Sen4CAP - Sentinels for Common Agricultural Policy

Design Justification File

ATBD for L4C agricultural monitoring product

Milestone	Milestone 1
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Acronym	Definition
EFA	Ecological Focus Area
GSAA	GeoSpatial Aid Application
LAEA	Lambertian Azimuthal equal-area
LPIS	Land Parcel Identification System
NDVI	Normalized Difference Vegetation Index
S1, S2	Sentinel-1, Sentinel-2
SUM	System User Manual
UTM	Universal Transverse Mercator

1. Logical model

The logical dataflow of the L4C agricultural practices monitoring processor is provided in Figure 1-1.

The agricultural practices monitoring focuses on Ecological Focus Area (EFA) practices and includes also the detection of harvest and tillage. It is conducted for arable land parcels and the parcels with a declared EFA practice (information being derived from the subsidy application dataset being based either on Land Parcel Identification System (LPIS) or GeoSpatial Aid Application (GSAA) data).

The input data are:

- the pre-processed satellite imagery (results of the satellite data preparation processor);
- the standardized subsidy application dataset and parcels buffer layers (results of the LPIS / GSAA declaration dataset preparation processor);
- and the EFA practice declarations and the temporal rules provided by the Paying Agencies (PAs).

There are two main processing steps. First the time-series are extracted for each parcel (feature) and stored in intermediate text files. Second, the extracted time-series are analysed and evaluated. The processing chains are described in detail in the following sections.

The implementation of the scripts for these two processing steps is open source and it is provided on Github.

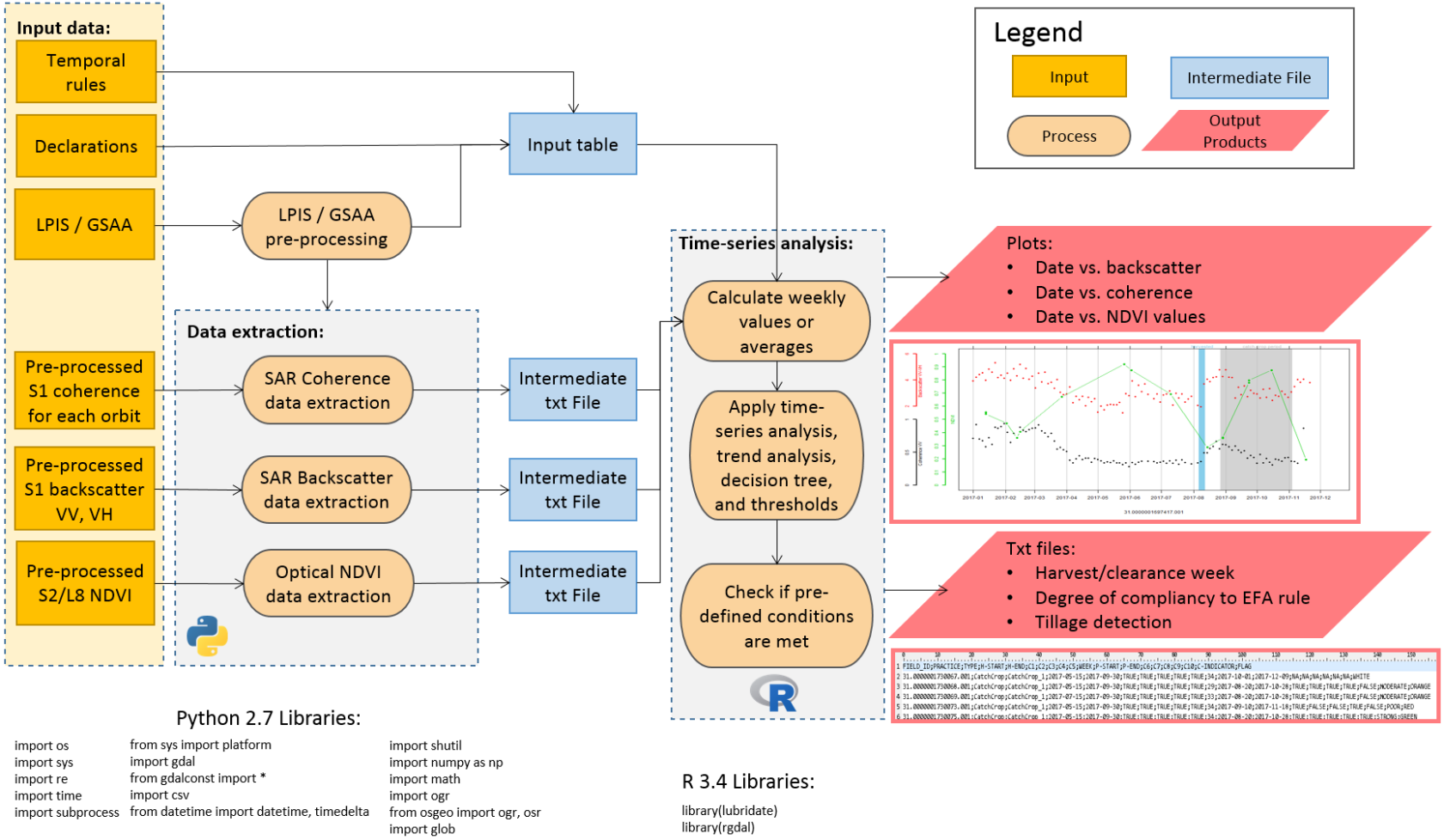

Figure 1-1. Logical data flow of the L4C agricultural practices monitoring product

2. Data Extraction and Time-Series Analysis

2.1 Data Extraction

The extraction of statistics from pre-processed Sentinel-1 (S1) and Sentinel-2 (S2) satellite imagery is conducted for each parcel (feature). The following steps illustrate the overall workflow:

1. Parcels buffer layers (results of the LPIS / GSAA declaration dataset preparation processor) which contain the features of the parcels are selected. The inner buffer size corresponds to the half pixel-size of the pre-processed satellite data. The 10-m inner buffer is used for the S1 and Landsat-8 (L8) data extraction. The 5-m inner buffer is used for the S2 data extraction. Both buffer layers are reprojected, such that the projection match the projection in which the pre-processed satellite imagery is available.
2. For each parcel (feature):
    a. A unique identifier is found, which is the parcel's sequential (internal) ID;
    b. Each available S1 VV Coherence image, S1 VV backscatter image, S1 VH backscatter image, S2 Normalized Difference Vegetation Index (NDVI) image and L8 NDVI image is clipped using the extent of the parcel from a buffer layer;
    c. The statistics of the clipped files are calculated (minimum, mean, maximum and standard deviation);
    d. If the statistics are found satisfactory (i.e. not equalling no-data), the statistics are written to an output intermediate text file together with the image acquisiton date (two dates in case of coherence) and the sequential parcel ID. Besides the acquisiton date and the squentional parcel ID, additional information about the input image is written to the output intermediate text file together with the statistics, which consists of the orbit and polarization of the image for the S1 bacskcsatter and coherence data and the source satellite of the NDVI data for the S2 and L8 data.

For the S2 NDVI images, cloud masks are included in the satistics calculation to ensure that at least 10% of the number of pixels on the parcel return values upon clipping the image to the extent of the parcel.

The S1 VV and VH amplitude to sigma-naught backscatter values are converted to decibels [dB] before the calculation of the statistics.

S1 VV Coherence images are derived for 6-day interval periods. The 6-day interval periods were found to be sufficiently dense for the L4C analysis.

The extracted data are stored in 3 intermediate text files:

- NDVI (S2 / L8)
- VV and VH backscatter (amplitude to sigma-naught backscatter) in dB (S1)
- VV Coherence for 6-day interval periods (S1)

2.2 Time-Series Analysis

The time-series analysis is conducted for each parcel (feature) from the input table. The information on the input table structure is provided in Section 2.2.1. The time-series analysis functions are described in Section 2.2.2 and the system workflow is described in Section 2.2.3.

The following steps illustrate the overall workflow of the time-series analysis:

1) For each parcel, the time-series of the extracted statistics are obtained from the 3 data extraction intermediate text files:
   a) NDVI time-series (S2 / L8)
   b) VV and VH amplitude to sigma-naught backscatter in dB time-series (S1)
   c) 6-days VV Coherence time-series (S1)
2) The time-series are analysed to monitor the presence/absence of the vegetation and the disturbance in the vegetation growth by a selected set of markers and evaluated for the defined time period. A potential harvest and tillage week is defined;
3) In case there is an Ecological Focus Area (EFA) practice declared on the parcel, another set of markers is evaluated, compared with national rules and an index of compliancy (degree of compliancy with the provided monitorable EFA rules) is evaluated.

2.2.1 Input variables

A standardized Input table has to be generated before the time-series analysis is started. The Input table is based on the standardized subsidy application dataset, EFA practice declarations and other inputs from the PA (e.g. the temporal rules, crop calendars).

The input table consists of following attributes:

- "FIELD_ID" : internal sequential parcel ID;
- "ORIG_ID" : original (PAs) parcel ID ;
- "COUNTRY" : country (e.g. “CZE”);
- "YEAR" : year of evaluation (e.g. 2017);
- "MAIN_CROP" : PAs main crop code or “NA” ;
- "VEG_START" : expected start of growth of the main crop vegetation (YYYY-MM-DD);
- "H_START" : expected earliest date of the main crop harvest period (YYYY-MM-DD);
- "H_END" : expected latest date of the main crop harvest period (YYYY-MM-DD);
- "PRACTICE" : EFA practice ("CatchCrop"; "NFC"; "Fallow"; or “NA”);
- "P_TYPE" : EFA practice sub-type (defined for each country/practice; or “NA”);
- "P_START" : start date of the EFA period (YYYY-MM-DD; or “NA”);
- "P_END" : end date of the EFA period (YYYY-MM-DD; or “NA”)

Beside these attributes, the geometry flags and pixels number flags, which are computed during the LPIS / GSAA declaration dataset preparation, are joined to the input table: "GeomValid", "Duplic", "Overlap", "Area_meter", "ShapeInd", "CTnum", "CT", "LC", "S1Pix", "S2Pix".

The flag "S1Pix" indicates the number of S1 pixels which belong to the parcel. Only the parcels with at least 1 S1 pixel can be processed by the time-series analysis processor and a minimum of 15 acquisitions (configurable).

2.2.2 Configuration parameters

For each country/practice, an "Agricultural practices" configuration file is prepared. The Agricultural practices configuration file sets the input thresholds for the NDVI, backscatter and coherence time-series analysis. See below the complete list of all parameters and their default values divided into two tables – analysis of harvest (Table 2-1) and analysis of EFA practices (Table 2-2).

The implementation of time-series analysis for harvest detection and EFA practices evaluation is rather complex and the users are advised not to change deault values using trial and error approach. The adjustment of configuration parameters is recommended only for advanced users that have full understanding and deep insight into the decision trees implemented in the system and impacts of each parameter on the entire evaluation process.

Table 2-1. Parameters for the harvest analysis (Markers no. 1-5)

Parameter name	Default value
Parameter description	
NDVI analysis	
OPTTHRVEGCYCLE	350
Used in Marker 1 as NDVI threshold to define the presence of vegetation on the parcel	
NDVIDW	300
Used in Marker 2 as the Lower limit of the NDVI loss thershold	
NDVIUP	350
Used in Marker 2 as the Upper limit of the NDVI loss threshold	
NDVISTEP	5
Used in Marker 2, 7 and 8 as the Value to which the computed NDVI loss threshold is rounded up	
OPTTHRMIN	100
Used in Marker 2 as the Minimum NDVI threshold	
OPTTHRBUFDEN	4
Used in the Marker 2 for the computation of the NDVI loss buffer threshold denominator	
Backscatter analysis	
AMPTHRMIN	0,1
Used in Marker 3 as the Minimum backscatter loss threshold	
STDDEVINAMPTHR	0 / 1
Specifies if the standard deviation should be used or not in the formula for computing the amplitude threshold value (which is used as input for Marker 4). The formula for computing amplitude threshold value: # if STDDEVINAMPTHR = 0 amplitude threshold value = meanValue - (stdDevVal / AMPTHRVALDEN) # if STDDEVINAMPTHR = 0 amplitude threshold value = meanValue	
AMPTHRVALDEN	2
Amplitude threshold value denominator	

AMPTHRBREAKDEN	6
Amplitude threshold break denominator	
Coherence analysis	
COHTHRBASE	0,05
Used in Marker 5 as the Basic increase in coherence threshold	
COHTHRHIGH	0,15
Used in Marker 5 as the High increase in coherence threshold	
COHTHRABS	0,75
Used in Marker 5 as the Absolute coherence threshold	

Harvest analysis parameters may be also configured for EFA practice evaluation. The configuration file for each practice includes the section defining default values for the above parameters. The generic naming convention is used – the prefix is added to the name of each parameter for each practice (e.g. CC_COHTHRBASE is used for catch crop analysis, NFC_COHTHRBASE is used for nitrogen fixing crop analysis, FL_COHTHRBASE is used for fallow land analysis).

Table 2-2. Parameters for the EFA and tillage analysis (Markers no. 6-10)

Parameter name	**Default value**
Parameter description	
EFA analysis	
EFANDVITHR	325
Used for marker 6 as the NDVI threshold for vegetation presence	
EFANDVIUP	400
Used for marker 7 and 8 as the Lower limit of the NDVI loss threshold	
EFANDVIDW	300
Used for marker 7 and 8 as the Upper limit of the NDVI loss threshold	
EFACOHCHANGE	0,2
Used for marker 10 as the High increase in coherence threshold	
EFACOHVALUE	0,7
Used for marker 10 as the Absolute coherence threshold	
EFANDVIMIN	-10 000
Used for Marker 7 as Minimal value of NDVI. Can be overwritten for each practice independently. -10000 means that value is not used.	
EFAAMPTHR	0.01
Used for Marker 9 as Slope threshold	Can be overwritten for each practice independently (by default is set to -10000 which means the 0.01 value is used)
Catch crop analysis	

CATCHMAIN	None
Name of the main crop, specified if catch crop is the second crop. Can be overwritten for CatchCrop via the CC_CATCHMAIN.	
CATCHPERIOD	56
The length of the practice period	
CATCHPERIODSTART	None
The earliest possible start of the catch crop period. Global value can be modified or can be overwritten for CatchCrop. The expected format is yyyy-mm-dd.	
CATCHCROPISMAIN	None
Catch crop is main crop. The value can be set to one of the values in P_TYPE from the input tables. Global value can be modified or can be overwritten for CatchCrop	
CATCHPROPORTION	None
EFA NDVI buffer threshold. Empty value means a proportion of 1/3. Global value can be modified or can be overwritten for CatchCrop	
Fallow land analysis	
FLMARKSTARTDATE	None
Fallow Land Markers start date. The expected format is yyyy-mm-dd.	
FLMARKSTENDDATE	None
Fallow Land Markers end dates. The expected format is yyyy-mm-dd.	
Tillage analysis	
TLCOHTHRBASE	0,05
Used to define the threshold for basic coherence increase (used for marker M5 evaluation similarly to harvest detection analysis)	
TLCOHTHRABS	0,75
Used to define the threshold for absolute coherence value (used for marker M5 evaluation similarly to harvest detection analysis)	
TLMONITORINGENDDATE	None
Used to stop tillage monitoring in the defined date in case no tillage has been detected. The expected format is yyyy-mm-dd.	

2.2.3 Time-series analysis functions

The main time-series analysis function (Table 2-3) runs in a loop for each parcel. The function calls three sub-functions, presented in Table 2-4 to Table 2-6.

Table 2-3. Time Series analysis function

Input
• Variables from an Agricultural practices configuration file
Output
• .csv file with the results of the time-series analysis (harvest and EFA practice) • Optional: graphical product – the graphical products are provided via Geopedia • Optional: continuous product - .csv file for each parcel (markers 1:5 for each available week)

Table 2-4. Sub-function to check if the intermediate text files are not empty

Input
• Variable: ID of a parcel (internal sequential parcel ID) • Variable: VV backscatter time-series of a parcel • Variable: VH backscatter time-series of a parcel • Variable: 6-days VV coherence time-series of a parcel • Variable: NDVI time-series of a parcel
Output
• Variable: TRUE/FALSE value (if FALSE the time-series analysis of a parcel is cancelled)

Table 2-5. Sub-functions to evaluate an EFA practice (prepared for each *country*/*practice*/*year*)

Input
• Variable: backscatter ratio time-series of a parcel • Variable: coherence time-series of a parcel • Variable: NDVI time-series of a parcel • Variable: time-series analysis of the harvest for each available week for a parcel • Variable: results of the time-series analysis of the harvest for a parcel
Output
• Variable: updated results of the time-series analysis (harvest and EFA practice) of a parcel

Table 2-6. Sub-function to evaluate the EFA markers in a defined priod in time

Input
• Variable: start of the EFA practice period (P_START) • Variable: end of the EFA practice period (P_END) • Variable: backscatter ratio time-series of a parcel • Variable: coherence time-series of a parcel • Variable: NDVI time-series of a parcel
Output
• Variable: EFA markers evaluated for each week (TRUE/FALSE/NA value) in the defined time period

2.2.4 Time-series analysis workflow

The following steps illustrate the workflow of the time-series analysis function for a parcel.

2.2.4.1 INPUT VARIABLES AND TIME-SERIES

INPUT VARIABLES

Variables from the Input table are defined for a parcel: FIELD_ID, ORIG_ID, COUNTRY, YEAR, MAIN_CROP, VEG_START (general start of of vegetation period), H_START (start of harvest period), H_END (end of harvest period), PRACTICE (EFA practice), P_TYPE (EFA practice sub-type), P_START (start of EFA practice period), P_END (end of EFA practice period) and S1PIX (number of S1 pixels within the 10 m inner buffer).

READ INPUT TIME-SERIES

Read the input satellite data time-series for a parcel (based on the internal sequential ID).

CHECK INPUT TIME-SERIES

The sub-function presented in Table 2-4 is called to check if the input intermediate text files are not empty. If FALSE, the time-series analysis of the parcel is cancelled and the parcel cannot be evaluated.

PROCESS INPUT TIME-SERIES

The backscatter values are in dB, the backscatter ratio is therefore computed as a difference of VV-VH.

The increase in coherence between the two following dates is evaluated separately for each orbit.

The input time-series are aggregated to a “week” values. A “week” is defined as a 7-day period starting on the first Monday of the year (isoweek). The aggregated values defined for each week are:

- week-mean value of backscatter ratio;
- week-mean value of NDVI;
- maximal value of backscatter ratio in a week;
- maximal value of coherence in a week;
- and maximal increase in coherence in a week.

In addition, 3-weeks mean of the backscatter ratio and the difference between the week-mean of the backscatter ratio and the previous 3-weeks mean of the backscatter ratio is computed (further as “backscatter difference”).

All week-values are merged in one table. Gaps (i.e. weeks without value) are expected in case of NDVI due to cloud cover but they shall not occur in case of coherence and backscatter time-series. In case of a gap in NDVI, a nearest previous and nearest next NDVI value is defined for the week.

2.2.4.2 TIME SERIES ANALYSIS FOR HARVEST

HARVEST MARKERS

Markers No. 1 – 5 represent the harvest markers that are analysed for harvest/clearance detection.

For the time-series analysis, the markers are evaluated for all the avaliable weeks of the year. However, the results provide only the marker values for the last available week of satellite data. The information about the last available week of the satellite data for a parcel is provided in the attribute L_WEEK.

I) Marker 1 (presence of vegetation based on NDVI) is evaluated.

The week-mean NDVI values are compared with the input NDVI presence threshold (Table 2-7) in the period from the start of the vegetation season (VEG_START) to the end of the havest period (H_END).

Table 2-7. Input threshold for Harvest detection Marker 1

Input threshold (from Agricultural practices configuration file)
• NDVI value defining the presence of vegetation on the parcel

If the NDVI week-value is bigger than the specified threshold the Marker 1 is set TRUE from that week up to the end of the harvest period.

II) Marker 2 (loss of vegetation based on NDVI) is evaluated.

A "NDVI loss threshold" and a "NDVI loss buffer value" are computed based on the NDVI week-mean values and the input thresholds (Table 2-8). Potential start of the harvest period is defined based on the computed threshold and buffer value.

Table 2-8. Input threshold for Harvest detection Marker 2

Input threshold (from Agricultural practices configuration file)
• Lower limit of the NDVI loss thershold • Upper limit of the NDVI loss threshold • Value to which the computed NDVI loss threshold is round up • NDVI loss buffer value (variable) • Minimum NDVI threshold

The previous and next NDVI values of a week are compared with the computed threshold, the buffer value and the potential start of the harvest period and the Marker 2 is evaluated for each week.

III) Marker 5 (loss of vegetation based on coherence) is evaluated.

For each week: the maximal increase in coherence in a week is compared with the input increase thresholds; the maximal value of coherence in a week is compared with the absolute coherence threshold; and the Marker 5 is evaluated. Thresholds are identified in Table 2-9

Table 2-9. Input threshold for Harvest detection Marker 5

Input threshold (from Agricultural practices configuration file)
• Basic increase in coherence threshold • High increase in coherence threshold • Absolute coherence threshold • Minimum absolute coherence threshold (variable)

IV) Marker 3 (loss of vegetation based on backscatter ratio) is evaluated:

Backscatter loss threshold is computed based on standard deviation of a filtered backscatter time-series. The backscatter difference (the difference between the week-mean and the previous 3-weeks mean of the backscatter ratio) is compared with the computed threshold and the Marker 3 is evaluated for each week (from the forth week of the available weeks).

Table 2-10. Input threshold for Harvest detection Marker 3

Input threshold (from Agricultural practices configuration file)
• Backscatter loss threshold (variable) • Minimum backscatter loss threshold

In case there is a high increase in coherence in a week (defined by a Marker 5 input threshold), the Marker 3 is evaluated for +-1 week.

V) Marker 4 (presence of vegetation based on backscatter ratio) is evaluated.

The backscatter presence threshold is computed based on mean and standard deviation of a filtered backscatter time-series. The maximal value of backscatter ratio in a week is compared with the computed threshold and the Marker 4 is evaluated for each week.

Table 2-11. Input threshold for Harvest detection Marker 4

Input threshold (from Agricultural practices configuration file)
• Backscatter presence threshold (variable)

HARVEST EVALUATION

Definition of the harvest/clearance week (H_WEEK) is based on the values of the markers M1 to M5:

- Pre-condition: it is supposed to observe at least one NDVI week-mean value in the vegetation season (from the start of vegetation season to the end of harvest period) that indicates presence of vegetation. If not, harvest detection doesn't make sense (i.e. if the Marker 1 is never TRUE, all other markers are set to "NR" and the H_WEEK is set to "NO-HARVEST");
- If the pre-condition is fulfilled, weeks in which all the markers are TRUE are selected and the first of these weeks are defined as the harvest/clearance-week (the value of the H_WEEK is a number of the week);
- If the harvest/clearance-week is not found, the H_WEEK is set to "NO-HARVEST".

For better presentation of the result, the detected H_WEEK is also presented in the attributes H_W_START and H_W_END. The former attribute corresponds to the first day of the H_WEEK and the later to the last day of the H_WEEK. The values are provided in the date format YYYY-MM-DD.

In 2019, an experimental attribute H_W_S1 was added to the results. The evaluation of this attribute is similar to the H_WEEK with one exception, the Marker 2 is not considered in the evaluation. The Marker 2 is based on NDVI and because of the cloud cover it can take more time when the loss of vegetation is confirmed from the NDVI data. The detection of the loss of vegetation with the attribute H_W_S1 is therefore based only on the S1 (SAR) markers. In this way, the result can be provided for the last available week (L_WEEK), but the result can be less accurate than the H_WEEK, which includes the analysis of the NDVI time-series. The H_W_S1 value corresponds to the first day of the harvest/clearance-week defined based on the Sentinel-1 data in the date format YYYY-MM-DD.

2.2.4.3 TIME SERIES ANALYSIS FOR EFA PRACTICES

In case there is an EFA practice declared on a parcel, a script for the time-series analysis of the EFA practice (sub-function presented in Table 2-5) is called (depending on the defined practice and country).

EFA MARKERS

Markers No. 6 – 10 represent the EFA markers that are analysed to assess the compliance of three agricultural practices: catch crops, nitrogen fixing crops and fallow land.

The sub-function shown in Table 2-6 is called to evaluate five EFA markers for each week of a defined EFA period (the EFA period is defined by the P_START and P_END attributes in the Input table). These markers are designed to detect if the vegetation is growing in the EFA period and if the growth of the vegetation is not disturbed. All or only selected markers can be used in the EFA practice evaluation.

The dates of start and end of the EFA practice period have to be defined in the Input table in format "YYYY-MM-DD". The evaluation is based on this information.

The three input time-series (NDVI, backscatter ratio and coherence) are cropped to the defined EFA period. The values are aggregated to the "week" values (week mean value of NDVI; week-mean value of backscatter ratio; maximal value of backscatter ratio in a week; maximal value of coherence in a week; and maximal increase in coherence in a week) and merged into one table. The markers are evaluated (TRUE/FALSE/NA value) for each week of the defined period:

I) Marker 6 (presence of vegetation based on NDVI):

For each week, the NDVI mean-value is compared with the input threshold (Table 2-12). Marker 6 for a week is TRUE if the NDVI week-value is bigger than the specified threshold.

Table 2-12. Input threshold for EFA Marker 6

Input threshold (from Agricultural practices configuration file)
• NDVI value defining the presence of EFA practice vegetation on the parcel

II) Marker 7 (growth of vegetation based on NDVI)

NDVI loss threshold is computed based on the NDVI week-mean values and the input thresholds (Table 2-13). NDVI threshold limits can be specified for the EFA or the values defined for harvest markers are used.

Table 2-13. Input threshold for EFA Marker 7

Input threshold (from Agricultural practices configuration file)
• Lower limit of the NDVI loss threshold (can be specified for EFA practice) • Upper limit of the NDVI loss threshold (can be specified for EFA practice) • Value to which the computed NDVI loss threshold is round up • Optional: minimal value of NDVI (default 300)

The NDVI week-mean values shall not decrease below the computed threshold and the NDVI values shall be bigger then minimal value of NDVI. If both conditions are fulfilled, the Marker 7 for a week is TRUE.

III) Marker 8 (no loss of vegetation based on NDVI)

NDVI loss threshold is computed based on the NDVI week-mean values and the input thresholds (Table 2-14). NDVI threshold limits can be specified for the EFA or the values defined for harvest markers are used.

Marker 8 for a week is TRUE if the NDVI week-value is not lower than the computed NDVI loss threshold.

Table 2-14. Input threshold for EFA Marker 8

Input threshold (from Agricultural practices configuration file)
• Lower limit of the NDVI loss threshold (can be specified for EFA practice) • Upper limit of the NDVI loss threshold (can be specified for EFA practice) • Value to which the computed NDVI loss threshold is rounded up

IV) Marker 9 (no loss of vegetation based on backscatter ratio)

From the second week to the N-1 week in the EFA period, a linear regression is fitted for +/- 2 weeks on the backscatter ratio time-series and the values of slope and p-value are computed (a minimum number of weeks - 3 weeks of data - is tested for this analysis).

Marker 9 for a week is TRUE if there is not a significant positive trend (a significant positive trend is considered the slope bigger than the defined slope threshold (Table 2-15) and the p-value lower than 0.05). The slope threshold value can be specified for EFA practice or a default value is used.

The marker is not computed (is NA) in the first and last week of the EFA period.

Table 2-15. Input threshold for EFA Marker 9

Input threshold (from Agricultural practices configuration file)
• Optional: slope threshold (default 0.01)

V) Marker 10 (no loss of vegetation based on coherence)

The maximal increase in coherence in a week and the maximal value of coherence in a week are compared with the defined thersholds (Table 2-16). The threshold values can be specified for the EFA practice or the values defined for harvest markers are used.

Table 2-16. Input threshold for EFA Marker 10

Input threshold (from Agricultural practices configuration file)
• High increase in coherence threshold (can be specified for EFA practice) • Absolute coherence threshold (can be specified for EFA practice)

The increase in coherence in a week shall not be bigger than the defined “high increase in coherence threshold” and the the maximal value of coherence in a week shall not be bigger than the “absolute coherence threshold”. If both conditions are fulfilled, the Marker 10 for a week is TRUE.

EFA PRACTICE EVALUATION

The time-series analysis of an EFA practice is very specific not only because of the type of practice (catch-crop, nitrogen-fixing crop, fallow land) but also due to specific rules for each country and year.

A script with a tailored analysis is therefore prepared for each country/practice/year (using the sub-function described in Table 2-5).

Some or all EFA markers and harvest analysis results are used for this evaluation.

If an EFA marker is selected (significant) for the practice evaluation, the EFA marker week-values are analysed and a decision/result (TRUE/FALSE/NA value) is evaluated for the whole EFA period (not a week).

If an EFA marker is not used in the tailored analysis, it is set to "NR" (not relevant).

The EFA markers are not evaluated before the start of the EFA practice period. After the start of the EFA practice period and before the end of the EFA practice period, the results are evaluated only for the weeks which are available. These results are not final. The final results are provided after the end of the EFA practice period.

The value of the compliancy-index (C_INDEX) is provided only after the end of the EFA practice period.

The compliancy-index (C_INDEX) of a practice is based on:

- results of the time-series analysis for the harvest (e.g. harvest week, presence of main-crop vegetation);
- on a tailored analysis of the EFA marker week-values.

The results of the time-series analysis for the EFA practice (M6:M10 and C_INDEX) are added to the result of the time-series analysis for the harvest and are returned to the main script.

Note 1: In some countries, the P_START and the P_END for the catch-crop period cannot be defined with the exact dates, but the catch-crop period is defined in a way that it shall start after the harvest but before, e.g. the 15th October and shall take 8 weeks. In such case, a targeted analysis is performed to estimate the most probable start and end of the catch-crop period. The length of the practice period has to be provided as an input paramerer in the Agricultural practices configuration file and in the Input table the start of the practice period (P_START) has to be set to the last possible start of the practice period and the end of the practice period (P_END) has to be set to "NA". If there is also available information on the first possible start of the practice period, it shall be provided as an input parameter in the Agricultural practices configuration file. In this case, the start (P_START) and the end (P_END) of the practice is updated in the results after the targeted analysis.

Note 2: In some countries, there is a special type of the catch-crop practice when the catch-crop is sown in/under the main crop and only the upper part of the main crop is harvested. The P_TYPE which corresponds to this special practice type has to be defined in a parameter in the Agricultural practices configuration file because in such a case a different decision rules are used.

Note 3: In some countries, there is a special type of the catch-crop practice when the catch-crop is grown as the main crop. The P_TYPE which corresponds to this special practice type has to be defined in a parameter in the Agricultural practices configuration file because in such a case a different decision rules are used.

GAPS IN THE S1 TIME-SERIES

The S1 data are essential for the agriculture practices monitoring. Usually, in a week it is expected to acquire about 2-4 values (both backscatter and coherence) from different S1 satellite paths for each parcel. If the there is no value in a whole week, the information in this week is missing ("gap" in the

time-series) and the monitoring for this week cannot be provided. The gaps in the S1 time-series have a strong negative impact on the reliability of the monitoring.

The S1 time-series is analysed and the number of the weeks for which the S1 data values (either backscatter ratio or coherence) are completely missing are reported for several important monitoring periods. The number of the missing weeks in these periods is provided in the results of the time-series analysis for each parcel to serve as a reliability information.

The missing weeks are reported for following periods:

- Year period - from the first week in the year to the last available week with the S1 data (L_WEEK). The result is reported in the attribute S1GAPS. This attribute provides an overall information about the missing weeks of the S1 data in the whole year;
- Harvest/clearance period – from the first week when the harvest/clearance is expected on a parcel (H_START) to the last week when the harvest/clearance is expected (H_END) or, if the harvest period not yet ended, to the last available week with the S1 data (L_WEEK). The result is reported in the attribute H_S1GAPS. If the S1 data are missing in this period, the harvest/clearance week (H_WEEK) can be incorrectly detected;
- EFA practice period – from the first week of the EFA practice period (P_START) to the last week of the EFA practice period (P_END) or, if the EFA period not yet ended, to the last available week with the S1 data (L_WEEK). The result is reported in the attribute P_S1GAPS. If the S1 data are missing in the EFA practice period, the result of the compliance index (C_INDEX) can be incorrectly interpreted;
- 5-weeks period before the detected harvest/clearance week – if a harvest/clearance week (H_WEEK) is detected on a parcel, the period of 5 weeks before the harvest/clearance week is examined. The result is reported in the attribute H_W_S1GAPS. If the S1 data are missing in this period, the harvest/clearance week (H_WEEK) can be incorrectly detected.

RELIABILITY FLAGS

In 2019, two new attributes were added to the results.

- H_QUALITY: Reliability flag of the detected harvest/clearance week (H_WEEK);
- C_QUALITY: Reliability flag of the compliance index (C-INDEX);

The flags warn about selected problems. They inform about the parcels, where the problems with the missing Sentinel-1 data could affect the reliability of the detected harvest week (H_QUALITY flag "1") or the result of the compliancy index (C_QUALITY flag "1"):

- H_QUALITY value "1" informs about the missing Sentinel-1 data in H_W_S1GAPS period
- C_QUALITY value "1" - informs about the missing Sentinel-1 data in P_S1GAPS period

The list of these flags is provided in the readme file for each product.

2.2.4.4 TIME SERIES ANALYSIS FOR TILLAGE DETECTION

Tillage monitoring is implemented as part of the harvest monitoring as it focuses on detection of tillage applied after the harvest of the main crop. The detection analysis starts in the first week after the harvest is detected (H_WEEK+1). It runs in continuous mode and the occurrence of tillage is evaluated weekly.

Three parameters are defined to parametrize the tillage detector, see the Table 2-2 for detailed description.

TILLAGE MARKERS

The markers M1 and M5 defined for harvest monitoring are also used for tillage monitoring.

1) **Marker M1** (presence of vegetation based on NDVI)

If the NDVI week-value is greater than the NDVI threshold (Table 2-7), the Marker 1 is set TRUE for this week. Otherwise the Marker is set FALSE or NotDefined in case NDVI cannot be computed.

2) **Marker M5** (status of vegetation based on coherence)

The marker is set TRUE if the maximum increase in coherence is greater then the threshold for basic coherence increase or the maximum value of coherence is greater then the threshold for absolute coherence value (see previous paragraph for thresholds specification). Otherwise the Marker is set FALSE.

TILLAGE EVALUATION

The tillage detection analysis is run from from the first week after the harvest is detected. The analysis is done weekly and these conditions are evaluated:

a) M1=FALSE OR M1= NotDefined
b) M5(previous week)=TRUE AND M5(current week)=FALSE

If both above conditions are TRUE the tillage is detected and the results are stored:

- TL_WEEK is used to store the week of the year when tillage is observed;
- TL_W_START is used to store the first day of the TL_WEEK;
- TL_W_END is used to store the last day of the TL_WEEK.

The tillage detection analysis is stopped if any of the below conditions is TRUE:

a) TL_WEEK is set (tillage is detected)
b) M1=TRUE (start of vegetation growth after the harvest of the main crop => tillage is not detected)
c) First date of current week > TLMONITORINGENDDATE (stop of tillage monitoring before the winter period => tillage is not detected)

Remark. If multiple drops for coherence marker are encountered, it is expected more activities occur after the harvest (e.g. harvest residuals management). The user shall be aware that the detector likely detects the first drop as tillage application.