IMPLEMENTING MULTI-SCALE AGRICULTURAL INDICATORS EXPLOITING SENTINELS

RECOMMENDATIONS FOR SETTING-UP A NETWORK OF SITES FOR THE VALIDATION OF COPERNICUS GLOBAL LAND PRODUCTS

IMAGINES_VALIDATIONSITESNETWORK

ISSUE 1.00

EC Proposal Reference N° FP7-311766

Start date of project: 01.11.2012 Duration : 40 months

Name of lead partner for this deliverable: EOLAB

Book Captain: Fernando Camacho (EOLAB)

Contributing Authors: Roselyne Lacaze (HYGEOS)

Frédéric Baret (INRA)

Project co-funded by the European Commission within the Seventh Framework Program (2007-2013)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	**X**
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

DOCUMENT RELEASE SHEET

Book Captain:	F. Camacho	Date: 19.03.2014	Sign.
Approval:	R. Lacaze	Date: 26.03.2014	Sign.
Endorsement:		Date:	Sign.
Distribution:			

CHANGE RECORD

Issue/Revision	Date	Page(s)	Description of Change	Release
	19.03.2014	All	First issue	I1.00

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. BACKGROUND OF THE DOCUMENT

1.1. EXECUTIVE SUMMARY

ImagineS is a FP7 R&D project built to support the operations of the Copernicus Global Land Service.

In particular, the project has defined the methodology to retrieve some biophysical variables (Leaf Area Index (LAI), Fraction of Absorbed PAR (FAPAR), Fraction of Green Cover (FCover), and Albedo) and developed the resulting software able to ingest, and process at global scale, the 333m resolution data from PROBA-V sensor. These processing lines are being to be integrated into the operational infrastructure of the Copernicus Global Land service to ensure its evolution towards the production of medium resolution products.

In parallel, ImagineS performs some field campaigns to collect ground measurements of vegetation variables because comparing the satellite-derived products with in-situ measurements is the only way to assess their accuracy and, then, to check if they are compliant with the users' requirements. Vegetation variables are measured following protocols, specifically defined to be useful for the validation of the satellite products, and agreed by the international community. ImagineS teams carry out this activity over few sites monitored by local teams who are motivated by a fruitful collaboration, and the exchange of data, with ImagineS.

Because the quality of the Copernicus Global Land service products need to be continuously checked, it would be relevant to establish a network of sites where ground measurements could be acquired on a sustainable way. Based upon its experience, ImagineS project presents here some recommendations to set-up such a network.

1.2. SCOPE AND OBJECTIVES

This document proposes a strategy, and a preliminary overall budget estimate, to set-up a network of sites where to collect ground data dedicated to the validation of the biophysical products of the Copernicus Global Land service.

1.3. CONTENT OF THE DOCUMENT

The document is structured as follows:

- Chapter 1 presents the rationale for building the network
- Chapter 2 describes the strategy to build this network
- Chapter 3 makes a first budget assessment
- Chapter 4 lists the references.

1.4. Related Documents

1.4.1. Inputs

Document ID	Descriptor
IMAGINES_RP1.1_URD	Users Requirement Document of ImagineS project
IMAGINES_RP1.2_SSD	Service Specifications Document of ImagineS project
IMAGINES_RP7.2_SVP	Service Validation Plan of ImagineS project

1.4.2. Output

Document ID	Descriptor
IMAGINES_RP7.5_FieldCampaign	Reports on field campaign and in-situ data processing

2. RATIONALE

Provision of consistent ground biophysical parameters (LAI, FAPAR, FCover) on a regular basis is mandatory for the validation of biophysical product of the Copernicus Global Land service. To reach Stages 3 and 4 of the CEOS Land Product Validation (LPV) validation hierarchy, a representative set of sites over the globe with regular updates of the ground information, as the satellite time series expands, is required. Moreover, the biophysical variables should be measured following CEOS LPV protocols to be useful for validation of satellite products (up-scaling).

Up to know, the largest compilation of ground data processed according to CEOS LPV guidelines was mainly achieved by Garrigues et al. (2008) coming from a range of initiatives (VALERI, NASA, CCRS, ESA…), but none of them are currently providing updated biophysical parameters. Existing networks such as LTER (Long Term Ecological Research network) (http://www.lternet.edu/), JECAM (Joint Experiment for Crop Assessment and Monitoring) (http://www.jecam.org/) or FLUXNET (http://fluxnet.ornl.gov/), are not fully dedicated to the validation of LAI/FAPAR satellite products and the sites, methodologies or measured parameters do not always match properly the validation requirements for global biophysical products.

Consequently, building a network of sites for the provision of regular and consistent ground data is necessary for the validation of Copernicus Global Land products whose quality needs to be verified continuously. This should be achieved taking benefit of both the existing infrastructures and networks where various in-situ measurements are already collected, and the decametric imagery necessary for solving scaling issues. Conversely, the ground data can be used for the validation of the high resolution biophysical products that will be derived from the current or future EO missions data.

3. THE NETWORK

For a statistical representation of the continental biomes, the network, in its operational configuration, i.e. after 4 years, should cover at least 50 sites worldwide. With 2 or 3 dates per sites, depending on the ecosystem, we should reach between 100 and 150 validation points (sites x dates). Moreover, the set-up of automated systems, to collect continuous measurements, can be achieved over a number of homogeneous sites (e.g. FLUXNET sites) for monitoring the vegetation dynamic. The description of the dynamics within validation experiments has been mainly missing up to now, although it brings new insight on the products quality including the temporal consistency and the derivation of phenological metrics.

3.1. Specifications of Sites

Several criterions should be considered to select the validation site:

- Type of vegetation
  - Main biomes and vegetation types should be sampled, including crops (various species), grasslands, shrublands, and different forest sites (BDF, EDF, ENF).

- 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 extent should be around few km² (≈ 3x3 km^2) so that ground sampling would be relatively easy.

- Accessibility and monitoring
  - The accessibility of the sites should be easy (presence of public paths or roads, and in case of private or restricted areas, getting authorization should be possible).
  - Collaboration with flux towers sites, where the installation of sensors for the continuous monitoring would be feasible with the support of the local teams.

- Sustainability of the validation. The sites should ensure to be used for at least few years. This requirement will be fulfilled if the local teams have activities focused on specific objectives, the validation being a complementary task. The JECAM sites as well as other networks of sites (FLUXNET, LTER) will provide a good basis for such extension. The validation activities will bring to the local teams access to methods, instruments and remote sensing images.

3.2. BUILDING THE NETWORK

The strategy could be to start with a number of core sites (first year) and to expand gradually the network, during the next 3 years, to reach the target objective of 50 sites worldwide after 4 years:

- The core sites, belonging to existing networks, which are also identified as ImagineS demonstration sites (various croplands and grasslands areas mainly), where solid collaborations have been already established with local teams.
- Then, the number of sites could be increased with other areas compliant with sites specifications by developing collaborations with existing networks, like JECAM, LTER, FLUXNET, Enviro-Net (http://www.enviro-net.org)
- A number of field campaigns could be organized additionally to cover the biomes/regions under-sampled by the existing networks.

Protocols should be established with each local team for managing the provision of guidelines and/or sensors for field acquisitions, the participation to collect ground measurements, the exchange of data, the joint promotion and communication.

4. DATA ACQUISITION AND PROCESSING

The methodology proposed here is consistent with the good practices for LAI validation as described by CEOS/LPV (Fernandes et al. 2014).

4.1. IN-SITU DATA ACQUISITION

A single pixel or a small cluster of pixels will constitute the Elementary Sampling Unit (ESU) 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 10-20 m in agreement with the pixel size of high resolution products.
- ***Number of ESUs.*** Considering the site heterogeneity a minimum of 20 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.

So that to capture the phenological evolution of some vegetation types, like crops or deciduous forests, multi-temporal (maximum 3) ground collections of measurements should be achieved during the season. A network of automated sensors (e.g. the PASTIS systems) could be installed over some of these sites for a continuous monitoring of canopy transmittance or gap fraction for the estimation of PAI (Plant Area Index or FAPAR on a daily basis (autonomous systems can record data every 2 to 10 minutes). The number of sensors should be enough to provide a good spatial characterization of the site according to its spatial variability and to reduce the uncertainty introduced by an insufficient sampling.

LAI, FAPAR and FCover should be retrieved jointly from the gap fraction using relevant measurement systems (like e.g. Digital hemispherical photographs), in addition to other indirect methods (e.g. LAI-2200, TRAC, AccuPar or others) measuring gap fraction or transmittance through the canopy.

Accuracy of the ground measurements is expected to be better that the requirements of the GCOS for satellite products (i.e., 0.5 for LAI, 0.05 for FAPAR). Uncertainties of ground measurements should be quantified either by comparison with destructive sampling or by performing inter-comparisons of retrievals with different devices over the same location.

Guidelines and protocols for ground data collection and reporting are available on the ImagineS website (ftp://www.FP7-imagineS.eu/documents/).

The in-situ measurements could be up-scaled using high resolution (decametric) images either empirically (i.e. by transfer functions) or physically (i.e. by neural networks) relating spectral optical satellite reflectances and measured biophysical variables.

4.2. REMOTE SENSING IMAGERY

The optical remote sensing images useful for up-scaling issues should fit the following specifications:

- Optical sensor characteristics:
    - Spectral bands: VIS/NIR, SWIR
    - Maximum cloud coverage: 5% over the area of interest
    - Single date: the closest observation to the date of the field campaign
- Spatial resolution: decametric from 10m to 30m
- Product specification:
    - Radiometric resolution: 12 bits per pixel
    - Radiometric accuracy: < 5%
    - Geometric accuracy: 1/3 spatial resolution
- Production time / delivery: normal. Data must be delivered in less than one week after the acquisition.
- Processing
    - Radiometric processing:
        - no atmospheric correction to get Top of Atmosphere (TOA) reflectances
    - Geometric processing:
        - Ortho-rectification
        - EPSG code: WGS84
        - Projected over a regular grid

No specific programming satellite acquisitions are necessary since these needs should be covered by the current (e.g. Landsat-8) or future (e.g. Sentinel-2) high resolution EO missions.

The resulting high resolution maps of biophysical variables would be used for the validation of Copernicus Global Land products.

A database and a dedicated web service should be built with the individual ground data, the up-scaled ground based decametric maps and the averaged value at the spatial resolution of Copernicus satellite products over the network of sites.

5. BUDGET ASSESSMENT

The main budget headings are:

- Field campaigns (in-situ data collection) shared in
    - Human resources and travel costs. They depends on the composition of the network, i.e. the location of sites (inside or outside Europe), the temporal sampling of each site (which depends on the ecosystem) i.e. how many time during the season the ground measurements are collected, the number of persons involved in the data collection, the duration (number of days) of the data collection, etc…The costs can vary from 7,5k€ for multi-temporal acquisition over a monitored site, easily accessible in Europe with 2 or 3 persons involved during typically 3 or 4 days to 15k€ for multi-temporal acquisitions over a site outside Europe. An average cost of 10k€ is expected for many sites.
    - Sensors. These costs are one-shot for a site. Below some costs of the most used sensors are given as examples:
        - A LAI-2200 sensor costs 9500€, an AccuPAR instrument costs 4500€.
        - A digital camera for taking hemispheric photographs costs 1500€
        - Each PASTIS system (for continuous monitoring) costs 700 €. A number of 20 systems are typically needed for each site (15k€). A number of about 10 and 15 sites could be instrumented. It is expected to provide the sensors to sites over existing networks with a little additional budget for maintenance over time (5k€ per year since the second year after installation).

- In-situ data processing (human resources):
    - by local teams: process the raw measurements and put retrieved biophysical values into a standard format (a template has been set-up by the ImagineS project)
    - Defining the up-scaling relationships, and generating validation maps database using high resolution images should be performed by the coordinating entity on a consistent and centralized way

- Coordination of the network, including management of sub-contracts with local teams, networking/promoting collaborations, development and maintenance of the web service for data/product exchange.

An overall budget estimate for 4 years is given in Table 1 below.

Activity	Budget (k €)		Comments
	Minimum	Maximum	
Field campaign			
Human resources and travel costs	450	550	For a target network of 50 sites
Sensors	200	300	
In-situ data processing	325	325	For about 125 maps (sites x dates)
Coordination	375	375	Coordination, sub-contracts, networking, workshops, web service
Total	**1.350**	**1.550**	

Table 1: Overall budget assessment per activity for 4 years.

The main activities per year are expected:

- Year 1: Prepare the data acquisitions over network of core sites (about 20 sites). Acquire sensor for 10 sites. Start networking and promotion activities. Set up protocols and guidelines for ground data acquisitions and web service for data exchange and visualization.
- Year 2: Add about 12-15 sites from existing networks. Acquire sensors for 10 additional sites. Data processing Year 1. Additional 1-2 field campaigns over under-sampled biomes.
- Year 3: Add about 12-15 sites from existing networks. Additional 1-2 field campaigns over under-sampled biomes. Data processing Year 2.
- Year 4: To complete all data processing and the validation database. Additional field campaigns over few sites if needed to reach 50 sites.

Year (all activity types included)	Budget (k €)		Comments
	Minimum	Maximum	
Year 1	350	400	12 core sites (ImagineS sites mainly)
Year 2	400	520	Additional 12 sites
Year 3	350	380	Additional 12 sites
Year 4	250	250	Target network of 50 sites with a total of validation points about 125

Table 2: Budget breakdown per year

Once the network is in its nominal configuration (50 sites after 4 years), the total (all activities included) operating costs could reach 325 k€ per year. This will include the maintenance of about 15 sites for continuous monitoring of canopy transmittance and 5 multi-temporal (three dates) campaigns over different sites per year.

6. REFERENCES

Garrigues, S., Lacaze, R., Baret, F., Morisette, J. T., Weiss, M., Nickeson, J. E., et al. (2008). Validation and intercomparison of global leaf area index products derived from remote sensing data. *Journal of Geophysical Research, 113*, G02028. http://dx.doi.org/10.1029/2007JG000635.

Fernandes, R., Plummer, S., & Nightingale, J. (2014). Global leaf area index validation good practices. In CEOS/LPV (Ed.) (p. 75) http://lpvs.gsfc.nasa.gov/PDF/CEOS_LAI_PROTOCOL_January2014.pdf