New Prototypes on Indicators and Variables

Four experimental prototypes have been developed related to Indicators and Variables as part of WP 41: Crop growth condition, Crop Emergence Date Map, Generic Land Cover Metrics and Multi-annual trends & potential change. See Table 1 for further information on the sites produced in phase 1 and 2.

Table 1: Demonstration sites for the new prototypes on indicators and variables

	Prototype Indicators and Variables – Demonstration Sites						
Site	***NORTH***	***CENTRAL***	***WEST***	***SOUTH-WEST***	***SOUTH-EAST***	***MALI***	***SOUTH-AFRICA***
Countries	*Sweden*	*Germany, Austria, Switzerland*	*Belgium, France*	*France, Spain*	*Greece, Bulgaria, Macedonia, Serbia*	*Mali*	*South-Africa*
Biogeographic Region	*Boreal*	*Continental, Alpine*	*Atlantic, Continental*	*Atlantic, Alpine, Mediterranean, Continental*	*Mediterranean, Continental, Alpine*	*Mali*	*South-Africa*
Phase 1			X				X
Phase 2		X	X				X

<u>CROP GROWTH CONDITION</u>

The Crop Growth condition is one of the four phenological prototypes focussing on agriculture. It aims at displaying the individual crop growing cycle and development of the plants, as well as farming management practices by comparing the profiles of the LAI index for three different crop types (winter barley, winter wheat, maize) at the test site in Belgium during the season of 2017 with those of the local average. The deviation of the 2017 LAI-gradient towards the average LAI-gradient reveals a shifting of the growing cycle for that year.

Input data set: This prototype relies on Sentinel-2 time series of 2017, focussing on the most important time slots within the growing cycle of the crop types. This is week 9 to week 31 (27/02/2017 - 06/08/2017) for winter barley and winter wheat and week 18 to week 43 (17/04/2017 - 29/10/2017) for maize.

Production: In this specific case, the LAI is actually a GAI being not limited to the one-sided green leaf area per unit ground surface – as it is usually the case – but taking into account that in the case of cereals, the whole plant shows photosynthetic activity. The LAI/GAI is calculated with the BVnet algorithm with reflectance values deriving from the ProSail radiative transfer model. This model uses the Sentinel-2 bands at 10 m and 20 m-resolution except the blue band (B2) and the B8 due to its overlap with B7 and B8a.

Method: The method aims at retrieving important growing parameters per crop, per period and per parcel to get a detailed profile of the crop development by applying the following steps:

- Identification of crop types at parcel level with the help of LPIS data
- Verification of the LAI profiles for winter barley, winter wheat and maize at parcel level with the local average profile

- Retrieving growing conditions per crop type, i.e. crop development in terms of earliness, maximum, maturity and management aspects such as time for sowing and harvesting.

Improvement: This product allows to identify local marginal behaviour along the season in terms of crop growth cycle, crop development or management practices by depicting quantitative anomaly derived from the comparison between the LAI profiles of each field with its surrounding ones.
The analysis of the individual development of crops within one growing season supports an accurate classification respectively the differentiation between crop types as well as between agricultural areas and other vegetation cover. Additionally, the accurate monitoring of the growing phase, starting with time of sowing, the sprouting of the plants, growing, growing peak, maturing, ending up with harvesting could support the selection of suitable time slots for EO data and thus reducing the amount of data.
The results of the crop growth condition prototype at the Belgium test site revealed a shift of 2-3 weeks for the beginning of the growing cycle within the year 2017 (compared to the local average) and proves thus quite promising.

Phase II will see the exploitation of the full potential of S-1 time series in addition to optical data.

CROP EMERGENCE DATE MAP

The Crop Emergence Date Map is an agricultural indicator layer providing information about the crop status at the field level. It responds to the growing demand of farmers to get detailed and realtime phenological parameters and thus more information on the development of their seeding, of germination and expected yield of their crops in times of variable climate conditions. The emergence date as an important parameter is subject to high inter-annual variability.
The aim of this prototype is

- To provide early-season information first phonological stages of maize, such as sprouting and first leaf development
- To offer operational implementation
- To allow further generalization of the method

Parameters for this layer have been calculated in an agricultural area at the demo site in Free State, Southern Africa, with Sentinel-2 time series for 2016 and 2017, focussing on the growing season of maize, from 1st of October until end of April. Due to late launch of S-2B, only S-2A data were available.

Production:
The pre-processing followed the already proven standards (see WP32), using MACCS algorithm, which is embedded within the open-source Sen2-Agri operational system due to its better cloud screening capabilities in comparison to Sen2Cor.
Several Indices such as NDWI, vegetation proxies like NDVI, MSAVI, FAPAR and others, as well as hue time series have been calculated basing on the Sentinel-2A 10m-resolution data in order to identify potential candidates for estimating the emergence date as precise as possible. Long-term Vis mean, yearly Vis, NDVI ratios have been analysed in terms of performance. Several band combinations have been tested to identify best practices for detecting sparse vegetation in humid as well as in dry areas avoiding at the same time potential interferences through soil properties.
In a second step, several detection methods have been tested, p. e. the application of thresholds (testing different time metrics, p. e. threshold intersection, highest slope, inflection point, maximum value, base logistic value), moving windows, function fitting or model fitting. The objective of testing these candidates was to identify the ideal combination of index and method.
The identification of the sprouting and the leaf development – in brief: the emergence date - of the plants complies with the phenological stages defined according to the classification systems from the

BBCH (Biologische Bundesanstalt and Bundessortenamt und Chemische Industrie). Presupposition within this classification system: a phenological stage is reached at the point where at least 50% of the plants fulfill the criteria of that stage.

Method:
The relative threshold method has been identified as the most suitable in terms of performance and robustness and has then be applied to the demo site. Linking a phenological event with the crossing of certain values in the VI profile. In combination with the NDVI, basing on S-2 Red (B4) and NIR (B8a) bands, and the MSAVI, the relative threshold, behaving dynamic and variable with changing land cover, soil and solar angle, provides an estimation of the emergence date with about 10 days accuracy.
The benchmarking of indices and methods was based on detailed ancillary data at parcel level. With a large reference dataset collected on the ground, provided by ARC, PIECES and an insurance company, UCL had detailed data sets about crop type and cultivar, crop density, agricultural practices, weed management, planting windows as well as datasets of point observations on farms, parcels, report date, phonological status at time of the observation, estimated emergence date at its disposal in order to calibrate and validate the results of the methodological approach.

Improvement:
Farming conditions at the demo site of Free State are quite challenging. Due to environmental and climate factors as well as to management decisions on farm level (crop variety, crop rotation, input availability, etc.) time slots for the stages reveal high annual variability. The date of crop emerging is highly dependent on a sufficient supply with water, favouring temperature, nutrients and sunlight. The demo site being quite heterogeneous in terms of these limiting factors, the production of these phenological parameters gets challenging.
Given these background, the results of the combination of NDVI, MSAVI and a flexible threshold are promising for an accurate estimation of crop emergence of maize. The validation showed an already satisfactory performance with a 10 day accuracy. The extension of the data base, especially the exploitation of both, S-2A and S-2B time series within the upcoming phase II will make the approach more accurate and results more reliable. The results for maize are most likely to be generalized to other crop types.

GENERIC LAND COVER METRICS OR MAXIMAL PHENELOGICAL ACTIVITY (MAP)

The prototype developed for the test site West has been drafted using Landsat-8 time series as **input data sets**. Unfortunately, 2017 was a very cloudy year, leading to a very limited number of exploitable Sentinel-2 images. Therefore Landsat-8 series, ordered by months and spanning from July 2013 to December 2017, were used to simulate a dense S-2A and B time series.

Production:
A **Maximal Phenological Activity (MPA)** layer, which is proposed as one of the potential Generic Land Cover Metrics to explore to support the production/analysis of more advanced products such as HRLs or other LC products was produced. Its concept has been detailed in the report (AD06).
Those layers constitute new products related to **phenology and vegetation monitoring**, and can be listed as:

- A pixel-based regroupment of the **maximum monthly NDVI** into 30 classes, based on the start, peak, end, and length of the phenological season -;
- Four reclassified layers representing the following phenological characteristics: the start of the season, the peak of the season, the length and the end of the season.

Those first products were created over the demonstration site West in Phase 1, and it is planned to extend the study to the Central site, as well as to one of the African sites in Phase 2.

Methodology: To derive the new products, the maximum NDVI was computed for each month and irrespective from the year. Then, an unsupervised classification was carried out, with roughly 30 classes. The winter months (starting from November to February) have been excluded from the investigation. However, the validation step is still missing, and this prototype was not deemed mature enough to be submitted.

Improvement: For the second phase of the project, further improvements could be envisioned:
- use of S-2 datasets for the year 2018,
- calculate NDVI on a bi-monthly basis in order to refine the phenological classes;
- validate the datasets in order to compute the thematic accuracies and deliver the prototype.

MULTI-ANNUAL TRENDS & POTENTIAL CHANGE

The experimental prototype on multi-annual trends and potential change aims at improving those HRL focusing on vegetation, such as grassland and forest by exploiting additional information provided by radar data. The basic idea is to identify the characteristic seasonal and long-term annual trends for certain vegetation types (such as grasslands, broadleaved and coniferous forest, various crop types) in order to differentiate them more accurately and to remove misclassification. These trends base upon dense time series of Sentinel-1 data of the years 2015, 2016 and 2017 for the testsite in Belgium, covering ascending and descending imagery. In phase I, the first prototype derives from sigma naught backscattering. The recent results being promising but baring certain limitations, the production in phase II will prefer the flattened gamma naught coefficient for overcoming misclassification caused by speckle, shadowing and topographically induced effects.

Production:
After pre-processing the full time series of Sentinel-1 IW GRD data for the years 2015, 2016 and 2017, 9 key temporal statistics have been calculated. In terms of growing phase, the seasons of March-April-May, June-July-August and of September-October-November have proved to be of large interest. Therefore a first calculation covered these seasons, an additional calculation based on the whole years of 2015, 2016 and 2017. These key temporal statistics are the backscattering temporal maximum, minimum, mean, median, standard deviation as well as the 5^{th}, 10^{th}, 90^{th} and 95^{th} percentile.

Methodology:
For each class of the HRL (broadleaved and coniferous forest and grassland), the key temporal statistics showed specific statistical distributions in terms of seasonal and annual trends. By applying thresholds, these statistical distributions can reveal potential changes on pixel level. Pixel values ranging within a certain threshold will be confirmed being correctly classified, pixel outside the threshold might be either real change or candidate for updating the classification and improving the HRL.

Improvement:
Referring to grasslands, considering multi-annual trends support the differentiation between grasslands and cropland. Using predominantly optical data, at certain growing stages, grassland and cropland or even grassland and recently afforested areas show very similar spectral characteristic whereas in a long-term perspective, grasslands and crop areas show different behavior.
Concerning the HRL Forest, the multi-annual trend provides the detection of misclassified forest and helps to differentiate between real changes and misclassification.

Further testing in phase II is needed to
- analyse potential deviations of the backscatter values of pixels within a certain HRL over time and space, and
- to understand to which extent these method would still be suitable for larger areas and areas comprising different biogeographic regions

Prototype Specifications

Table 2: Detailed specifications for primary CGC status layer of the demonstration site West

Crop Growth Condition CGC_2017_VECT_WE_03035_prototype_v01.shp	**Acronym** CGC	**Product category** Primary Status Layer
Reference year 2017		
Extent Demonstration site West		
Geometric resolution Vector layers		
Coordinate Reference System European ETRS89 LAEA projection		
Geometric accuracy (positioning scale) LPIS geometric standards		
Thematic accuracy NA		
Data type Shapefile with float 32-bits for attribute		
Minimum mapping unit (MMU) LPIS MMU		
Necessary attributes LAI anomaly		
Attribute coding (Thematic attribute values) Real-signed values		
Metadata XML metadata files are to be produced according to INSPIRE metadata standards		
Delivery format Shapefile		
Colour Table ArcGIS *.lyr format		

Class Name	Red	Green	Blue	
Sever Negative Anomaly “anomaly < -2”	255	46	46	
Light Negative Anomaly “-2 <= anomaly < -1”	255	149	0	
No Anomaly “-1 <= anomaly < =1”	240	240	240	
Light Positive Anomaly “1 < anomaly < = 2”	128	255	0	
Severe Positive Anomaly “anomaly > 2 ”	0	82	0	

Table 3: Detailed specifications for primary CED status layer of the demonstration site South-Africa

Crop Emergence Date	**Acronym** CED	**Product category** Primary Status Layer

CED_2017_VECT_SA_32735_prototype_v01.shp		
Reference year 2016-2017		
Extent Demonstration site South-Africa		
Geometric resolution Vector layers		
Coordinate Reference System WGS84 - UTM zone 35 South		
Geometric accuracy (positioning scale) LPIS geometric standards		
Thematic accuracy NA		
Data type Shapefile with integer 16-bits for attribute		
Minimum mapping unit (MMU) LPIS MMU		
Necessary attributes Emergence		
Attribute coding (Thematic values) Integer values		
Metadata XML metadata files are to be produced according to INSPIRE metadata standards		
Delivery format Shapefile		
Colour Table ArcGIS *.lyr format		