campaign (e.g., Baret et al., 2012). It therefore follows the general strategy based on a bottom up approach: it starts from the scale of the individual measurements that are aggregated over an elementary sampling unit (ESU) corresponding to a support area consistent with that of the high resolution imagery used for the upscaling of ground data. Several ESUs are sampled over the site. Radiometric values over a decametric image are also extracted over the ESUs. This will be later used to develop empirical transfer functions for upscaling the ESU ground measurements.

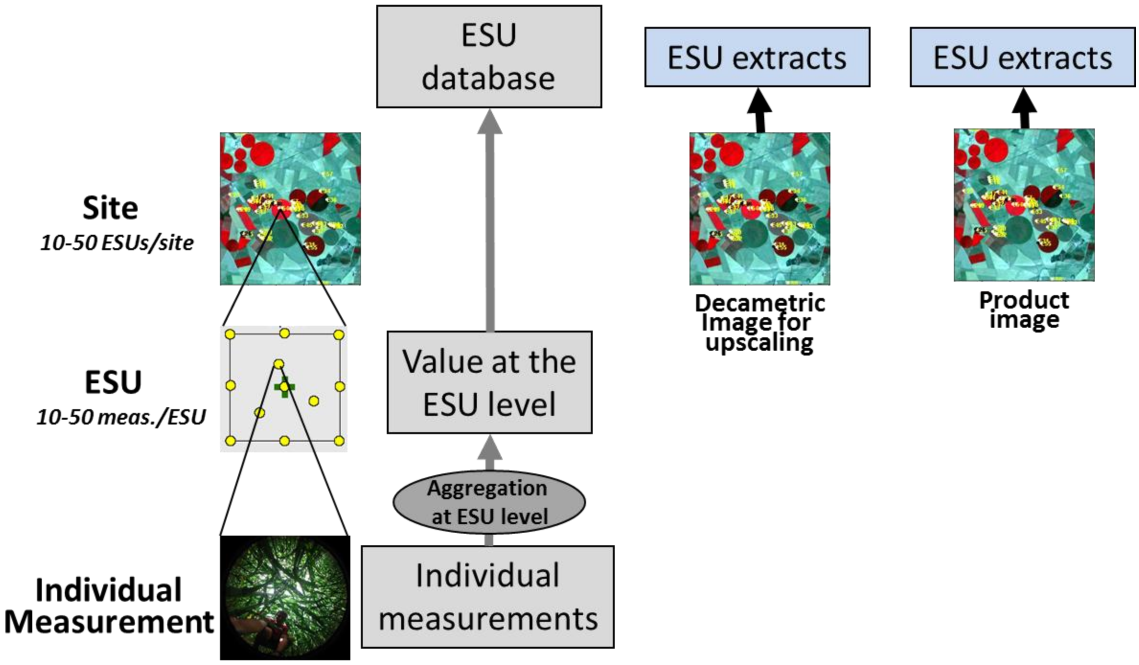

Figure 1. General strategy used to sample the validation site and extract the desired information.

4. SELECTION OF THE SITE

4.1. CRITERIONS CONSIDERED FOR SITE SELECTION

Several criterions should be considered to select the validation site:

- Type of vegetation
  - Crops and/or rangeland areas are preferable within ImagineS.

- Heterogeneity, topography and extent of the site
  - The site should be relatively flat to simplify the interpretation.
  - It should present a significant range of crops and development stages
  - The site should be composed of patches of vegetation large enough to minimize border effects when samples are taken in the center of the patch.
  - The accessibility of the fields should be easy (presence of public paths or roads, and in case of private or restricted areas, getting authorization should be possible)
  - The extent should be around few km² (≈ 3x3 km2) so that ground sampling would be relatively easy.

- Date for ground measurements and image acquisition
  - The measurement date(s) should provide: Good probability for clear sky, relatively good range of LAI values (from low to high) and minimize problems related to the presence of non-green vegetation elements.

Although not strictly mandatory when validating L3 products, multi-temporal campaigns may be also relevant to assess the temporal stability and consistency of the products. Therefore, several campaigns along the growing period are desirable. However, multi-temporal campaigns require significant efforts for ground data collection.

4.2. PROPOSITION FOR A SITE

Demonstration sites have been defined by local partners (Table 2)

5. AIRBORNE AND SATELLITE DATA

5.1. AIRBORNE DATA

It is not mandatory for the ground campaigns in ImagineS.

5.2. SATELLITE DATA

For upscaling of the ground biophysical measurements through empirical transfer functions, decametric satellite image is required.

A satellite image with a spatial resolution close to 10 m would allow accurate registration and very good spatial consistency required for developing and applying the empirical transfer functions for upscaling the ground measurements. Satellite data acquisitions are planned in ImagineS and the Global Land Service:

- SPOT

The images should be acquired within few days from the ground measurement collection.

6. SAMPLING THE SITE

6.1. Selection of ESUs

A single pixel or a small cluster of pixels will constitute the Elementary Sampling Unit that should be associated with the ground measurements representative of the corresponding area. The selection of the ESUs will follow the following rules:

- ***Size of the ESUs.*** The ESUs should be around 10-20m in agreement with the pixel size of high resolution products.
- ***Number of ESUs.*** Considering the site heterogeneity a minimum of 30 ESUs should be sampled over the study site (3x3 km^2). Note that additional control points over bare areas should be taken.
- ***Location of the ESUs.*** The ESUs should sample the variability observed over the site, both in terms of landcover and conditions. A stratified sampling based on the prior knowledge of the landcover is optimal. The ESUs may be conveniently located close to paths or roads to ease the access. However, adjacency effects should be minimized in order to provide more genericity to the validation exercise. ESUs should therefore be located at a reasonable distance (i.e. 50 m) from borders and surrounded by pixels with approximately the same type of vegetation as that of the considered ESU. Note that each ESU should be geo-referenced within few meters accuracy for later matching the products derived from satellite images. GPS devices may be used to achieve this geo-location accuracy.

6.2. Sampling an EsU

6.2.1. Sampling scheme

Over each ESU, the same sampling scheme will be used for the measurement of the several variables targeted.

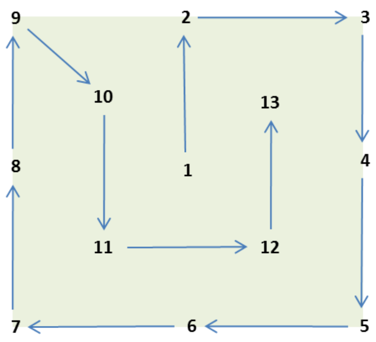

Figure 2. Typical sampling scheme proposed for an ESU.

A systematic sampling scheme (Figure 2) is proposed, allowing more independent individual measurements. The size at the ground level of the area sampled should be around 20m. The GPS coordinates of the centre of the ESU (point 1) will be measured within few metres accuracy. The sampling will thus include 13 individual measurements.

6.2.2. Leaf area index (LAI), FAPAR and FCover: DHP measurements

It is proposed to use digital hemispherical photography (DHP) to estimate LAI, FAPAR and fractional vegetation cover (FCover). This technique has been proven very efficient. However, great care should be taken to:

- Illumination conditions: better use diffuse conditions
- Use color cameras with high resolution (minimum 10 Mega pixels)
- Sample both overstory (looking upward) and understory (looking downward) when needed.

The processing could be conveniently achieved using the CAN-EYE software (https://www4.paca.inra.fr/can-eye/CAN-EYE-Home/Welcome) that will provide both estimates of effective LAI, true LAI (according to several ways to estimate leaf clumping) and FAPAR (actually FIPAR) for a range of sun positions.

7. GUIDELINES FOR REPORTING

A standardization of the reporting and data organization and format is recommended. It will considerably help the meta-analysis of an ensemble of campaigns which is the ultimate objective of the validation campaigns. The campaign should result into three documents:

- ***A general description of the site and the measurements***
- ***A file containing the values measured over each ESU*** along with some description of the ESU.
- ***Images corresponding to :***
  - Satellite image for upscaling the ground measurements.
- ***Ancillary data***

7.1. DESCRIPTION OF THE SITE AND THE MEASUREMENTS

This should take the form of a small report where the following information should be given:

- ***Description of the site***. The site should be roughly described in terms of
  - Location (lat-lon) and extent (km). A google earth extract with the limits of the site indicated could be very useful.
  - Date of measurement(s): the date(s) when the measurements were completed.
  - Type of vegetation: describe the main types of vegetation and variability. A decametric landcover classification map could help understanding the landscape structure. Describe if some particular objects may be encountered (urban areas, water-bodies, snow …)
  - Topography: describe the topography of the site. A DEM map could help understand particular problems.
  - Describe the sampling scheme for ESUs. Geo-located ESUs over the google earth image would be very efficient.
- ***Description of the measurements over ESUs*** for each variable of interest (LAI, FAPAR, FCover)
  - Device(s) used to the individual measurements
  - Sampling scheme used for the ESU (number and location of the samples).
  - Data processing method to compute the ESU value.
  - Corresponding detailed definition of the variable (accounting for green vegetation, understory, clumping)
- ***Description of the available images***
  - **Airborne images** (if any)
  - **Satellite images used for georeferencing and upscaling** ESU measurements. The satellite used, day and time of overpass and view

direction (for explaining possible BRDF effects) need to be documented as well as possible processing including registration, projection, radiometric calibration and possible atmospheric correction.

- ***Description of the ancillary data*** acquired that includes (when available):
    - *Atmospheric characteristics* through sunphotometers. Location and time (in UT) of measurements is mandatory along with device type and data processing. The format of the data file should be documented here. (not mandatory here)
    - *Ground radiometric measurements*, requiring as well Location and time (in UT) of measurements is mandatory along with device type and data processing, with emphasis on the radiometric calibration. (not mandatory here)
    - *GPS ground control points* for more accurate geo-referencing. The accuracy of the position and the projection system used should be indicated. The format of the data file should be documented here.

7.2. DESCRIPTION OF EACH ESU

Each ESU should be described according to an agreed format. For this purpose a template xls file should be used. It will mainly describe for each ESU:

- The position (coordinates)
- The dimension (typical diameter)
- The altitude
- The date of measurement
- The type of vegetation and state
- The measurement performed (Method, sampling, processing, value and uncertainties)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	Site #	Site name	Abrev. (4 char.)	ESU #	Latitude (°)	Longitude (°)	Altitude (m)	Extent (m) of ESU (diameter)	Land Cover %							Start Date (dd/mm/yyyy)	End Date (dd/mm/yyyy)	LAI					
2									Savana	Grass	Crop	DBF	NF	EBF	Other			Method	Nb. Replications	Process. LAIeff	Process. LAItrue	Value	Uncertainties
3																		Destructive					
4																							
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Figure 3. The Excel file template used to describe ESUs with the LAI measurements.

7.3. IMAGES

All images should be in GEOTIFF format with a name that includes the date (year-month-day) and time (UT) of the flight.

7.4. ANCILLARY DATA

The ancillary data should be provide in simple ASCII format with location and time (UT) properly documented. They include:

- Atmospheric measurements
- Ground radiometric measurements
- Ground control points GPS measurements.

8. REFERENCES

Baret, F (2012). Proposition for a delta campaign. ESA VALSE2 project technical report, 2.0. 14pp

VALERI: w3.avignon.inra.fr/valeri/