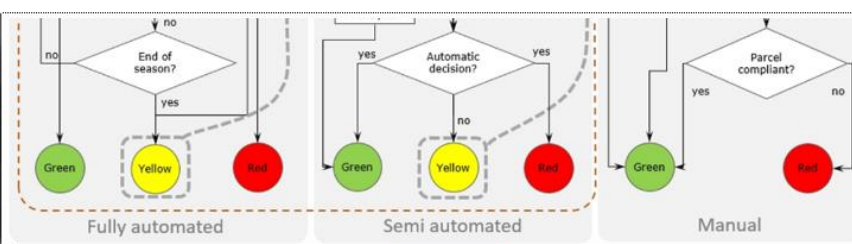


JRC TECHNICAL REPORTS

Second discussion document on the introduction of monitoring to substitute OTSC: rules for processing applications in 2018-2019

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Abstract

This document describes the main concepts and components of the 'checks by monitoring'. It elaborates and details the discussion on monitoring as a substitute of the current sample approach (5% on-the-spot-checks) of aid applications or payment claims.

This second discussion document elaborates on the rationale, concepts and procedures that form the heart of the monitoring approach, a move from a sequential compliance control followed by penalties towards a continuous monitoring that informs proactively when lodging claims and sends out warning alerts to prevent unintended non-compliances.

This agricultural parcel monitoring takes advantage of the substantial modification of the control framework, most notably the timing of changes to the application and content of the control file.

This document constitutes the Commission's proposal of common practices and includes comments from: DG AGRI D3, DG AGRI H3, DK, BE-FL, MT, ES, CZ and HU.

Declaration: the document provides details of the current status of the thinking process and should be viewed as provisional. There are points to flexibilities in some areas and further elaboration will be added following discussions with the main stakeholders and practitioners involved in the processing and management of aid application process.

1 Background

This discussion document builds upon the first discussion document on the introduction of monitoring to substitute the on-the-spot-checks (OTSC) ([Devos et al., 2017](#)), which proposed the following working definition of monitoring:

“procedure based on regular and systematic observation, tracking and assessment of the fulfilment of eligibility conditions and agricultural activities over a period of time, which involves, where and when necessary, appropriate follow-up action.”

The Commission Implementing Regulation (EU) 2018/746 amending Implementing Regulation (EU) No 809/2014 elaborates this into:

“procedure of regular and systematic observation, tracking and assessment of all eligibility criteria, commitments and other obligations which can be monitored by Copernicus Sentinels satellite data or other data with at least equivalent value, over a period of time that allows to conclude on the eligibility of the aid or support requested” with, “where necessary, and in order to conclude on the eligibility of aid or support requested, appropriate follow-up activities”.

The first discussion document also presented the various technical elements of monitoring; the annex illustrated some of the key aspects of the monitoring approach and provided recommendations in the form of case studies and proofs of concept.

The purpose of the current document is to elaborate a key aspect of what is called “checks by monitoring”: the processing of the agricultural parcel as declared by the farmer to ensure that timely warning alerts can be issued in the process whilst assuring a reliable conclusion of the accompanying check process.

Since the publication of this first discussion document in November 2017, there have been a number of developments that allow JRC to elaborate, detail and even adapt the concepts and procedures proposed therein.

1.1 Legal framework

On the 18th of May 2018, an amendment to Commission Implementing Regulation (EU) No 809/2014 was adopted. This amended regulation offers a formal and stable legal framework wherein monitoring can operate. The main legal requirements for such operation are:

- The checks by monitoring rely on Sentinels satellite data and equivalent data and appropriate follow-up actions. Such follow-up actions may include requesting the beneficiary for relevant evidence.
- The pre-conditions for monitoring are: effective system of Geospatial Aid Application (GSAA), of administrative crosschecks and of retroactive recovery of undue payments combined with a good quality LPIS.
- The checks by monitoring differ from the ‘5% on-the-spot-checks’ (further referred to as OTSC) in that there is no announcement of the individual controls, no fixed timing, no control rates and no area measurements. A common communication to all relevant beneficiaries suffices.
- The introduction of monitoring must cover at least one whole area scheme (i.e. BPS\SAPS / Greening / RD-measure).
- During the first 2 years of introduction, partial implementation by region is allowed if the selected area(s) are identified on the basis of objective and non-discriminatory criteria. In the third year of implementation, the whole area has to be checked by monitoring.

- All parcels declared in the selected scheme should be subject to monitoring. A priori exclusion of parcels, e.g. based on parcel size, shape or declared crop type must be avoided. For the parcels less likely to reach conclusive assessment based on the Sentinel data analysis alone, alternative information sources should be foreseen, e.g. based on the geotagged photos, LPIS imagery, depending on the nature and monetary relevance of that parcel.
- Monitoring implies a new mode of interaction between farmer and administrations. To achieve the purpose of preventing non-compliances, farmers and administrations become partners in the control process.
- All schemes or areas that are not covered by the introduction of monitoring must be controlled under the OTSC regime.
- The decision to introduce monitoring must be notified by December 1st of the year preceding the monitoring.

1.2 Relevance for the Common Technical Specifications for monitoring

By the end of 2017, several paying agencies had approached JRC with a request for participation to monitoring pilot projects or collaboration on related methodologies. JRC organised 3 technical meetings with the technical experts from these paying agencies to identify major concerns and best practices as input for the developing technical guidance (also known as Common Technical Specifications - CTS) for monitoring. From these technical meetings emerged the idea that the technical guidance would involve three parts.

A first, preparatory part that guides the paying agency towards the decisions to introduce monitoring or not ([Devos et al., 2018](#)). This part involves understanding how well the IACS and LPIS systems meet the pre-conditions laid down in the regulation and how much of the landscape and agricultural practices can be reliably processed by the automatic analysis of Sentinel data in combination with additional evidence. This part relies on machine learning analysis of the past, as well as on IACS and Sentinel data.

A second part addresses the processing of the applications within the selected schemes or measures and territories. This relies on the automated, but controlled processing of the Sentinel data during the season, issuing warning alerts and providing compliance verdicts as the information becomes available. This part is not relying on a "claimless application" but uses the application to tier the holdings by scheme, target the observations and so reduce the need for processing. This processing of an individual agricultural parcel and its holding is the core of this particular discussion document.

A third part will relate to the solutions that monitoring data and technology offer but that is neither derived nor dependent on the farmer's application. These "monitoring" or rather remotes sensing methodologies are relevant for and operate at the level of the whole system. Examples include the detection of non-agricultural surfaces, the handling of farmer evidence and others.

1.3 The main purposes of the proposed approach

As the recitals of the amendment of Implementing Regulation (EU) No 809/2014 clarify, the main drivers for introducing the monitoring approach are the reduction of the burden of controls and to use warning alerts in combination with an option to correct the aid application in order to prevent non-compliances. The latter driver requires that such warning alert is provided to the farmer in a timely manner. Monitoring is not intended as an instrument to have the paying agency "post-fill" or modify the farmer's aid application after the agricultural season concerned has passed. Timeliness is therefore of the foremost importance.

As implied on a regulation that deals with checks, any process and ensuing decisions must also be reliable, transparent, accountable (verifiable) and documentable.

At this point in time, with the experience available within this paying agency community, both requirements make it necessary to be cautious with a front-end use of fully automated processes such as machine learning based on neural networks, genetic algorithms and/or fuzzy systems. This situation may change in the future and will obviously be subject to future studies and research.

Machine learning techniques are however essential in the processing of the past IACS and Sentinels data, as these are complete, unrelated to the ongoing procedure and not subject to timely decisions. The key success factor for the proposed approach is therefore to transpose the results, information and understanding provided by the machine learning processes of the past years into predictable observations or likely detections of the current campaign years, taking into account the regional diversity as well as season variability. Paying agencies already possess much information on crop variability and local practices which should be recovered for this transposition process.

In order to increase the transparency of the data analysis in the automated dossier processing the concept of a marker (section 2.3) for communication of observations is proposed. Such crop/activity monitoring approach, based on detection of particular signal phenomena, is much more comprehensible as a process (to beneficiaries) when comparing to the "black box" artificial intelligence based crop mapping algorithms.

2 Concepts

2.1 Overview

To reconcile the requirements and purposes, a series of concepts needs to be defined. Each concept deals with a particular piece or level of information so that the whole combination allows the transposition of raw Sentinel image data into well targeted and informed decisions on eligibility.

- The concept of **signal** reflects a time series of Sentinel data values or their derivatives.
- The concept of **marker** describes an objective observation of behaviour of the land as depicted in Sentinels signals.
- The concept of **feature of interest**, relates to the unit of land that exhibits that behaviour (in practice most often the real world field, crop or unit of management).
- The concept of **scenario** represents the series of likely and reliable markers that the feature of interest would show or should not show, based on the practices of the land use that is declared.
- The concept of **lane** allows the eligibility checks of each individual scheme to be phrased in terms of the markers that should be found for each individual holding.
- Each check is formulated as a **rule** that looks for the necessary and sufficient markers.

Figure 1. The six key concepts allowing for well targeted, informed decisions on eligibility.



The “feature of interest”, “lane” and “rule” concepts are introduced in this document. “Signal”, “marker” and “scenario” are further developed compared to the first discussion document.

In combination, these six concepts should allow for a timely, holding based warning alerts or eligibility decisions.

The “should” will obviously have to be confirmed by the preparatory analysis. Using machine learning techniques on the existing Sentinel and IACS data, paying agencies are able to predict what crops and activities can be reliably and efficiently monitored. The analysis also provides the information needed to populate (in ICT terms “instantiate”) the various concepts. The guidance for this analysis is **not** part of this document, but it can be found in the separate technical guidance on the decision to go for substitution of OTSC with checks by monitoring ([Devos et al., 2018](#)).

Again, the outputs of the monitoring process are documented warning alerts and eligibility decisions. The intended output is neither a crop map nor a traditional OTSC control file as these are not required by the amended Regulation and would not allow to make the best use of the new approach.

Legislation on checks by monitoring requires also the checks of 5% of beneficiaries concerning eligibility criteria, commitments and other obligations that by nature cannot be monitored (cf. Article 40a(1)(c) of the Commission Implementing Regulation (EU) No 809/2014 as amended by Implementing Regulation (EU) 2018/746). In these cases the physical inspection should be limited to checking the eligibility criteria, commitments and other obligations (N.B. no area measurement is needed) that could not be checked by monitoring due to the nature of the monitoring methodology.

At this point we state that the concept of “cannot be monitored by nature” needs to be considered and implemented not only in the framework of the 6 concepts discussed below but also in light of the requirement to have a high quality LPIS allowing for certain eligibility criteria to be checked during the LPIS update process. Such framework allow to specify what phenomena can and cannot be observed either in the payment campaign or over longer time spans. For example many permanent grasslands or permanent crops do not offer striking evidence of the practices occurring therein, but the absence of maintenance could, over some years, trigger a land cover change that will be picked up by a non-Sentinel monitoring system (such as LPIS update cycle). On the other hand, some arable land may display much more practices than is needed to conclude on its eligibility.

Member States may, after cost benefit analysis, decide that particular criteria (e.g. a very rare crop or practice) do not offer reliable (representative) training sample for the automatic processes, even if the crop/practice could potentially provide clear physical phenomena that could be picked up by Sentinels. These cases can be automatically marked by the system for follow up (with a yellow flashing light, see the traffic lights metaphor explained in section 2.7) and be redirected to checks based on a non-Sentinel data source, e.g. geo-tagged images.

2.2 Signal

In electronics, the term signal indicates an electrical quantity or effect that can be varied in such a way as to convey information.

- In the Sentinel context, the quantity is the intensity of either reflected sunlight (Sentinel 2) or scattered radio waves (Sentinel 1) or any combination and derivative of these.
- In a monitoring context, the signal variation will be plotted along the temporal dimension or axis. *Note that whereas for imaging one plots the signal variations along the two spatial axes, for monitoring, temporal signal analysis occurs for each individual spatial coordinate (i.e. image pixel position).*

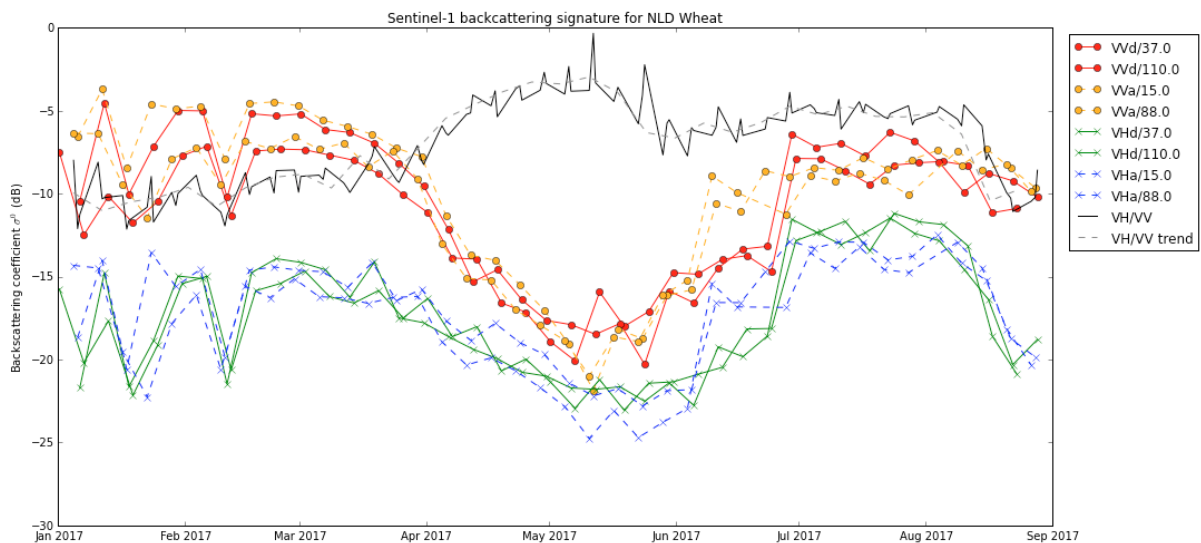
The first bullet implies that the “signal” can be expressed in many forms:

- the raw, processed or calibrated values of a certain band e.g. (reflectance, scatter coefficient),
- a composite indicator (vegetation index, SAR coherence).

The second bullet implies that signals can be graphed 2-dimensionally with time on the horizontal axis and signal value on the vertical axis.

The information enclosed in the signal will be unlocked by analysing these graphs.

Figure 2. Ten different signal graphs (x=date, y= scatter coefficient [dB]) produced by a Sentinel 1 time series over a wheat field in the Netherlands.



2.3 Markers

A dictionary defines marker as something that demonstrates the existence or presence of a particular quality or feature. In this technical context of monitoring, such definition can be interpreted to be a "structured record of an observation on the signal", with ISO 19156 defining observation as "act of measuring or otherwise determining the value of a property".

Markers play the key role in the agricultural parcel (AP) monitoring by providing a function similar to that of the photointerpretation key in the OTSC mapping: they explain and add meaning to an objective observation of the signal. Despite all automated analyses needed to detect and tune the marker parameters, the markers separate the proposed methodology from a black box procedure.

Their role implies that markers describe at least two aspects: the objective observation on the signal and the contextual conditions that provide meaning to that observations.

The central component of the marker, called **core** (see Figure 3), is a pure remote sensing observation of a land cover temporal event i.e. behaviour detectable within a given type of signal. This behaviour can be a continuity, a change, a transition, an appearance or a disappearance of vegetation or other land cover. Cores reflect well known phenomena, documented by the remote sensing community.

- Essentially, a core describes on which signal a particular event is best detected, e.g. the bare soil index signal reveals the presence of bare soil when positive for two consecutive data captures.
- Alternatively, if one would be considering mapping, the core would be the tool to produce a binary mask of the territory; the event is either present or not.

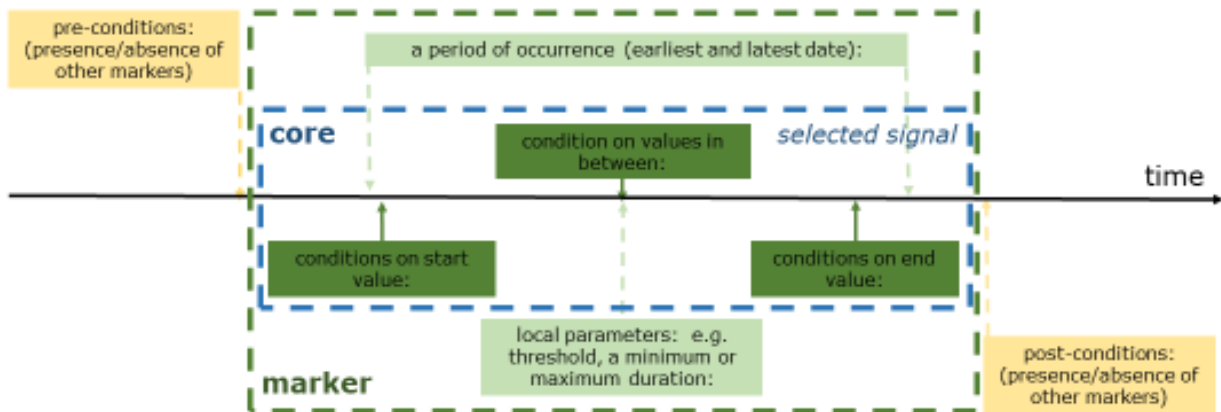
For the marker to become effective, i.e. introduce precision needed for the local context where it is used, restrictions can be applied on the core through the use of **parameters**. The intensity, the starting date or the duration of a particular behaviour is not uniform over the globe. A phenomenon like "fast vegetation growth" will appear differently on a signal taken in the Mediterranean than on one taken in the Baltics. In mountainous areas, a phenomenon like "appearance of vegetation" will be delayed for parcels in elevated positions compared to those located in the valley below. The marker intensity (or amplitude of the signal) of the same crop can vary inside and between regions and can change from one year to another. Therefore the behaviour that the marker describes (the $\Delta s/\Delta t$ shape

on the curve) should be considered as the prime marker characteristic. The parameters of the marker allow the core to be fine-tuned to accommodate these differences and thus make the markers applicable in different regions.

Since the cores represent community best practices, they can be centrally documented and managed, e.g. as part of the common technical specifications. The operational markers themselves (i.e. core + implementing parameters) must be documented and managed by the individual paying agencies.

Furthermore, whereas cores are expected to be generic and stable over time, the markers themselves, via their parameters, are subject to continuous improvement as more know-how, ancillary data and processing methodologies become available. As previously indicated, the parameters can in theory be fine-tuned to accommodate any known information on the particular location, reflecting e.g. seasonal variation of rain and temperature, soil properties, local land use restrictions or topography. Whenever such information can be expressed in temporal terms (a time shift of the behaviour, a higher speed) for that location, the marker's parameters can be adjusted.

Figure 3. The marker concept (dark green= core; light green= parameters; yellow = logical conditions), updated from the first discussion document.



Markers can be detected from the signal by applying formal analytic rules, such as queries, thresholding, regressions etc. Conformity of these rules is then documented as an occurrence of that particular marker.

2.4 Feature of interest

Markers describe observations of the land and the basic feature subject to monitoring is not the image pixel itself, but the agricultural parcel or the unit of management. In the frame of monitoring, it makes little sense to observe the signal over the narrow 10m x 10m area as many pixel-based classifications do, but rather to monitor the signal derived over the continuous patch of pixels that represent the whole or a part of the field.

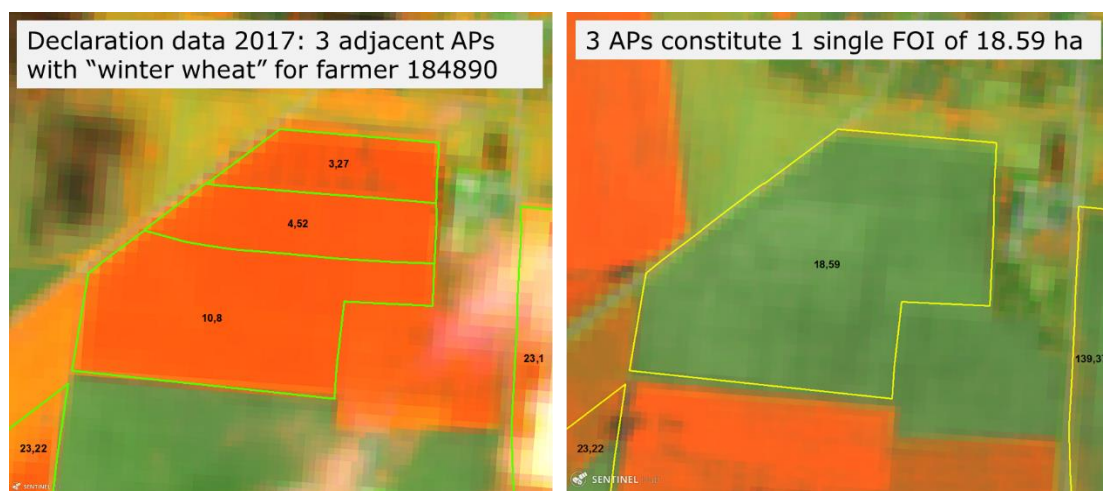
Such clustering allows a further broadening of the type of signal available by adding a series of statistical values to the raw data. Statistical spatial parameters as homogeneity or geometric congruity can be added to the intensity of reflection or scattering. For homogenous land covers, clustering per feature of interest may also improve signal quality by removing outlier pixels and other noise.

The feature of interest (FOI) refers to a homogeneous real world feature (as meant by conceptual modelling terminology), which in agriculture corresponds most often to either the "field" or the "crop" (see Figure 4). Experiences from the OTSC and LPIS QA processes

confirm that such field (or unit of management) is not always on a one to one cardinality with either the agricultural or the reference parcel. One agricultural parcel can be simply a part of the farmer's crop field; several reference parcels (e.g. cadastral parcels) can be worked by a single farmer. Looking at the OTSC and LPIS QA experiences may provide an indication on the cardinality between AP and feature of interest in the given landscape.

To improve the effectiveness of a marker on arable land, it sometimes makes sense to aggregate all adjacent declared agricultural parcels under a single use (i.e. same farmer and same crop for the year) into a single feature of interest. Small or irregularly shaped agricultural parcels can be aggregated into a single larger feature that is more suitable for being monitored by Sentinel type of imagery. On the contrary, it makes little to no sense to aggregate larger and regular agricultural parcels, even under such single use, when these represent features of interest already suitable for monitoring standalone. The feature of interest may be perceived as a vehicle to overcome image resolution and parcel dimension issues where possible.

Figure 4. Declared agricultural parcels (left) and corresponding feature of interest (right).



The feature of interest also serves another function. There are documented cases e.g. of grassland management where sub-parcelling is required, e.g. because only half of the grassland may be mowed at any given time. Such sub-parcels are not part of the declared agricultural parcel but can be relatively easily detected within a feature of interest. The detection of such temporary sub-parcels within the feature of interest is tell-tale of the management and can be described through a characteristic marker. A similar FOI approach could even be considered on arable land, e.g. when a large single field is declared by more than one applicant, with GSAs representing cadastral documentation rather than actual practice.

Features of interests may, under certain conditions, also help to deal with detection issues on the agricultural parcels such as areas under common grasslands or large permanent crop expanses. Such FOI could span several farmers active within these permanent grasslands or permanent crop areas, and the FOI's outcome is applied to each farmer active therein. This transfer of outcome towards conclusive results relies on valid "homogeneity" conditions for the FOI.

2.5 Scenario

A dictionary defines scenario as a description of possible actions or events in the future. For application in the monitoring proposal, that concept could be translated in "a description of the expected and reliable land cover markers over the feature of interest, given the GSAA application declaration".

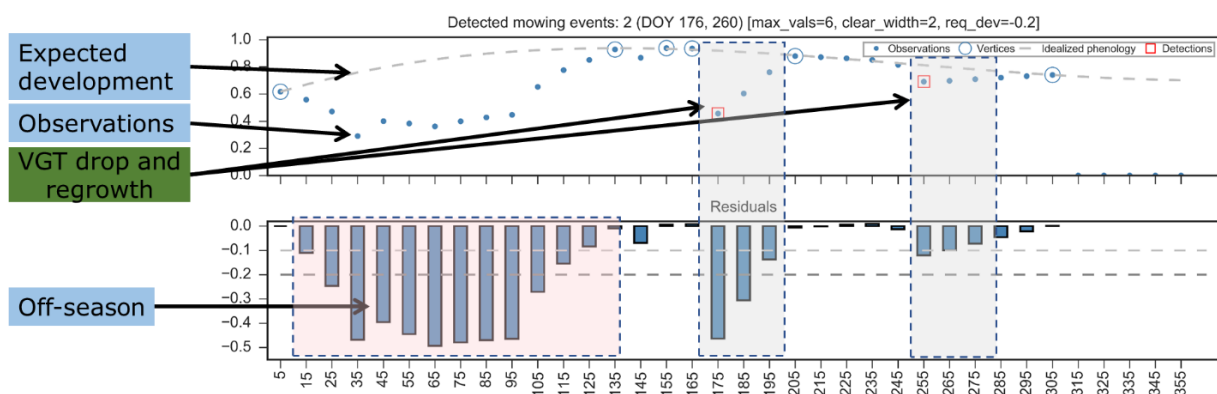
The scenario brings the local business logic into the process by integrating results and information derived from machine learning analyses with the available local know-how on

crop phenology and/or the agricultural practices. Indeed, where markers merely observe the land cover behaviour, the scenario places that behaviour in the context of the local farm practices. By doing so, an observed event can reliably be attributed to a particular activity.

For example, any arable crop will invariably trigger the appearance of bare soil, growth of vegetation, removal of vegetation and possibly other land cover events. What is characteristic is that these events will occur in a certain sequence, with a crop dependent timeline, possibly linked to last year's use (crop rotation). A permanent grassland under a hay making regime will show vegetation year round, with drops of biomass after each mowing action.

The scenario brings meaning and explanation to the series of markers it contains as it frames the marker into a known and predictable context. As a consequence, marker parameters are set for each particular scenario. For example the marker to detect bare soil in a maize scenario will have other parameters (e.g. range of day of the year) than the bare soil marker for a winter wheat scenario.

Figure 5. A scenario for hay land, based on the NDVI signal. The NDVI-signal of grassland can be predicted throughout the year (upper part of the graph) and deviations (lower part) of the graph from that expected signal during the summer period indicate mowing. In this case, 2 markers can be detected, the first confirming the use as hay land (short mowing), the second evidencing a compulsory maintenance activity.



2.6 Lane

A lane represents the processing for a single scheme/support measure/type of operation under monitoring. The word "lane" is loosely derived from the term "swim lane" in the UML flow diagrams, as it also visually distinguishes sub-processes, with each sub-process representing a scheme that will be monitored.

We recall that the regulation demands that whole Direct Payment schemes and/or whole Rural Development measures or types of intervention are subject to monitoring, even if the transition period allows a regional phasing in thereof.

The lane ensures that the tasks, i.e. coming up with an eligibility verdict for payment, within the sub-process or scheme operate autonomously from those in other lanes. i.e. the sub-process in each lane only evaluates what is needed for its sub-tasks and produces an autonomous eligibility. Each lane can however exchange information (i.e. provide, conclusions, markers or parameters) with other lanes which will subsequently take that information into account.

The lane ensures a targeted and reductive approach. Eligibility conditions for the lane can be phrased for a feature of interest or at holding level. Given the availability of the agricultural parcel and the a priori conditions of the holding, the general eligibility rules of the scheme, if applicable, can now be dynamically formulated in terms of markers that are expected to turn up on each parcel of the monitored holding.

2.7 Traffic lights representation

The processing flow is visualised by the system of traffic lights. As published in the first discussion document ([Devos et al., 2017](#)), there are five meaningful “traffic lights” states. Note that “orange” is now called “yellow” and “blinking” is renamed “flashing”. Three of these lights represent parcel/FOI or holding state:

1. Yellow: parcel/holding assessed, but insufficient evidence to either explicitly conclude as compliant "green" or non-compliant "red", hence subject to further processing.
2. Green: parcel/holding assessed as compliant.
3. Red: parcel/holding assessed as non-compliant.

The following two lights indicate two categories of the ongoing processing of the inconclusive yellow light cases:

4. Flashing Yellow: parcel in need of additional evidence and/or farmer’s input before processing can continue.
5. Flashing Blue: expert judgement required regarding the additional information from non-monitoring sources and its subsequent processing and interpretation.

As indicated in the next section and in Figure 6, the traffic light colours can be projected upon parcels in two ways:

- if a detected marker/parcel combination is directly applicable to the lane conclusion, it is represented as a traffic light e.g. in BPS/SAPS/ESPG,
- if the detected marker/parcel combination requires additional consideration before deciding on the final traffic light for the lane, e.g. based on holding level characteristics (e.g. in CD and EFA), it is represented as a coloured flag.

One could regard the first four lights as largely corresponding to states and activities where the automation is in full control without a human conductor. By contrast, the flashing blue light indicates the opposite: processing control is transferred from the automation system to the human expert, who obviously can launch automated procedures and who should transfer control back to the system upon completion of his intervention.

2.8 Lane rules

Lane rules are the set of necessary and sufficient criteria based on which the automatic algorithm needs to make a conclusive decision. Generally, the set can be derived from comparing and analysing the scenarios applicable for the particular holding. This involves discarding the unnecessary or irrelevant parcel characteristics but focussing on that behaviour that allows to confirm a scenario or to discriminate between crops. The selected markers resulting from that process are what the algorithm will be looking for.

Any set of markers evidencing compliance of specific parcels/FOIs with a given requirement could be called *compliance rules*. For example:

- For a voluntary coupled payment, all necessary markers to identify the crop (i.e. discriminate from all other potential crops) would be needed in the rule.
- For a crop diversification decision, the observance of the marker that discriminates it from the other crop in the holding will be sufficient as a rule, assuming crop areas are reliable.
- For a BPS/SAPS, any single marker that best shows the agricultural activity related to events of the scenario could be sufficient (e.g. mowing on permanent grassland).

An affirmative decision on the compliance rule leads to the green light.

On the other hand, lanes can also consider the appearance of markers that contradict the truthfulness of the declared scenario, e.g. the unauthorized ploughing (i.e. appearance of bare soil) within permanent grassland where ploughing is banned. Such a set of markers could be called *non-compliance rules*. Note that these markers can come from the declared scenario (as above) but also from a series of incompatible scenarios. Incompatible scenarios would also be those related to non-agricultural land covers and land uses (forest, water, urbanization).

Any evidence on any non-compliance rules turns on the red light.

A third type of rules, ancillary to the automatic processing, are called *validity rules*. The validity rules are those that help control and steer the automatic process. If violated, they trigger a change in processing, either automatically or manually depending on the nature and context.

Examples of a validity rule could be:

- Observing variability within a parcel which contradicts the assumption of correctness for the declared area or crop. Interaction with the farmer could lead to the provision of new scenarios.
- Observing a ploughing in a parcel of permanent grassland where ploughing is not banned. Although this grassland may no longer be permanent, the parcel may still be compliant if sown with new grass or left lying fallow, but then a new scenario is needed.
- Not finding markers of the compliance rules just before the deadline of an activity so that the farmer can preventively be warned.

These validity rules are rather generic, i.e. applicable to many landscapes and practices. Hence it makes sense to share these rules between Member States.

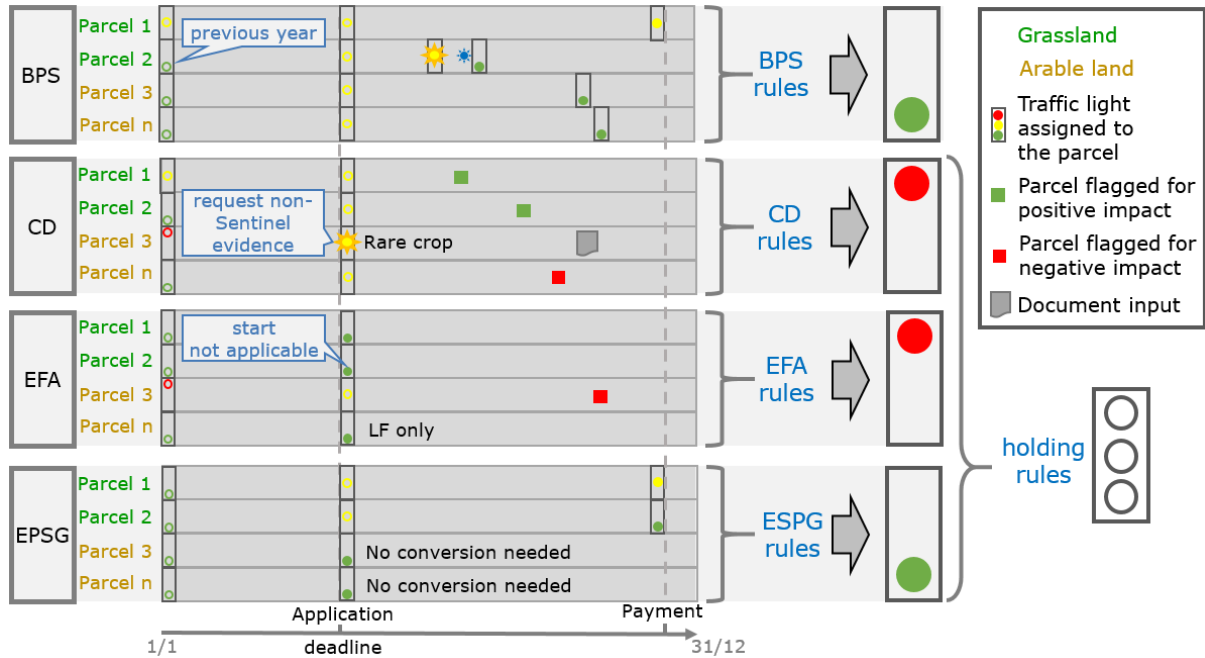
Paying agencies should select appropriate compliance and non-compliance rules for each lane and carefully set the parameters of these markers. The decisions on the compliance and non-compliance rules over the year allow the assignment of the traffic lights to the parcel (one for each lane), for the lane and for the holding.

Figure 6 illustrates many sequential elements of the traffic light assignment that will be discussed in later chapters:

- For each lane, the parcel comes with its legacy from the previous year to be considered in the FOI of the following year (not relevant for 2019).
- After receipt of the application, each parcel is assigned a starting colour for the lane: green if no a priori monitoring is needed (e.g. a permanent grassland parcel is irrelevant for the crop diversification), yellow if there is a legacy from the past (not relevant for 2019), flashing yellow if monitoring is likely to be inconclusive given the declared scenario and other data sources will be required.
- The parcel starting conditions can be transferred to the FOI that holds it, if appropriate.
- In the subsequent months, the detected markers will be used to make decisions expressed as traffic lights (green, yellow, red). Some conditions may ask farmer input (yellow flashing), other can trigger follow-up action (blue flashing) that confirms compliance.
- Rules for BPS/SAPS (and related top-up schemes) and ESPG operate at parcel level so light colours can be assigned directly on parcels by the marker that corresponds to each rule. Crop diversification and temporary EFA rules apply to the holding level, but by analogy, to facilitate further dossier processing, the parcels can be coloured flagged based on how each parcel impacts the holding's outcome (see section 2.7).

- At the holding level, all applicable lanes must be concluded upon, i.e. showing green light for the holding to become compliant (i.e. accepted for full payment).

Figure 6. Four lanes for BPS/SAPS, crop diversification, ecological focus area and permanent grassland. Note how each parcel/FOI is autonomously monitored and processed by each of the four lanes. Monitoring output in the lane is illustrated with traffic lights (BPS/SAPS/EPSPG) and flags (CD/EFA).



3 The core processes

3.1 Reliance on automation

From the very beginning, automation has been the inevitable solution to solve the monitoring paradox being that more farmers and more data are processed while reduction of burden is to be achieved.

The Commission proposes a single, universal expectation on the reliability of the automated system, based on the statistical widespread concepts of the type 1 (α) and type 2 (β) errors:

1. type 1 error [α] is the rejection of a true null hypothesis (a "false positive" or false RED finding), the α expectation is set at 5%,
2. type 2 error [β] is the failure to reject a false null hypothesis (a "false negative" finding or false GREEN), the β expectation will be set at the later point when having more information on performance of the monitoring systems. Whilst in principle this value should be set at 5%, in absence of historical data and as to ensure the practicability of the monitoring procedure in the initial phase, the initial value for β can be set in the range of 10-20%.

A type 1 error occurs when an applicant with correct declaration is classified by the automation system as non-compliant. In such cases, applicants will most likely and rightly disagree with the verdict and react or launch appeal procedures. The expectation of a 5% means that less than 1 out of 20 non-compliant farmers should have a cause to appeal.

A type 2 error occurs when an applicant who in reality is not (completely) compliant passes through the automation and hence receives (a part of the) subsidies he is not entitled to. An expectation of β of e.g. 10% means that only 1 out 10 non-compliant applicants can slip through the automation system undetected. It is unlikely that this will trigger reaction or appeals from his part, but there remains the following year where the applicant faces the same odds.

The feasibility of achieving these expectations over a reasonable amount of time for a given system and landscape can reliably be derived from validating the machine learning results with the corresponding field observations. However, as monitoring is an approach that is believed to be improving at every campaign year, the phrase "over a reasonable amount of time" was added to indicate this is not an absolute starting criterion.

An annual quality management mechanism (see section 3.5) based on a systematic, but very reduced collection of ground truth allows to demonstrate both achieving the target errors as well as to assess the performance improvement over the years.

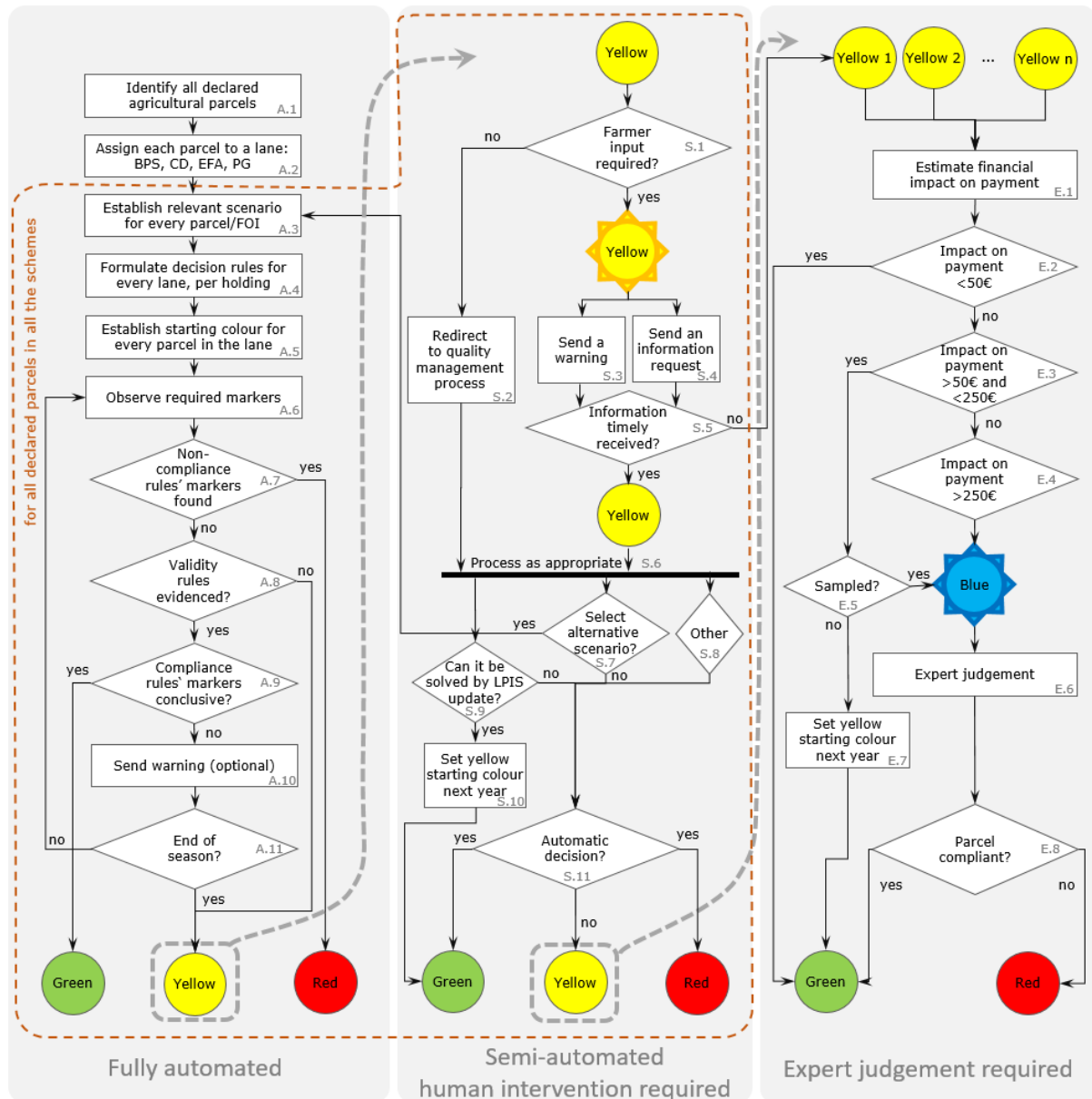
3.2 Inconclusive assessments: intervention and manual follow-up

Figure 7 presents a flow diagram describing the many possible options for further processing in various degrees of automation. The first column of the data processing schema can be fully automated. All the declared parcels need to be identified (A.1) and assigned to different lanes (A.2; section 2.6). The relevant scenarios (A.3; section 2.5) need to be associated with appropriate decision rules (A.4; section 2.8). After establishing the starting light colours for every lane (A.5), the markers should be observed (A.6) in the time series of Sentinel data as long as necessary to arrive to a conclusive decision (green/red light). If applicable, when the deadline for a given activity approaches, warnings/reminders can be sent to the farmer (A.10), e.g. when obligatory mowing has not been observed close to the time limit. In cases where non-compliance rules' markers are found (A.7; section 2.8), a red light is assigned to the parcel. Conclusive compliance rules' markers (A.9; section 2.8) allow to set a green light to the monitored parcel. In case of no conclusive decision by the end of the local agricultural cycle (A.11) or triggered by appropriate validity rules (A.8; section 2.8), follow-up actions should be taken for the resulting yellow light.

The challenge is to have a workable method to continue processing from there.

Addressing this challenge requires a cautious analysis to enable the processing of parcels in groups that share a similar but simplified semi-automatic processing based on the nature of the FOI, the scenario and the potential of other information source than Sentinel. Not all choices and actions are applicable to every parcel.

Figure 7. Flow diagram for the decision process on the parcels (switching traffic lights), the three columns represent the levels of human operator involvement.



The diagram in Figure 7 offers a catalogue of choices in a preferred logic.

At this point additional information can be requested from the farmer (S.1) or, under the right circumstances, the parcel processing can be redirected to the quality management process (S.2). All other information, e.g. relevant crop mapping results, can be considered at this point of data processing (S.6).

When the farmer's input is timely received (S.5) it should be further processed as appropriate (S.6), e.g. perhaps reprocessing the parcel/FOI with a scenario better fitting the farmer's input (S.7) can in turn lead to an automatic decision (S.11).

Feedback from the quality management process (S.2) or the farmer's input (S.5) can feed into the LPIS update process (S.9). However, to process the ongoing year the light can be set to green as well as to yellow light as next year's starting position (S.10). In the first year of monitoring each parcel starts without legacy.

Member States will have to analyse the logic and determine applicability of each option in their specific context and given the information needs. For example:

- It makes little sense to warn farmers (S.3), when there is no time to react.
- Is the information requested (S.4) from the farmer relevant to come to the conclusion of the holding?
- It makes sense to request for a confirmation/correction (S.4) in the declaration, e.g. on an incorrectly declared cover crop.
- Referral to the LPIS update (S.9) could be applicable where absence of agricultural activity (so no compliance rule markers are detected) inevitably triggers a change of the land cover. In these cases, the very nature of the land cover change evidences abandonment or conversion of land and red or green lights may be assigned retroactively and the rules of retro-active recovery have to be applied where necessary. During the 2019 implementation, experiences will be gained on identifying and documenting appropriate methods.
- What type of farmer input can be processed automatically (S.11)?

It goes without saying that in those cases where the path to solution is predictable, an automation of the processing should be set. Such cases could be:

- observing the failure to perform an activity with the deadline approaching and thus automatically sending a warning message (A.11),
- for a crop that cannot be identified by monitoring (e.g. Durum Wheat) automatically sending a request to the farmer to provide evidence (S.4).

Automation of the processes presented in the middle part of the diagram in Figure 7 (semi-automated processing), should offer low processing cost and high consistency/transparency. Still, as farmer interaction is involved, it could also require some amount of human supervision, e.g. in the screening, processing and categorisation of the received feedback. Experiments from the JRC have revealed that in cases where the automatic processing is not yet conclusive, the standalone Sentinel time signals often do allow a trained operator to come to an unambiguous conclusion.

In all other cases, control of the further processing of yellow lights is transferred to (human) expert judgement (right hand side column in Figure 7): the flashing blue lights. Since expert judgement is often a high cost activity, it only matters where the financial impact is relevant. Therefore the financial impact on the payment should be estimated (E.1). That financial impact for parcels with inconclusive assessment is calculated at the beneficiary level for all the schemes/measures as a product of the unresolved area and the corresponding rate/average entitlement value. For the calculation algorithms the reader is referred to the DGAGRI "Q&A on check by monitoring for claim years 2018 and 2019" document.

The value of financial impact on the payment calculated at beneficiary level for all schemes/measures decides how the parcel should be processed:

1. low impact (E.2) on payment < 50€: ignore (process as if green for this year),
2. medium impact (E.3) on payment > 50€ and <250€:
 - (a) a part is subject to sampling (E.5) and, expert judgement must lead to either "green" or "red".

The sample size should be set so that the number of expert judgement cases does not become prohibitive. Thus a sample of 5% of inconclusive parcels in this category must be followed up.

- (b) the remainder is processed as with low financial impact (point 1 above), i.e. process as if green for this year, but set yellow starting colour next year (E.7).
- 3. high impact (E.4) on payment > 250€: expert judgement must lead to either "green" or "red" (E.8).

The obvious drawback of this exact calculation is that the final financial impact can only be correctly calculated when all schemes of the holding have been concluded upon. As the financial impact of greening payments is very sensitive to farmers' business choices, one expects large arable holdings with some small critical parcels to constitute the bulk of these cases. So, to reduce the risk of all cases materializing just before payment, MS could predict the worse-case outcome for each susceptible holding (for which it is known to be less likely to come to the conclusions) and launch supportive reminders where the thresholds could be breached and when farmers' actions remain relevant.

For the processing, the expert judgement (E.6) can use any reliable tool that is available to come to a conclusion:

- (a) request declaration/geotagged image from the farmer, effectively returning control to the automated system after that decision,
- (b) make a photo interpretation and/or timeline interpretation of the Sentinel data,
- (c) look for any administrative/alternative evidence to make a decision,
- (d) redirect to an explicit check during LPIS update,
- (e) carry over the particular case to the next year as yellow, e.g. in a case where the expert expects that LPIS update to reveal a land cover change or yellow-flashing in case the farmer needs to provide particular evidence, whatever is most appropriate.
- (f) If all above options or combination thereof (would) fail to come to a conclusion, a parcel/holding field visit should be performed. Where such a visit to the field does not allow to conclude on compliance with the eligibility criteria in question, that parcel should be assigned a green light for the ongoing year and a yellow for the following year.

3.3 Practical consequences

The combination of all choices and options that the MS selects from the diagram should ensure that the final "green" and "red" follow the proposed type I and type II error rates, but at the same time ensure that no type of holding, practice, crop or parcels is a priori excluded from monitoring. Monitoring must deliver a fairness to the control system.

The semi-automated column of the diagram in Figure 7 is key in the re-design of interaction with the farmer that the monitoring approach allows and should be duly considered (see also section 3.4). Member States should not too readily bypass these procedures by controlling the flow and appropriate processing by setting financial criteria. Monitoring is primarily based on physical properties and factual observations of the land. The financial thresholds of the manual processing are intended as a back stopper only and should not be viewed as an a priori excuse to exclude any parcel with low financial impact (albeit on holding level) from the monitoring cycle.

For logistic and practical reasons, the sampling related to parcels with yellow lights with medium impact on payments (point 2.a above) may be organized in a "clustered" way, similar to the CwRS zones. Member States may use photo interpretation of concurrent (i.e. where the phenomenon can still be expected to be visible) imagery to come to conclusion and avoid field visits where possible.

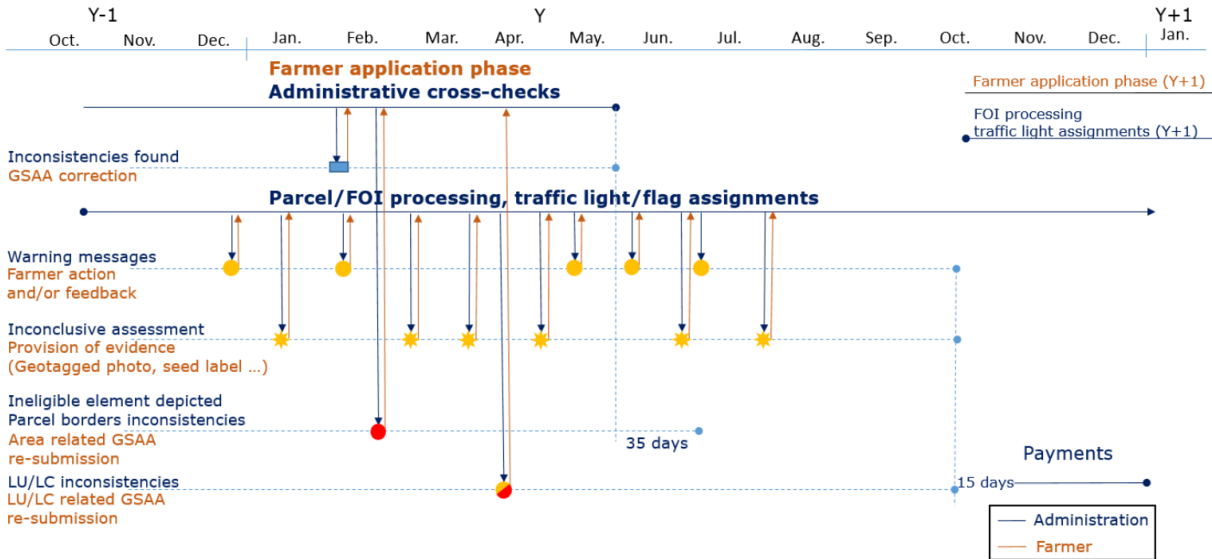
In cases where a conclusion is redirected to another system than monitoring (e.g. LPIS update), that other system must hold the appropriate placeholders and interfaces to communicate with the monitoring system. This also requires a good understanding and documentation on the rationale behind the redirection of these yellow cases.

3.4 Active role of farmers

Within the OTSC system, the role of farmers can be limited to the phase of application/GSAA declaration. All other phases of the dossier processing up to the payment would be ensured by the MS administration.

The inherent properties of the monitoring system imply a much more active role of farmers (see Figure 8).

Figure 8. Flowchart evidencing processes and events when, on request of the administration, a farmer may be asked to act upon.



During the phase of declaration and the preliminary checks, if inconsistencies are detected during the cross-checks, the administration can inform the farmer and propose to modify his/her GSAA.

During the monitoring of individual parcels/FOIs, the administration can send alerting/warning messages to farmers to remind them about an action/practice they are requested to accomplish before a specified deadline (e.g. mowing of grassland). In reaction, farmers may be invited to send a confirmation when the work is done or even a geotagged photo as evidence.

Among the different cases of inconclusive assessment of a parcel/FOI (yellow light), as a part of follow-up action the administration can ask the farmer to provide an evidence. It can consist for instance in sending geotagged photo(s) of the parcel of concern or provision a scan of seeds label to inform about a requested crop mixture.

Also, during the monitoring phase, if inconsistencies are found concerning parcel/FOI limits (see examples in Figure 18 and Figure 19), the farmer will be given the possibility to amend his/her GSAA.

Thus, it appears obvious that the active role of farmers is crucial to guarantee the efficacy and efficiency of the whole monitoring process. Beneficiaries and administrations become partners in this process. Anyhow, the opportunity is provided here to remind that, the ultimate responsibility concerning the content of the application/GSAA always lies with the farmer.

In design of the administration-farmer interaction processes the following rules and deadlines should be considered:

- The farmer can modify the application until 35 days after the application deadline - under the provisions of preliminary cross-checks - and/or during the period for amendments (normally until 31 May). This allows for correcting area and declared land use/crop, after the farmer has been informed about the results of preliminary checks (even for parcels with a “conclusive” red light).
- The declared use of individual agricultural parcels can be modified up to a date fixed by the MS, but no later than 2 weeks before first payment of instalments for the given scheme. The modification has to comply with the other eligibility criteria.
- Under certain conditions (see question 23 in to the DGAGRI “Q&A on check by monitoring for claim years 2018 and 2019”) a declared agricultural parcel can be withdrawn (in writing) from the application at any time without penalties, even when the farmer has been warned or informed of a conclusive red light.

Monitoring can reveal that the location and spatial extent of the “land use shares” (e.g. crops, land laying fallow) relevant for greening are different from the initial farmer declaration. When still within the declared BPS/SAPS area, this will – under the compensation mechanism of the greening controls - not necessarily require an explicit consultation of the farmer or a modification of the declared land use.

Such modifications require restarting the processing (from process A.3 onwards in Figure 7) for the revised application, using corrected FOI, scenarios, rules etc.

3.5 Quality management and ground truth

Although there is only one general quality expectation (i.e. manage the type I and type II error rates), it is unavoidable to have some quality management considerations. As previously indicated (section 3.1), that would serve two purposes:

- achieve a better understanding, scaling and tuning the functioning of the monitoring algorithms and the data collection procedures,
- make a verification and documentation of the type I and type II error rates over the years.

Both activities are driven by the markers which express the outcome of the automatic monitoring process.

The Commission Services propose at the minimum a quality control measure that links field observations to the monitoring process outcomes. Although in this system level set up the numbers involved can be very low, it is important that the entire system and the whole territory are covered and analysed. This system control mechanism and data collections is NOT directly linked to the processing of application as presented in Figure 7, rather it is a small scale, independent system wide collection of ground truth.

The primary purpose is to keep the monitoring system in touch with the reality on the ground by collecting representative ground truth that is used for the performance/tuning of the monitoring. A secondary benefit would be that these activities act as ambassadors, seen by farmers in a non-intrusive way, giving them credibility and confidence in the method.

The use of the field observation is to assess and improve markers and parameters for the scenarios and perform additional verification of detected non-compliance markers, not to process applications as during an OTSC. To be effective and cost efficient, following considerations can be made for the methodology of ground truth collection:

1. Ground truth for marker and marker parameters has a clear expiry date; the FOI should be visited with a short delay, as it makes less sense to go on a field where a marker picked up something many months before.
2. Activities are limited to pre-set periods, when summer crops or winter crops are present and markers make sense.
3. To reduce the workload to a minimum and avoid any logistic obstacles, an appropriate sampling scheme could be elaborated, e.g. based on a weekly transect per homogenous 200kmx200km territory or, if smaller, NUTS1 region with random start location and direction that processes 40-50 FOI/markers per transect (e.g. selected by weighted convenience sampling). This would result in 10 daily FOI ground observation for such territory or region during the relevant season, available for feedback in the monitoring system maintenance and tuning.

Details of the quality management processes will be further elaborated based on experiences collected during 2019.

4 Proposed technical specifications and templates

4.1 Marker core

As described in Section 2.3, the marker has two distinct components: the core and the parameters.

The core always relates to a particular observable state or behaviour of a property of the land phenomenon. This property is primarily related to the "material" that constitutes the observable land phenomenon. It can be biotic (vegetation) or abiotic (water, artificial construction, mineral deposit) in origin. The core requires the capturing of the conditions (presence/absence) of the given "material" at the start and at the end of its occurrence, as well as in between.

Each core reflects a temporal event associated with a particular land phenomenon. Since its elements are observable using remote sensing, they can be instantiated through well-documented signals and their derivatives obtained by remote sensors (ex. EO satellites). Table 1 provides the list of main marker cores with the values for their elements (properties, conditions), the events they relate to, as well as the most common signal parameters from optical sensors, based on the experience acquired by the scientific community.

The list of the marker cores as well as marker parameters is extendable. The state-of-the-art of remote sensing today (optical, SAR) allows the observation of wide variety of properties of the material (moisture, texture, roughness) and its change in time (coherence, structural changes in vegetation).

Table 1. Examples of main marker cores

Property	Conditions on start	Conditions in between	Conditions on end	Event	Example of instantiation (application) through the most well-known signal types based on past experience of the scientific community
green herbaceous vegetation	present	present	present	presence of green herbaceous vegetation	Normalized Difference Vegetation Index (NDVI); Red-edge Normalized Difference Vegetation Index (NDVI _{re}); Soil Adjusted Vegetation Index (SAVI); Normalized Difference Water Index (NDWI)
green herbaceous vegetation	absent	n/a	present	appearance of green herbaceous vegetation	dNDVI/dt; dNDVI _{re} /dt; dSAVI/dt; dNDWI/dt; SAR coherence
green herbaceous vegetation	present	n/a	absent	disappearance of green herbaceous vegetation	dNDVI/dt; dNDVI _{re} /dt; dSAVI/dt; dNDWI/dt; SAR coherence

Property	Conditions on start	Conditions in between	Conditions on end	Event	Example of instantiation (application) through the most well-known signal types based on past experience of the scientific community
green herbaceous vegetation	absent	absent	absent	absence of green herbaceous vegetation	NDVI; NDVI _{re} ; SAVI
dry vegetation	present	present	present	presence of dry vegetation	Plant Senescence Reflectance Index (PSRI); VV backscattering
dry vegetation	absent	n/a	present	appearance of dry vegetation	dPSRI/dt; VV backscattering
dry vegetation	present	n/a	absent	disappearance of dry vegetation	dPSRI/dt; VV backscattering
dry vegetation	absent	absent	absent	absence of dry vegetation	PSRI; VV backscattering
water	present	present	present	presence of water	NDWI; Water ratio index (WRI)
water	absent	n/a	present	appearance of water	dNDWI/dt; dWRI/dt
water	present	n/a	absent	disappearance of water	dNDWI/dt; dWRI/dt
water	absent	absent	absent	absence of water	NDWI; WRI
bare soil	present	present	present	presence of bare soil	Tasseled Cap Brightness (TCB); Normalized Difference Bareness Index (NDBal)
bare soil	absent	n/a	present	appearance of bare soil	dTCB/dt; dNDBal/dt; SAR coherence
bare soil	present	n/a	absent	disappearance of bare soil	dTCB/dt; dNDBal/dt; SAR coherence
bare soil	absent	absent	absent	absence of dry bare soil	TCB; NDBal

Property	Conditions on start	Conditions in between	Conditions on end	Event	Example of instantiation (application) through the most well-known signal types based on past experience of the scientific community
woody vegetation	present	present	present	presence of woody vegetation	NDVI _{re} ; SAVI
woody vegetation	absent	n/a	present	appearance of woody vegetation	dNDVI _{re} /dt; dSAVI/dt
woody vegetation	present	n/a	absent	disappearance of woody vegetation	dNDVI _{re} /dt; dSAVI/dt
woody vegetation	absent	absent	absent	absence of woody vegetation	NDVI _{re} ; SAVI
vegetation heterogeneity	present	present	present	presence of heterogeneous vegetation	avgNDVI/ stdevNDVI
vegetation heterogeneity	absent	n/a	present	appearance of heterogeneous vegetation	d(avgNDVI/ stdevNDVI)/dt
vegetation heterogeneity	present	n/a	absent	disappearance of heterogeneous vegetation	d(avgNDVI/ stdevNDVI)/dt
vegetation heterogeneity	absent	absent	absent	absence of heterogeneous vegetation	avgNDVI/ stdevNDVI

4.2 Marker parameters

4.2.1 General introduction

As explained in Section 2.3, the applicability/effectiveness of the marker core in a particular (local) context requires the use of additional parameters. These parameters complement and fine-tune the elements of the core marker (see Figure 9) and give a “meaning” of the core marker in the local context.

These parameters can be grouped in the following categories:

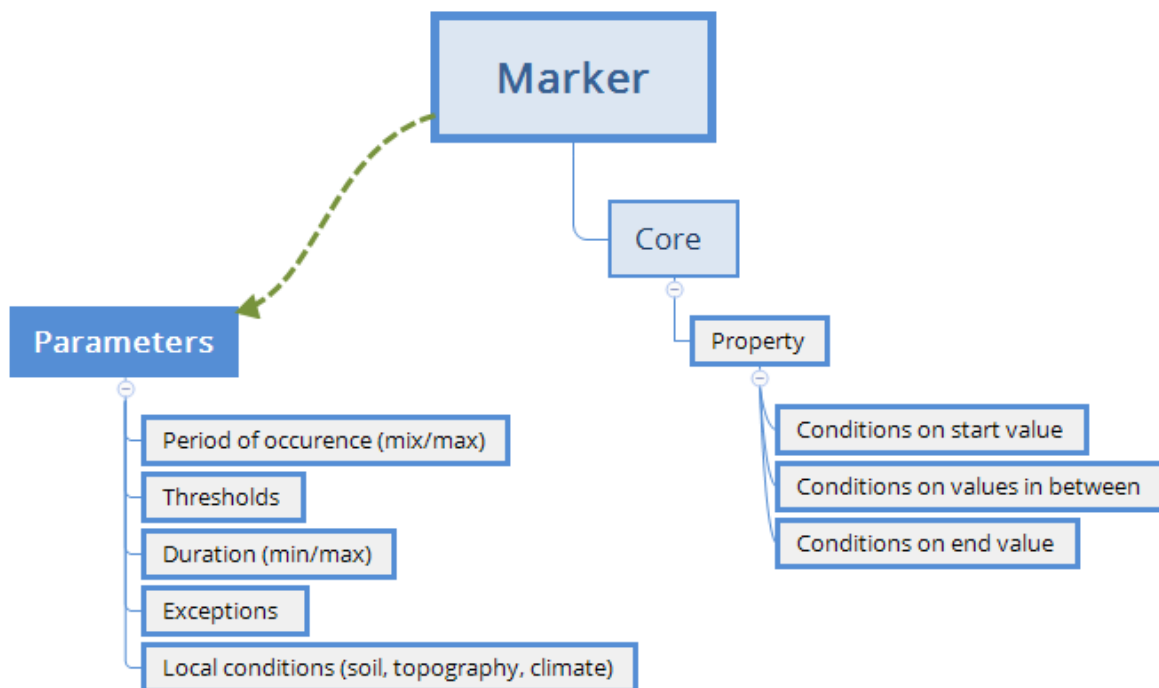
- Temporal: minimum and maximum period of occurrence, minimum and maximum duration,

- Behavioural: constraints, thresholds, expectations,
- Contextual: local conditions (soil, topography, climate).

Contrary to the marker core properties that are rather fixed, the parameters are subject to constant improvement, update and fine-tuning. This requires their proper documentation. Figure 9 below provides a graphical illustration of the marker and its components.

The marker parameters and their values should be based on the crop calendar in the particular agro-climatic region and the statistical information derived from the image time-series from previous years e.g. with machine learning algorithms based on neural networks. The monitoring algorithm, but also crop maps that would result from such time-series analysis, can be improved with the information collected by the field observations for the quality management purposes (see section 3.5). Indeed, any observation on early or delayed development of the crop can be used to offset the values of the marker parameters.

Figure 9. Illustration of the marker and its components: parameters and signal behaviour.



These calibrated marker parameter values allow to make a better interpretation of the timing of the appearance of the markers and consequently, better tap into the prevention potential of the monitoring system.

4.2.2 Parametrization of markers through machine learning

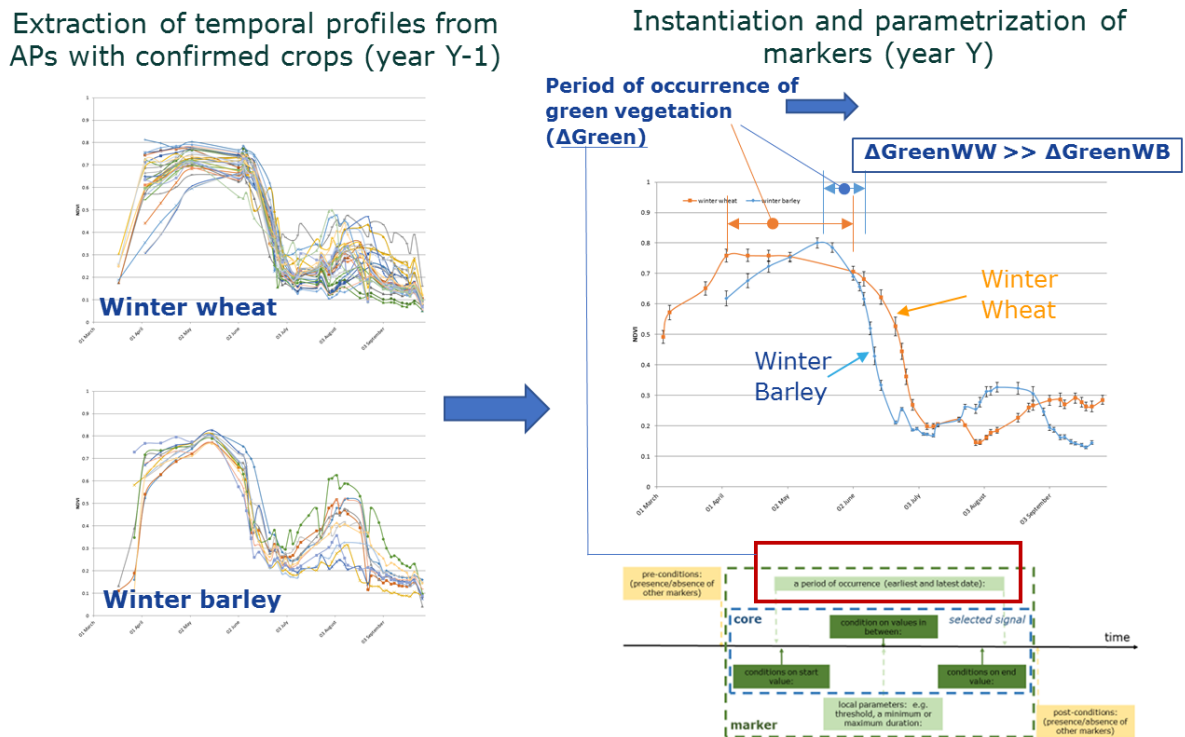
The parametrization of the markers using the results from machine learning consist of following distinct phases:

1. Definition of the scenarios and selection of the appropriate marker cores in year Y.
2. Analysis of the outcomes from machine learning for the same scenario on the agricultural parcels/FOIs in year Y-1. Categorization of the FOIs based on the probability of occurrence of the given scenario.

3. Extraction of temporal profiles for the selected markers from these agricultural parcels/FOIs in Y-1 where the scenario has been confirmed with the highest probability.
4. Construction of the generic temporal profile for the given scenario on the basis of the superimposition of individual temporal profiles and identification of the critical points (min, max, inflection) related to the state or change of state of the given land phenomenon (associated with the scenario).
5. Instantiation and parametrization of the relevant marker(s) with the critical points values derived in the previous step.

Figure 10 shows an example of instantiation for the marker for discrimination between two types of winter crops (wheat and barley). The series of events expected to occur on agricultural parcel/FOIs declared with these two crops should correspond to the typical scenario for annual winter crops, where we expect activities such as ploughing, sowing and harvest. The marker cores suitable to represent the impact of these activities on the land cover phenomenon, are basically appearance, presence and disappearance of green vegetation in particular periods in the agronomic year. The most common signal type used to "instantiate" the core markers is the NDVI. The expected NDVI temporal profiles associated with these two crops present in a given region could be extracted from the results obtained from machine learning conducted on the agricultural parcels/FOIs declared with these crops in the previous year. For the generation of the profiles only those FOIs where the declared crop is confirmed with maximum probability (e.g. crop confirmed in all prediction labels made with different training samples) are taken.

Figure 10. "Instantiation" of markers using machine learning – example with winter crops.



An analysis of the generic temporal profiles for each crop reveals that starting time of NDVI increase, the time of NDVI maximum and starting time of NDVI decrease are different. As previously mentioned, an offset of the start and end values can be due to early or delayed farmer activity in the given year. However the period of gradual decline of high NDVI values after its maximum (ΔGreen), associated with the period of gradual decline of green vegetation is anyhow much shorter for the barley than the wheat, due to the faster ripening of the former comparing to latter. Thus, the key candidate marker to discriminate between

these two crops (relevant in the context of greening and VCS schemes) is the period of presence of green vegetation after reaching its maximum (ΔGreen). The values for the parameter "period of occurrence" would be sufficiently different to allow a reliable discrimination of these crops present in the particular region, even before the period of senescence and subsequent harvest.

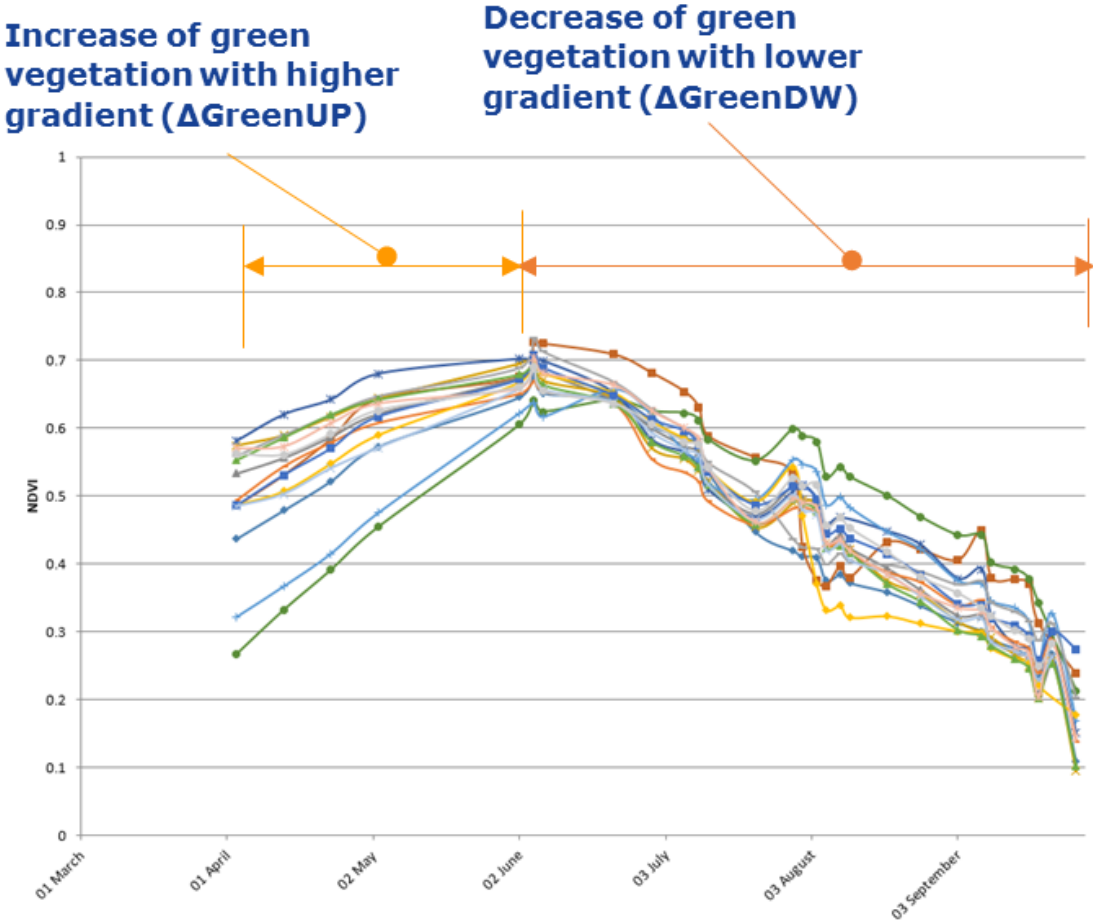
4.2.3 Markers, parameters and scenarios

As previously mentioned, the depiction of the events associated with a given scenario would require the use of particular markers. The scenarios that are expected to occur on agricultural land can be grouped in two generic types:

1. these exerted on arable land and related to annual crops and
2. these exerted on permanent crops and permanent grassland, related to perennial/permanent crops.

In order to understand the integral difference between these two type of scenarios, one must understand the complex interaction between land cover (biophysical phenomenon present on the land) and land use (activity of the farmer exerted on that land). On one hand the land cover is the easiest detectable indicator of human interventions on the land, but on the other, it is the main feature constraining the use of that land.

Figure 11. Temporal NDVI profiles of natural permanent grassland. Markers involved in the monitoring of the scenario are not related to a particular annual activity, but rather aim to confirm the persistence of the agricultural character of the land cover.



Following that logic, it becomes clear that by definition the arable land is a type of land cover that allows and requires the conduction of annual agricultural activities (interventions) that in majority leave notable "traces" on the land. Since these "traces" can

be depicted by different markers, the scenarios related to annual crops would imply the presence of particular markers indicating change of the state of the land phenomenon.

Contrary to that, by definition permanent crop and permanent grassland are types of land cover that constraint at certain extent the annual activities to only those that have impact in longer multi-annual term. This means that farming activities exerted in a single year might not leave notable "traces" on the land (Figure 11). Their impact will be largely manifested through the preservation of the agricultural character of the land cover in the following years.

In this case the scenarios would mostly imply absence of markers indicating notable change of the state of the land phenomenon. An occurrence of particular markers might indicate instead a change of the agricultural character of the land, which could lead to a non-compliance. Such "non-CAP" scenarios could be:

- abandonment: detectable through the use of (multi-annual) non-compliance rules' marker indicating a gradual multi-annual increase of woody vegetation,
- construction and building-up: detectable through the use of (annual) non-compliance rules' marker indicating an abrupt presence of artificial sealed surface.

The occurrence of these two scenarios would require an interaction with the farmer and require priority attention in the LPIS update processes. Where undue payment has been made to the farmer, unduly paid amounts have to be recovered.

4.3 Feature of interest

In principle, the feature of interest is defined during the initial (preparatory) phase of the parcel monitoring, on the basis of the collected farm declarations and the information from the LPIS. By default, the FOI should correspond to the individual agricultural parcel. However, adjacent agricultural parcels declared with same crop and land use (even not necessarily declared by same farmer), can be aggregated into a single FOI.

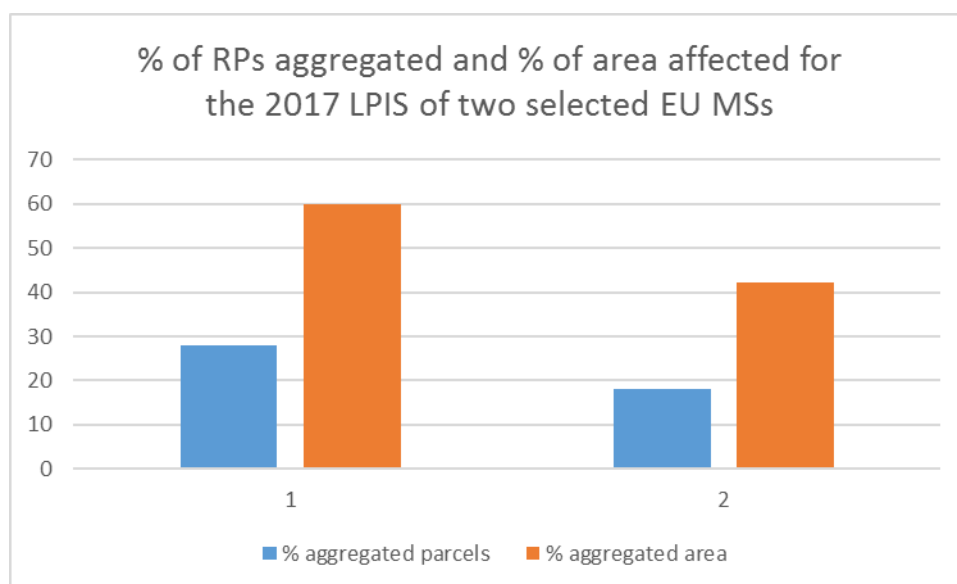
Aggregation of the same crop cover/use expands the original agricultural parcel towards the extent of the next visible crop, land cover or land use limits matching the smallest contiguous cluster of adjacent parcels declared. By default, the extension should be capped to the boundaries of the declared parcel or reference parcel. However there might be exceptions for particular LPIS implementations e.g. agricultural parcel.

Certainly, the presence of linear landscape or non-agricultural features used as boundaries between neighbouring agricultural parcels in the parcel aggregates would introduce "noise" in some of the markers applied on the FOI. In this respect, it is important to take into account all information available in the IACS on the location and nature of these features (EFA layer, spatial data on retention of landscape features, buffer strips, etc.).

EU MS might benefit from the results of previous LPIS QA (RP aggregation) experiences and the results from the OTSC, to assess how many "parcel aggregations" might be possible and how much area would be involved.

The concept of Land Under Inspection (LUI) used in the LPIS QA is very close to the concept of the FOI, since both were designed to overcome the constraints preventing a complete inspection of the unit of management (represented by either the AP or the RP). The review of the 2017 ETS results of those EU Member States that applied RP aggregation revealed the substantial gain with respect to the possible optimization of the number of parcels under inspection.

Figure 12. Estimate of the AP to FOI relationship impact for two selected Member States based on LPIS QA observations.



There might be cases, where instead of aggregation, a subdivision of the agricultural parcel on smaller units is needed. This can be a typical case for large parcels with permanent grassland, where different and well visible management practices occur.

Once the FOI is detected in the initial phases, the “hypothesis” of its validity is checked during the monitoring. Each FOI undergoes a verification of the validation scenario through a set of specific markers aimed to detect unexpected “noise” or variability within the FOI. The outcome of this verification results in re-definition of the FOI in consultation with the most up-to-date information provided by the farmer.

Based on all said above, there will be two “moments” in the monitoring process (see Figure 13), where the creation of the feature of interest would be required:

1. **At the initial stage of data preparation** before the start of the monitoring (process A.3 in Figure 7), when the information provided by the farmers is assessed and cross-checked with LPIS and other third-party data. Adjacent parcels declared on areas (by the same or different farmers) under common grasslands and large permanent crop expanses could be aggregated to form larger FOI. Under certain conditions, adjacent parcels declared on arable land that share the same crop or agricultural activity can be aggregated as well.

In such case, the FOI creation workflow could comprise the following steps:

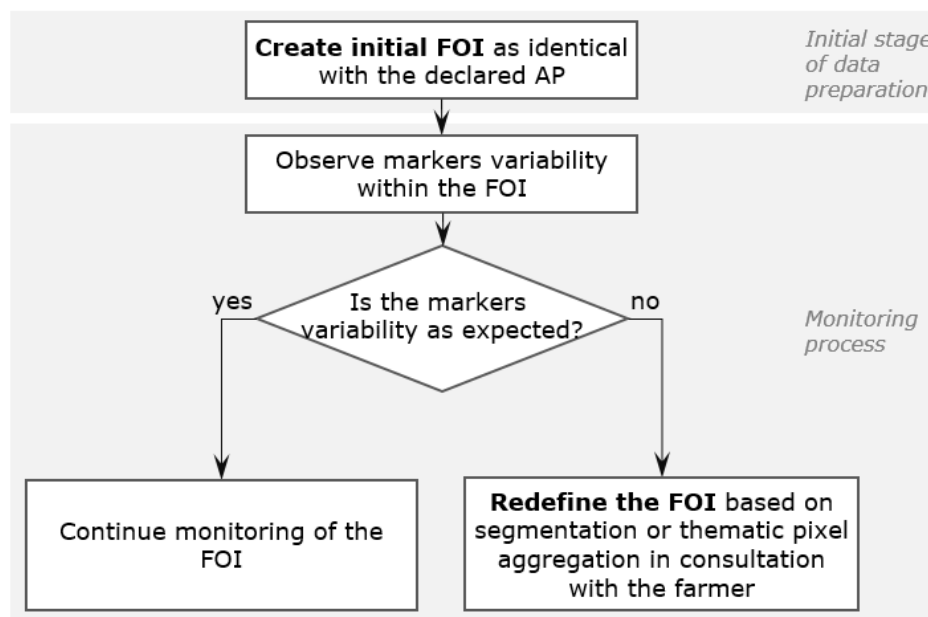
- Take the farmer declaration (GSAA) and generate initial FOIs identical to the individual declared parcels,
- Check the declared land use for each individual FOI and the correspondent agricultural land cover from the LPIS,
- Check the declaration for single crop within the FOI, e.g. horticulture will have heterogeneous crop pattern,
- Check whether adjacent FOIs have the same crop/land use,
- Check the size of FOIs,
- Check for any elements in the LPIS data preventing the FOIs to be aggregated, i.e. reference parcels (one farmer), roads, ditches, EFA elements, etc,
- Check for other information from the declaration or national rules preventing the FOIs to be aggregated, i.e. GEAC or SMA requirements, Natura 2000 object, etc,

- Based on the outcomes of the analysis, merge whenever possible:
 - Adjacent FOIs located on common permanent grassland and permanent crop,
 - Adjacent FOIs of size below a given threshold, located on arable land and declared with the same crop/land use.
2. **During the monitoring process** (process A.6 in Figure 7) when the information from the Sentinel data feed reveals a mismatch between the initially defined FOI and the actual unit of management present on the ground. A new FOI could be generated based on image segmentation (or thematic pixel aggregation) of the image stacks. A correct and unambiguous relation must be established between the new and the old FOIs.

The FOI creation workflow for the second case could comprise the following steps:

- Check on-the-fly (on the basis of the marker parameters), whether the 1-1 cardinality between the FOI and the true unit of management present on the ground (and depicted in the Sentinel data) is respected.
- If not, perform analysis (segmentation or thematic pixel aggregation) and generate a new FOI if needed, taking into account all the possible constraints from LPIS or third party data. If needed, consult with the farmer on the nature and reason for the observed change (e.g. erroneous declaration or unexpected change after declaration, e.g. due to bad weather event).

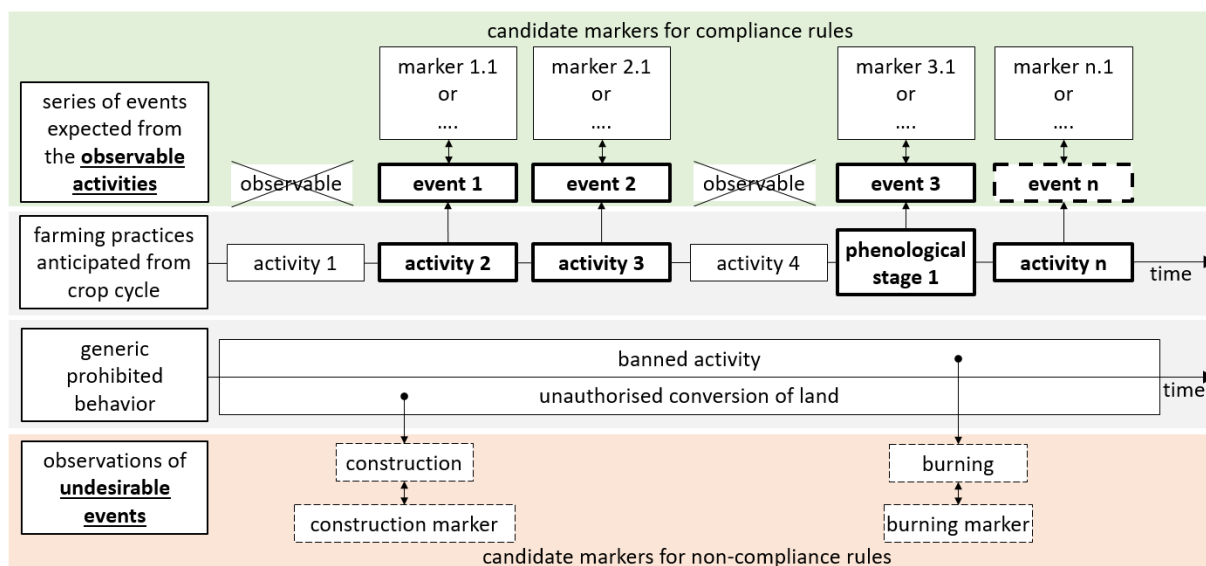
Figure 13. Creation of the FOIs during the monitoring process.



4.4 Scenario

A scenario must be composed of a series of events that are expected to occur for the specific parcel/FOI (i.e. based on its declared crop). The scenario must depict the life cycle of the declared crop with expected and measurable/observable events (see Figure 14). Farmer activities (e.g. pesticide spray) that cannot be detected in Sentinel data (or equivalent) must not have any counter-part events and thus must not contribute to the scenario.

Figure 14. Schematic temporal representation of the scenario with its counter-part anticipated farming practices. Activities that are not observable do not contribute to the scenario. Each of the events must be accompanied with at least one marker. In this schema, secondary events are represented with dashed boxes.



At least one marker must be assigned to each of the events in the scenario. If possible, more than one marker should be assigned in order to:

- Increase the chances to detect the event with at least one of the assigned markers;
- Increase the confidence of the detection and minimize the probability of miss-detection of the event by multiplying independent sources of evidence (e.g. mixing Sentinel 1 and Sentinel 2 markers).

Events may also be ranked (e.g. mandatory vs. secondary) depending on the importance of their respective activities to characterise the crop cycle and/or the farming activities. For instance, a scenario on an arable crop is mostly characterised by a bare soil event (i.e. ploughing activity) followed by a presence of intensive vegetation increase (i.e. the growing period). The event of removal of the vegetation (i.e. harvesting activity) might be comparatively less important for the arable crop characterization. This categorization of events can help defining a holistic strategy of the monitoring. For instance, failing to detect a mandatory event could trigger the request of alternative evidence sources (e.g. geotagged photo).

When relevant, a scenario may also contain one or more non-compliance events. A non-compliance event is an event that should not be seen on the specific parcel/FOI if the crop is assumed to be correctly declared, e.g. construction or burning should not take place on agricultural land. As for regular events, at least one marker must be assigned for each of the non-compliance events. For instance, no marker to detect bare soil should be seen on a protected permanent grassland scenario.

5 Example and prototype

5.1 Case study

The purpose of the case study is to validate the conceptual elements of signal, marker, feature of interest, scenario and lane rules in the context of automatic processing.

For this purpose, several true declarations were investigated. Eventually one was selected where the parcels showed particular or challenging behaviour. Indeed, whereas standard behaviour would imply the detection of compliance markers only, the prototype should also show that it is able to pick up non-compliance markers.

The selected application was then reduced to only three parcels to ensure that the observed behaviour was indeed relevant for the eligibility assessment of the various schemes.

The result of these operations is therefore that a hypothetical farm was created. Although it is based on true parcels from a true application, the assessment itself is not a true case and no privacy or financial aspects can be drawn from it.

5.1.1 Declaration data

The hypothetical holding declared three adjacent crops via the GSAA polygons as summarised in Table 2.

Table 2. A hypothetical holding declaration.

RP ID	AP	Crop	RP -LC	Area [ha]	EFA	EFA Type	Period
41829615	1	winter wheat	arable land	2.92	Y	Green cover	16 Oct - 1 Apr
41829614	2	winter wheat	arable land	15.98	N		
41829613	3	winter barley	arable land	3.01	N		
			total area:	21.91			

The location of these GSAA polygons is illustrated in Figure 15.

Figure 15. Three geospatial aid application (GSAA) of the prototype farm against a concurrent aerial photography background.



5.1.2 Applicable scenarios

With the arable land area of 21.91ha, the hypothetical crop is subject to the greening measures of crop diversification (dominant crop cannot exceed 75%) and ecological focus area of at least 5%. The declaration addresses these requirements by indicating one agricultural parcel (AP1) that would be followed by a green cover crop.

To be admissible as a green cover crop, the local requirements specify that it has to be ploughed under by the 15th of April of the following year.

The declaration implies three different scenarios relevant for claim year 2016 (Table 3): two of the main crops (winter barley and winter wheat) and one of a secondary crop (green cover). Winter wheat and winter barley have a very similar phenology and are notoriously difficult to discriminate by remote sensing on national scale. However, at holding scale, the harvest of barley predates that of the wheat by two weeks due to its earlier maturing.

Green cover crops can have a wide variety of phenology, but what defines them is the presence of vegetation during the winter months, followed by the ploughing before April 15th, well ahead of the harvest.

The resulting three scenarios can be described solely based on markers operating on the Sentinel 2 NDVI signal, making it rather easy to portray and discuss. However, note that in practice, even better detection and discrimination will be possible by choosing marker operating on other signals.

Table 3. The three scenarios relevant for the prototype farm. The ochre cells link to agricultural practices (scenarios), the blue cells relate to remote sensing markers (signal and behaviour), the green cells represent the calendar for the area.

Scenario	Activity	Observed ?	Event	Signal	ds/dt	Day of year	Parameter
WWheat	ploughing	y	bare soil	NDVI	<0.2	213-90	
	seeding	y	crop	NDVI	>0.5	135-170	
	sprinkling	n					
	harvesting	y	vegetation removal	NDVI	0.5> - <0.2	171-212	
land use homogeneity	-	y	vegetation homogeneity	avgNDVI/stdevNDVI	>5	290_2015 - 200_2016	If goes < 5 then should be >5 within 20 days
WWcover	ploughing	y	bare soil	NDVI	<0.2	213-274	
	seeding	y	crop	NDVI	>0.5	1-91	
	sprinkling	n					
	ploughing	Y	bare soil	NDVI	0.5> - <0.2	91-95	< April 15
Land use homogeneity	-	Y	vegetation homogeneity	avgNDVI/stdevNDVI	>5	290_2015 - 200_2016	If goes < 5 then should be >5 within 20 days
WBarley	ploughing	y	bare soil	NDVI	<0.2	213-90	
	seeding	y	crop	NDVI	>0.5	135-170	
	sprinkling	n					
	harvesting	y	vegetation removal	NDVI@Δt	0.5> - <0.2	156-198	Harvest date of the WW and WB differs of >15d
land use homogeneity	-	y	vegetation homogeneity	avgNDVI/stdevNDVI	>5	290_2015 - 200_2016	If goes < 5 then should be >5 within 20 days

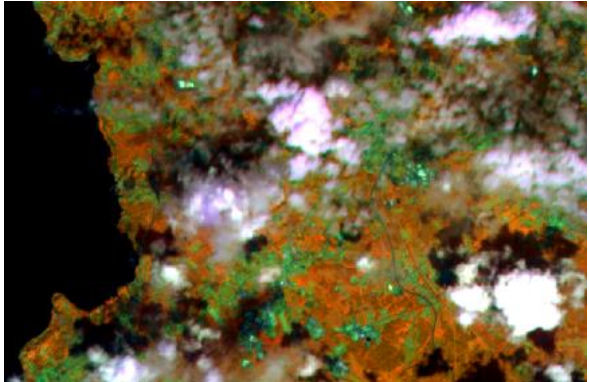
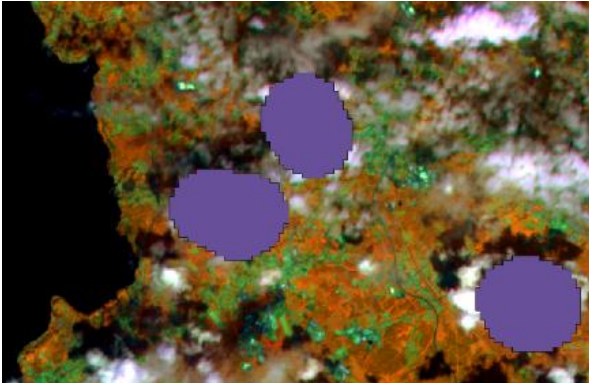
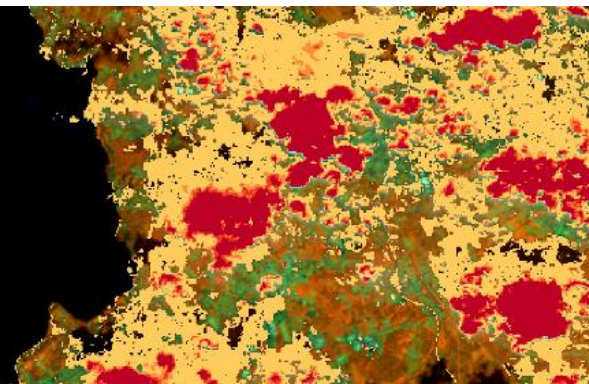
5.1.3 Data pre-processing

5.1.3.1 Detection of clouds and cloud shadows

In time series analysis it is very important to reduce noise in the data. In case, for instance, of deriving vegetation index temporal profiles from Sentinel-2 images decreasing noise introduced by geometric inaccuracy, clouds and cloud shadows is crucial. Section 2.3.2 of the document by [Devos et al., 2017](#) has already touched upon the importance of using pre-defined cloud and haze masks.

In order to exclude cloud and cloud shadows from statistics calculated for the APs/FOIs it is recommended to use the cloud and cloud shadow mask included in [Level-2A](#) products (enhanced when compared to the cloud and cloud shadows mask provided with [Level-1C](#) product). Difference in both cloud and cloud shadows masks are presented in Figure 16.

Figure 16. Comparison of cloud masks in Sentinel-2 Level-1C and Level-2A images produced by ESA and available for download at the [Copernicus Open Access Hub](#).

Product	Example
Sentinel-2A image acquired on 26 June 2017	
Cloud (opaque and cirrus) mask (purple) provided with the Level-1C product	
Cloud and cloud shadow mask provided with the Level-2A product Legend: Probability (%) of each pixel being cloud/shadow <ul style="list-style-type: none"> 0.1 – 46.5 46.6 – 69.3 69.4 – 92.1 > 92.2 	

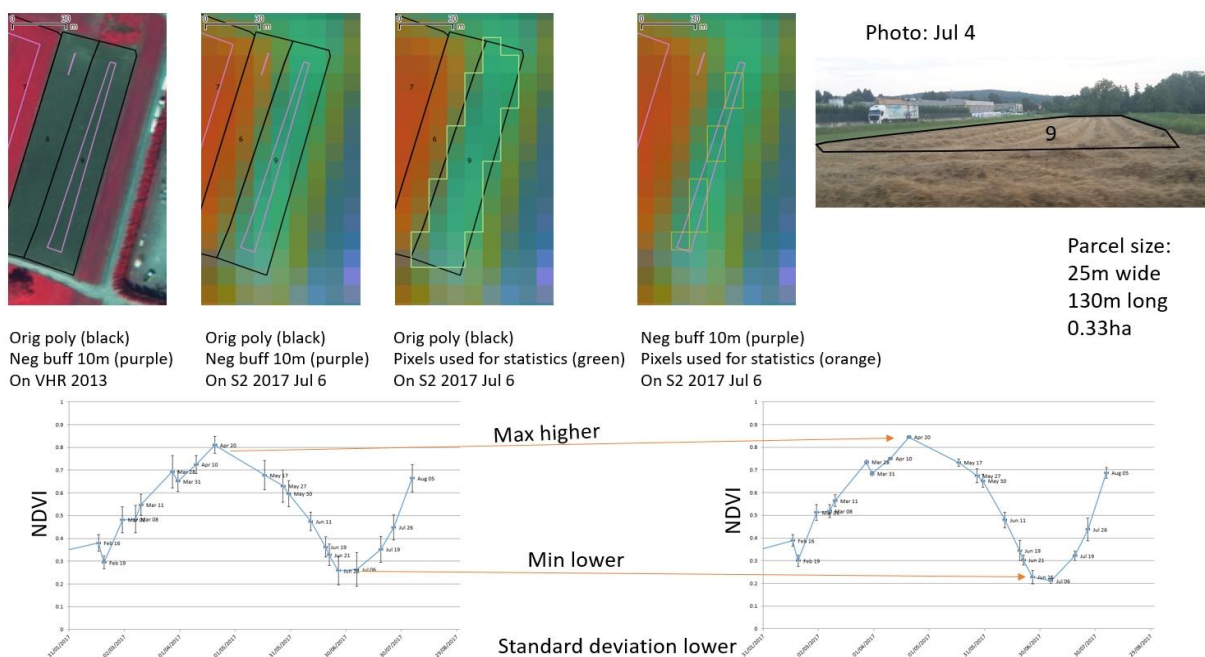
Data noise detection can be further improved by including metadata and meteorological data at the date pre-processing stage. The availability of concurrent Sentinel 1 microwave imagery can facilitate the detection of noisy captures since snow and clouds impact on microwave imagery in a completely different manner than they do on the optical data. Correlation analysis between the signal behaviour in the optical and microwave images will be able to provide conclusive evidence of most meteorological phenomena.

5.1.3.2 Removing border effects on area of interest

When performing analyses where vectors representing agricultural parcels are involved (in contrast to analyses made per FOI created based on segmentation or thematic pixel aggregation; see further section 4.3), applying an inner buffer (removing a 1 or 2 pixels from the agricultural parcel's perimeter) will ensure that only 'purer' signal/information from the in-field is analysed. The buffer indeed holds pixel values that could be subject to spatial displacement (in fact representing the neighbouring parcel or non-agricultural land) or be influenced by the presence of physical boundary features (hedges, ditches, tree lines). These pixels can introduce bias in the calculation of the image statistics within the parcel.

The example below shows that, although the number of pixels available for calculation of the markers is reduced after application of the buffer, this leads to higher maxima, lower minima and lower standard deviation, in other words to a better discriminative power of the signal.

Figure 17. Comparison of the NDVI profile of a complete parcel and of its central part only.



5.1.4 Processing

With the straightforward NDVI-only based scenarios presented in section 5.1.2, we can present the parcels behaviour over time in a single graph.

Figure 18. NDVI signatures of the three parcels declared in the prototype farm, the vertical bars represent variability within parcel.

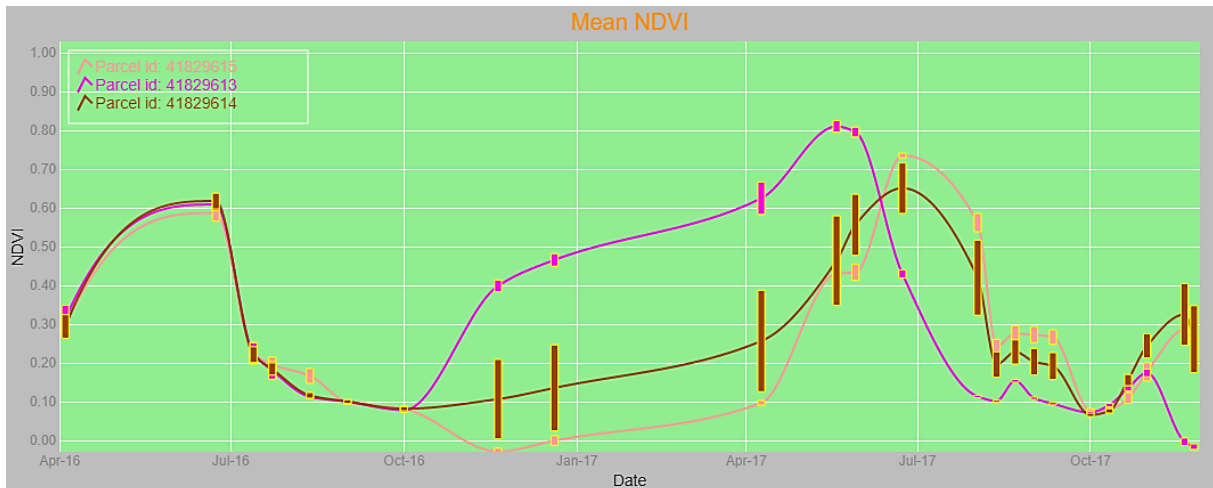
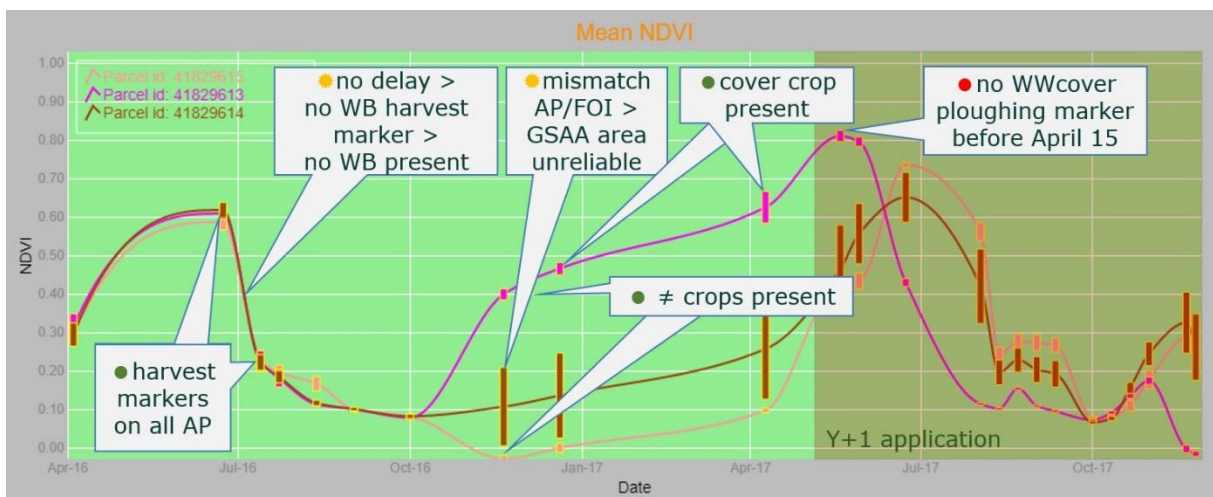


Figure 19. Human interpretation of the events occurring at the declared parcels as expressed in the markers of the 3 applicable scenarios: green light: compliance rule marker, yellow light: inconclusive marker (scenario may need reconsidering); red light: non-compliance rule marker.



The graph and markers allow to make a complete and conclusive decision on the compliance of this prototype holding.

1. All parcels show harvest markers and very low variability, so are eligible for direct aid. (conclusive decision on one lane).
2. However, all harvest markers appear at exactly the same date indicating that only one single main crop is present (either wheat or barley, we assume it is wheat as this is the largest declaration). This single main crop is not complying with the crop diversification requirement.
3. A winter cover is found sown on parcel AP3 (marked in purple) and on a part of AP2 (marked in brown in Figure 15). The high standard deviation of the NDVI signal (starting in December) in parcel AP2 indicates that the declared area cannot be relied upon. Therefore new FOIs were derived using multi-temporal segmentation of Sentinel 2 pixel intensity (Figure 20) providing rough area estimates (Table 4). These estimated areas indicate that the holding could still be compliant with the crop diversification and ecological focus areas.
 - CD: largest crop must be < 16.43ha (12ha < (3/4 of 21.91ha))
 - EFA: cover FOI must be > 1.1ha (9ha > (5% of 21.91ha))

4. It is clear that winter cover is not removed as evidenced by the absence of the ploughing marker on parcel AP3 (marked in purple) by April 15th, but is maturing to yield and cannot longer be considered a winter cover. The assumption of compliance above is proven wrong and the holding is non-compliant for both greening measures (conclusive decision on two lanes).

Figure 20. The declared agricultural parcels (marked in yellow) and the corresponding actual crop cultivation extents revealed by multi-temporal Sentinel 2 intensity segmentation. The new FOIs are marked in pink, brown and purple.



Table 4. Summary of detected crops, the declared agriculture parcel areas and the estimated FOI areas.

AP	detected main crop	AP area [ha]	Est. FOI area [ha]
1	winter wheat	2.92	9
2	winter wheat	15.98	5
3	winter wheat	3.01	7

Note that during the above process, there has been no need to verify anything in the field nor has there been a need to do area measurement. Rough estimate of FOI areas were automatically generated by counting pixels. These estimated areas were sufficient to draw conclusions on compliance on crop shares.

5.2 Prototype implementation

5.2.1 Scope of automation

As previously mentioned the success of monitoring to reduce the burden of controls ultimately depends on the ability of processing the Sentinel data automatically. Hence, the prototype focusses on that automatic processing of data and the ability to detect the critical markers.

The prototype does not yet automate the elaboration of the decision logic per lane itself.

It was programmed in Google Earth Engine and uses the scenarios presented and analysed in section 5.1.2 to look for the markers resulting from the farmer declaration in the applicable time windows. Due to the fact that routines allowing for automated creation of

FOIs were not available in the Google Earth Engine at the time of prototyping, all analyses are performed for the declared agricultural parcels.

5.3 Results

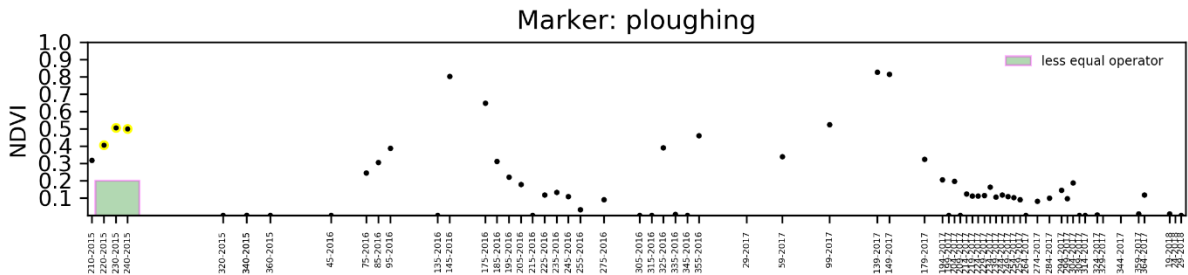
The next three figures show the automatically detected markers for the scenario resulting from the farmer's declaration for each of the three declared agricultural parcels. The green boxes on the signal graphs indicate the time window and the value range within which the compliance markers should be located to confirm the scenario. If that is the case, the NDVI values are circled in green.

It should be noted that in these three compliance scenarios, a missing or invalid compliance marker does not necessarily mean that a non-compliance is detected. In fact such non-compliance rules markers, if relevant, could be explicitly designed (consider these as red boxes).

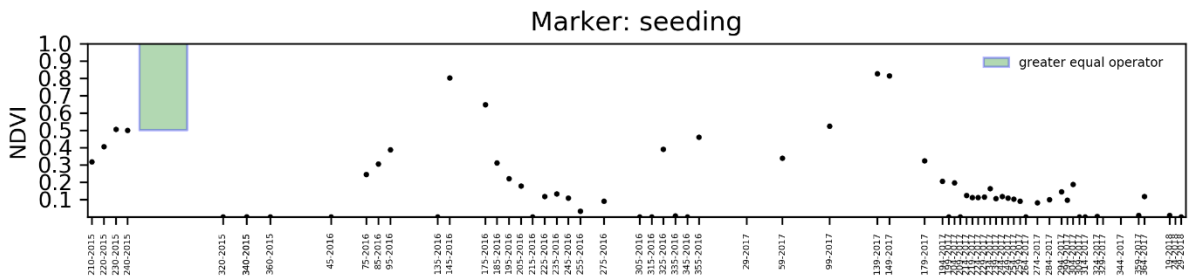
Similarly, when the marker value lies just above or below the green box and the observed dates are just before or after the marker range, MS could, if documented agricultural practice supports it, decide to use the marker to assign a yellow light (consider this as a yellow frame surrounding the green box). In these graphs of the prototype, the absent compliance markers are indicated with a yellow circle, however, no direct consequences are attached to them.

Figure 21. Markers for parcel AP1 (marked pink in previous figures), scenario of Winter Barley.

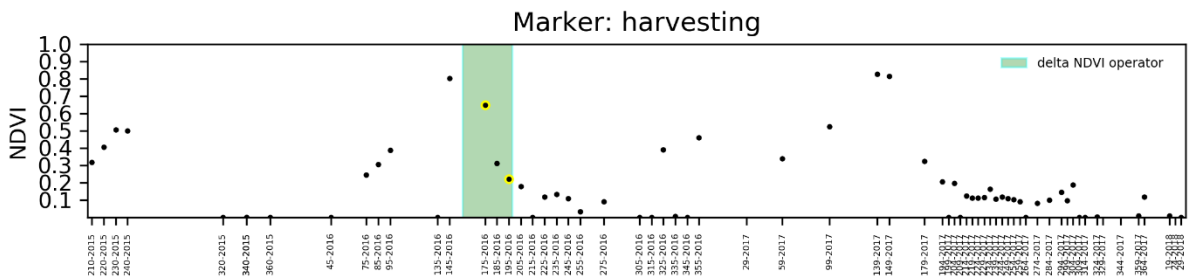
Parcel ID: 41829613, Scenario: Winter Barley



Checking for minimum NDVI threshold value of 0.2 during period 2015-213 to 2015-250
 Minimum value found: 0.406653026506 on day 220-2015
 -> Not confirmed.



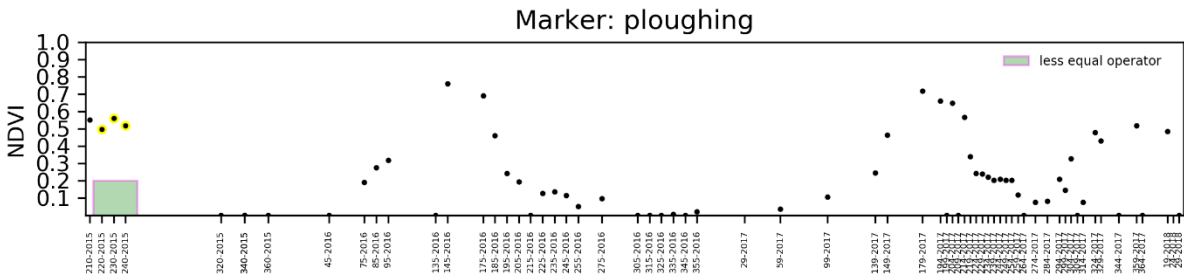
Checking for maximum NDVI threshold value of 0.5 during period 2015-250 to 2015-290
 -> No observations within time window



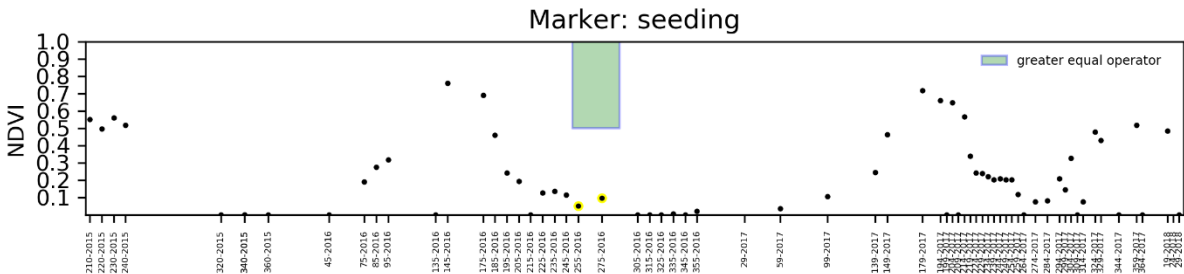
Checking for delta NDVI value of -0.5 during period 2016-156 to 2016-198
 Largest delta NDVI value found: -0.427125826741 (from DOY 175 to 195)
 -> Not confirmed.

Figure 22. Markers for parcel AP2 (marked brown in previous figures), scenario of Winter Wheat.

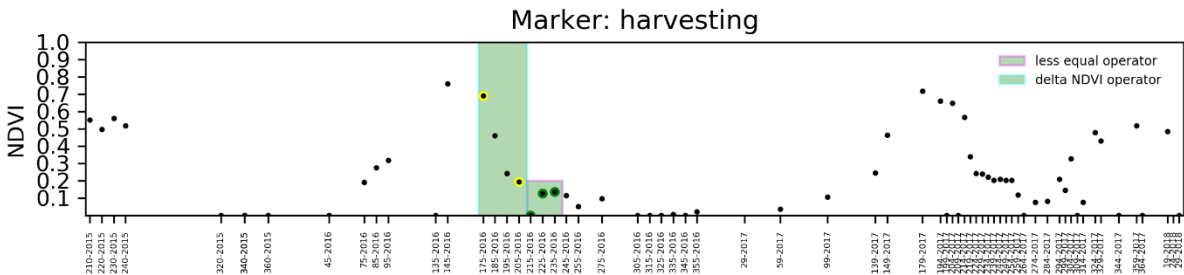
Parcel ID: 41829614, Scenario: Winter Wheat



Checking for minimum NDVI threshold value of 0.2 during period 2015-213 to 2015-250
 Minimum value found: 0.49767837796 on day 220-2015
 --> Not confirmed.



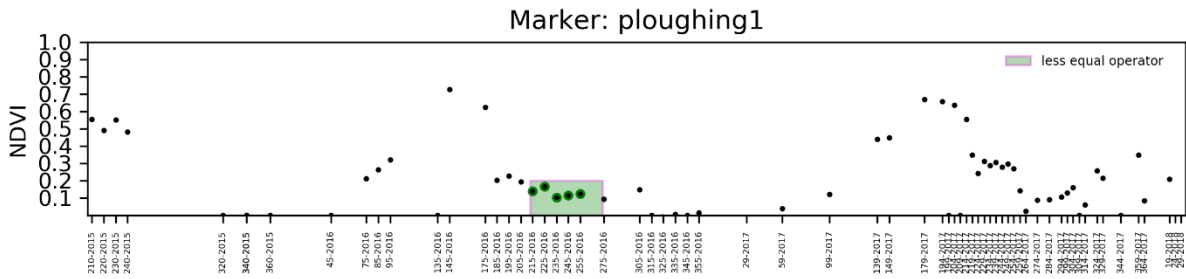
Checking for maximum NDVI threshold value of 0.5 during period 2016-250 to 2016-290
 Maximum value found: 0.0963979135006 on day 275-2016
 --> Not confirmed.



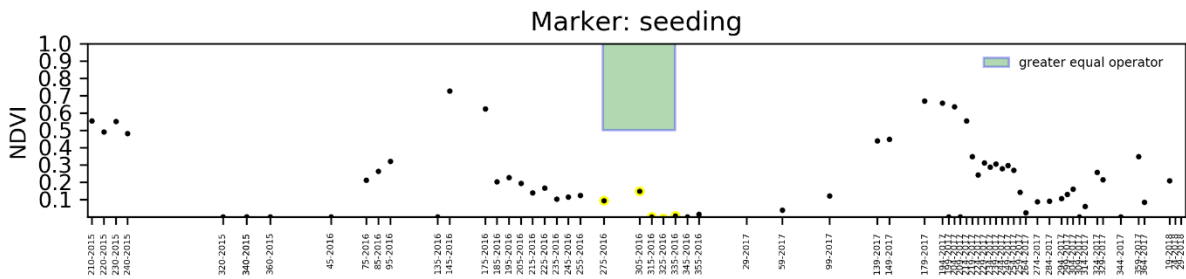
Checking for minimum NDVI threshold value of 0.2 during period 2016-212 to 2016-242
 Minimum value found: 0.125657691117 on day 225-2016
 --> Confirmed.

Checking for delta NDVI value of -0.5 during period 2016-171 to 2016-212
 Largest delta NDVI value found: -0.499007872917 (from DOY 175 to 205)
 --> Confirmed.

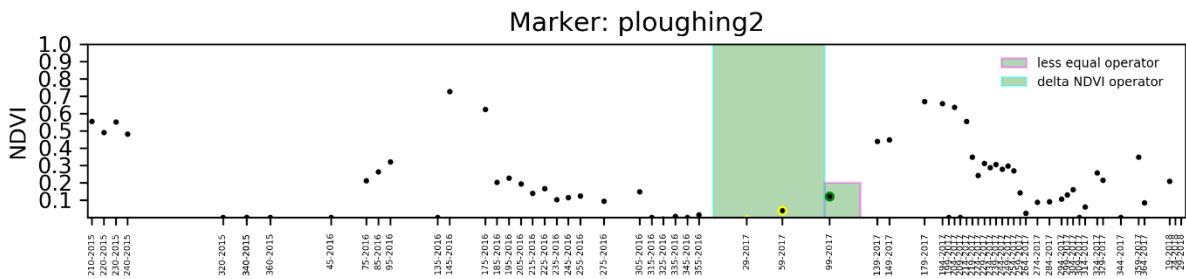
Figure 23. Markers for parcel AP3 (marked purple in previous figures), scenario of Winter Wheat. Parcel ID: 41829615, Scenario: Winter Wheat cover



Checking for minimum NDVI threshold value of 0.2 during period 2016-213 to 2016-274
 Minimum value found: 0.103687684953 on day 235-2016
 --> Confirmed.



Checking for maximum NDVI threshold value of 0.5 during period 2016-274 to 2016-335
 Maximum value found: 0.147472117859 on day 305-2016
 --> Not confirmed.



Checking for minimum NDVI threshold value of 0.2 during period 2017-95 to 2017-125
 Minimum value found: 0.119912614289 on day 99-2017
 --> Confirmed.
 Checking for delta NDVI value of -0.5 during period 2017-1 to 2017-95
 Largest delta NDVI value found: -0.0527851805014 (from DOY 59 to 29)
 --> Not confirmed.

The following table illustrates in a structured way the log output of the automated evaluation of the markers. The computing time for the compliance check for the 3 parcels and 3 markers was 0.015 seconds.

Table 5. Log of the automated evaluation of the markers.

parcel_id	scenario	activity	marker core instance		parameters			marker outcomes		evaluation
			math operator	signal	time window start	time window end	required value	observed value of signal	observed value date	
41829613	Winter Barley	ploughing	less equal	NDVI	213-2015	250-2015	0.2	0.406653026505	220-2015	Not confirmed
41829613	Winter Barley	seeding	less equal	NDVI	250-2015	290-2015	0.5	No observations	None	Not observed
41829613	Winter Barley	harvesting	delta	NDVI	156-2016	198-2016	-0.5	-0.427125826741	175-2016 - 195-2016	Not confirmed
41829614	Winter Wheat	ploughing	less equal	NDVI	213-2015	250-2015	0.2	0.497678377959	220-2015	Not confirmed
41829614	Winter Wheat	seeding	less equal	NDVI	250-2016	290-2016	0.5	0.096397913500	275-2016	Not confirmed
41829614	Winter Wheat	harvesting	less equal	NDVI	212-2016	242-2016	0.2	-0.499007872916	175-2016 - 205-2016	Confirmed
41829614	Winter Wheat	harvesting	delta	NDVI	171-2016	212-2016	-0.5	0.125657691117	225-2016	Confirmed
41829615	Winter Wheat cover	ploughing1	less equal	NDVI	213-2016	274-2016	0.2	0.103687684953	235-2016	Confirmed
41829615	Winter Wheat cover	seeding	less equal	NDVI	274-2016	335-2016	0.5	0.147472117859	305-2016	Not confirmed
41829615	Winter Wheat cover	ploughing2	less equal	NDVI	95-2017	125-2017	0.2	0.119912614289	99-2017	Confirmed
41829615	Winter Wheat cover	ploughing2	delta	NDVI	1-2017	95-2017	-0.5	-0.052785180501	59-2017 - 29-2017	Not confirmed

5.4 Discussion

Section 5.2 presents a series of markers sought for and confirmed on each of the parcel following the scenarios based on farmer declaration.

For this type of farm (this particular combination of declared crops), the lane rules can be expressed in a straightforward manner:

- For BPS/SAPS: for arable crops, the FOI must end with removal/bare soil for all,
- For crop diversification:
 - The largest crop must be < 16.43ha
 - Either wheat (in presence of the barley)
 - Or wheat not followed by green cover,
 - If green cover, the ploughing marker must appear for the green cover by DOY Y+1 <105
- For ecological focus area:
 - The green cover FOI area must be > 1.1ha (9ha > (5% of 21.91ha)
 - The cover FOI ploughing marker must appear DOY Y+1 <105

The above lane rules, supported by the understanding of the agricultural reality of that area, result in very few markers needed for the conclusion:

- the harvest markers on the main crop,
- the detection markers and ploughing markers of the green cover crop.

However, it is clear that the non-compliance verdict at the end is an outcome that is undesirable for both applicant and the administration. There have been two events during the season that casted doubt on the correctness of the declaration and hence scenarios:

- The absence of barley in the main crop.
- The observation that the GSAA did not correctly represent the actual FOI.

Either of these observations could have triggered a warning to the applicant who could have corrected his application or behaviour. Implicitly it would have raised his awareness that the monitoring would anyway detect the final non-compliance if he did not remove the green cover crop in time.

6 Additional sources of information

Title	Description	Responsible Organization	Reference link
SEN4CAP	The SEN4CAP project aims at providing to the European and national stakeholders of the European Common Agricultural Policy (CAP) validated algorithms, products and best practices for agriculture monitoring relevant for the management of the CAP. Special attention will be given to provide evidence how Sentinel-1 and Sentinel-2 derived information can support the modernization and simplification of the CAP in the post 2020 timeframe.	European Space Agency	http://esa-sen4cap.org/
Copernicus Data and Information Access Services (DIAS)	The European Commission (EC) has launched an initiative to develop Copernicus Data and Information Access Services (DIAS) that facilitate access to Copernicus data and information from the Copernicus services. By providing data and information access alongside processing resources, tools and other relevant data, this initiative is expected to boost user uptake, stimulate innovation and the creation of new business models based on Earth Observation data and information.	European Space Agency	http://copernicus.eu/news/upcoming-copernicus-data-and-information-access-services-dias DIAS infrastructures: <ul style="list-style-type: none"> • Onda https://www.onda-dias.eu/cms/ • Creodias https://creodias.eu/ • Mundi https://mundiwebse rvices.com/ • Sobloo https://sobloo.eu/
A Large Scale Pilot to support further integration and digitization of IACS across Europe	The topic is pending upon the final adoption of the Work Programme 2018-2020	European Commission - DG AGRI/DG Connect	https://ec.europa.eu/jrc/sites/jrcsh/files/mahy.pdf
Inventory of Sentinel Pilot projects	A catalogue of the MS projects on Sentinel use for the CAP	European Commission - DG JRC	https://g4cap.jrc.ec.europa.eu/G4CAP/pilot4cap

7 References

Devos W., Fasbender D., Lemoine G., Loudjani P., Milenov P., Wirnhardt C.: Discussion document on the introduction of monitoring to substitute OTSC - Supporting non-paper DS/CDP/2017/03 revising R2017/809, EUR 28830 EN, Publications Office of the European Union, Ispra, 2017, doi: 10.2760/258531.

Devos W., Lemoine G., Milenov P., Fasbender D.: Technical Guidance on the decision to go for substitution of OTSC with checks by monitoring. Document. DS/CDP/2018/17, EUR 29370 EN. Publications Office of the European Union, Ispra, 2018, doi: 10.2760/693101.

Commission Implementing Regulation (EU) No 809/2014 of 17 July 2014 laying down rules for the application of Regulation (EU) No 1306/2013 of the European Parliament and of the Council with regard to the integrated administration and control system, rural development measures and cross compliance. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02014R0809-20180516>

Questions and answers on the provisions of checks by monitoring introduced to Regulation (EU) no 809/2014 by Regulation (EU) no 2018/746. Ares (2018) 4341814-22/08/2018.

8 List of abbreviations

AP	Agricultural parcel
BPS	Basic payment scheme
CAP	Common Agricultural Policy
CwRS	Control with remote sensing
EFA	Ecological focus area
ESPG	Environmentally sensitive permanent grassland
FOI	Feature of interest
GSAA	Geospatial aid application
IACS	Integrated Administration and Control System
IXIT	Implementation extra information for testing
LPIS	Land Parcel Identification System
NDVI	Normalised difference vegetation index
OTSC	On the spot check
RDP	Rural development programme
RP	Reference parcel
VCS	Voluntary couple scheme
YFS	Young farmer scheme

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