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Discussion document on the introduction of monitoring to substitute OTSC

Supporting non-paper DS/CDP/2017/03 revising R2014/809

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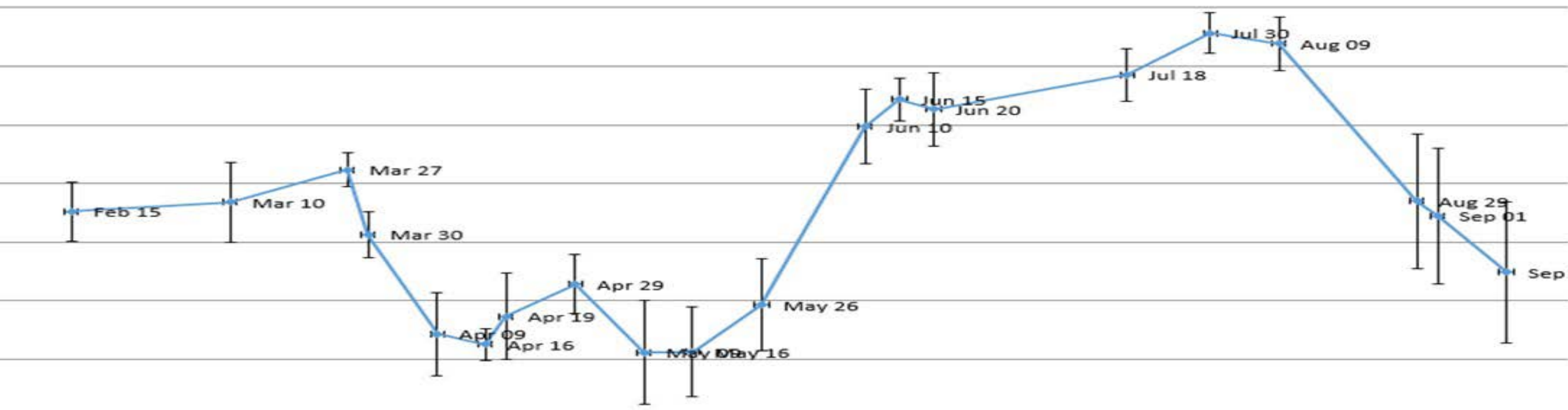

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Abstract

This document describes the main concepts and components of the future 'monitoring approach'. These need to be considered and developed for substituting the current sample approach (on the spot checks) of aid applications or payment claims by a new monitoring system covering all of the applications or claims. The goal is simplification and reduction of the burden of controls. This approach aims for a substantial reduction in the number of field visits.

Such a substitution requires a shift in both thinking and procedures, based upon adopting technology now available. These topics are elaborated in some detail.

An annex provides illustrations, examples, field cases and elaborations of the key topics.

This document constitutes the Commission’s (draft) interpretation of common standards.

1 Elements of a monitoring system for the checks of area-based aid schemes and area-related support measures.

This discussion document builds upon the DG AGRI working document DS/CDP/2017/03 to introduce the possibility for substituting the OTSC by a system of monitoring for checking the fulfilment of land use and land cover related CAP requirements.

For this technical entry, the JRC proposes a working definition of monitoring:

"*A 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*."

From this working definition follows that the main differences with OTSC are that

- the timing of a decision for both payment and recovery depends primarily on the information accumulated through the regular observations on the land instead of operating along a fixed calendar
- there is no sampling of holdings because the whole territory is monitored. However, some scheme or measure related requirements, commitments and other obligations may require explicit field visits and hence sampling.

Furthermore, the approach developed in this document does not necessarily guarantee applicability for all eligibility conditions. Specific eligibility conditions and certain commitments under RDP, corresponding to a large extent to a complex set of agronomic practices, can most likely not be monitored by the proposed framework and MS should develop a specific control mechanism.

Whereas this technical document is primarily based on experiences and practices for the 1st pillar aid schemes and their applications, monitoring can in principle be applicable to 2nd pillar measures and their payment claims too. The suitability of monitoring 2nd pillar measures and claims must be assessed on a case by case base. Meanwhile, the term payment scheme can also be read as support measure and the term aid application can be read as payment claim.

The main part of the document discusses the various technical elements of monitoring; the annex illustrates some of the key aspects of the monitoring approach and provides recommendations in the form of case studies and proofs of concept.

Declaration: the document provides details of the current status of thinking concerning the monitoring approach, and should be viewed as provisional. There are gaps 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.

1.1 What data sources can offer regular observation?

The main sources of free and EU-wide satellite images across all Member State are offered by Europe's **Sentinel 1 (S-1 Radar) and Sentinel 2 (S-2 optical) satellites.** Both complement one another and the nominal revisit of the twin A and B sensors is every 5 days for S-2 and every 6 days for S-1 over the continental territory of EU. Overlapping orbits and ascending/descending combinations of S-1 provide denser coverage locally:

- The optical bands of Sentinel 2 are in general suitable for identifying bare and (partly) vegetated soil, vegetation characteristics, photosynthetic activity (indication of vegetation/crop growth), characteristic phenological states (e.g. flowering, senescence) and non-agricultural land cover (e.g. water, forest, built-up areas)
- The microwave polarized intensity bands of Sentinel 1 are influenced by canopy structure, volume and water content and soil surface roughness and moisture; abrupt changes in backscattering and inter-scene interferometric coherence can often be attributed to a mechanical activity on the land.

As illustrated by Figure 1, both sources are equally important because they address different and often complementary physical and operational aspects.

Processing of these Sentinel data can be improved by combining these with additional imagery (e.g. from free or commercially available HR/HHR satellites) and non-imagery sources.

The secondary source of data comes from the farmer, as he evidences his/her agricultural activity by providing geotagged photos. There should be not need to generally tap into this complementary source. Rather this data capture mechanism should focus on those practices and conditions where the Sentinels alone are known to offer insufficient data to successfully complete the monitoring process.

In addition to these data from the Sentinels and geotagged photos, data from other satellite sources, precision farming tools, third-party government data, etc., can provide valuable input complementing the monitoring process and improving analyses. Monitoring does not exclude a priori any other source of supplementary information. All relevant and reliable data which contribute in a cost-effective way to the end-result (i.e. the full diagnosis of aid application) should be considered.

Recommended MS actions:

1. *R1.1 Familiarise with the Sentinel family of data and related services*
2. *R1.2 Introduce the use of microwave data (radar) according to local conditions*
3. *R1.3 Familiarise with the relevant additional data sources and their use*

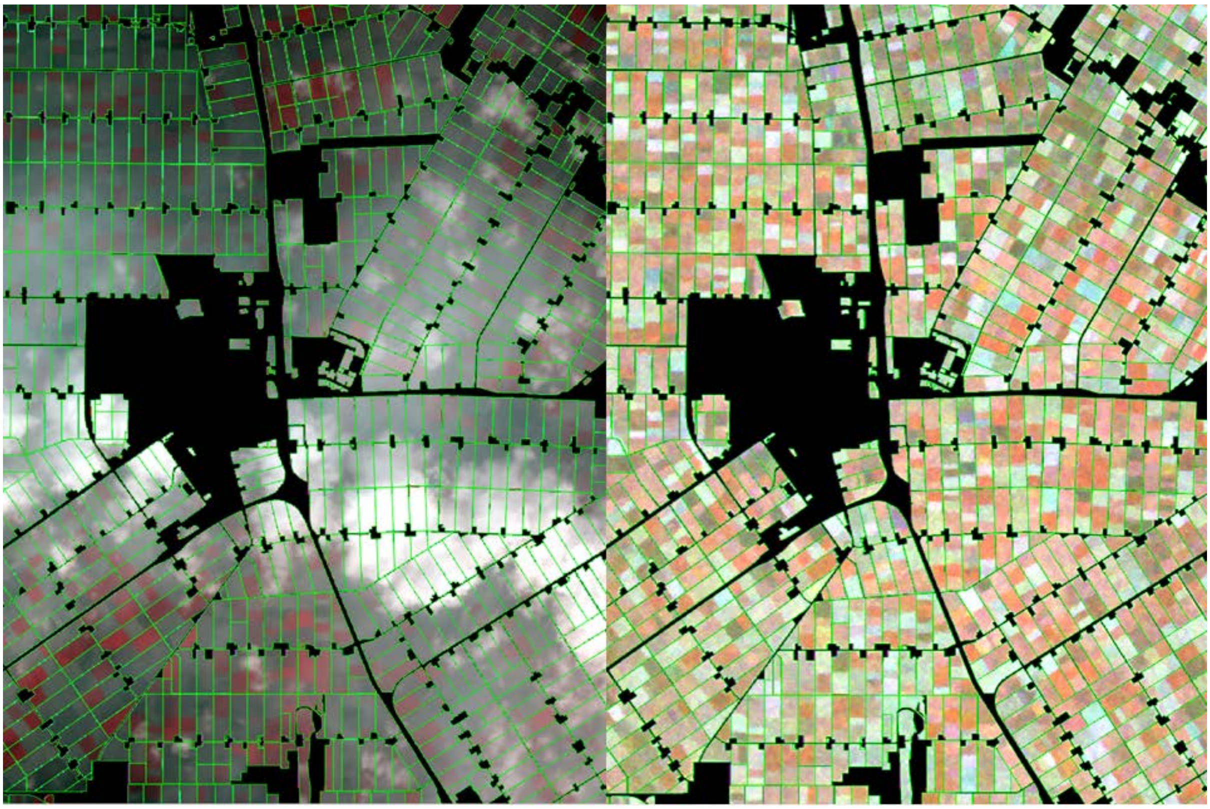


Figure 1: Sentinel 1 (microwave) and Sentinel 2 (optical) images of agricultural parcels

- left: Sentinel 2a, 13 April 2015, false colour composite with abundant clouds
- right: Sentinel 1a, 4th-16th-18th April 2015, VH composite unaffected by clouds

1.2 What is meant by implementing systematic observations?

Whereas the current on the spot check mechanism provides a specific "snapshot" verification of a sample of applications, a monitoring approach requires a complete system rethink. For monitoring, both the procedure (actions and milestones) and the ICT requirements are fundamentally different.

Both classical and CwRS OTSC data capture relies on the ability of trained experts to visually interpret the controlled land and to come up with an eligibility verdict or area measurement. In CwRS, a limited set of image "snapshots" allows the operator (in a computer-assisted environment) to apply the same cognitive logic as if in the field, albeit from a different viewing perspective. In the context of monitoring, which implies a systematic observation of all agricultural areas subject to declaration for direct aids, such human judgement can no longer be directly applied given the vast amounts of data involved and the need to assess every single application. In addition, greening, cross-compliance and some rural development measures would require checks going beyond the mere detection of agricultural area and activity.

To tackle these challenges, systematic monitoring of all farmer declarations and detection of complex land phenomena monitoring requires a different approach to extract the relevant information from the stack of images. This will require automation of mass data handling, in particular in the fields of image and data processing and decision making.

In addition, since monitoring will be primarily based upon the use of EU-wide, free and open Sentinel data, the generation of timely parcel evidence is not per se limited to the control authorities, as in the current OTSC. It should be plausible to consider third party expertise based on transparent analyses of such external sources. In this case, the methodological approach used in the monitoring should ensure sufficient reliability, robustness and reproducibility of the results.

It is unrealistic to expect that every Member State or Paying Agency will be able to fully develop such an automated system for its local needs; rather it will need to customize and reuse basic common components residing in the cloud or available centralized services (such as Copernicus Data and Information Access Services - DIAS). As a consequence, image and application processing and data storage will no longer take place in the local ICT environment but most probably use CAP-community-wide hubs and servers. The bulk of the local processing tasks will deal with the launch of spatial queries and the documentation of results and decisions.

As regards legal aspects, most are not different from the current OTSC provisions: results and methods can be audited or possibly disputed by farmers and the methodological approach used should ensure reliability, robustness and independent reproducibility. In addition, as most of information will be processed through cloud computing, the inclusion of data encryption and protection techniques could be considered to address data privacy and sensitivity issues.

Recommended MS actions:

1. *R2.1 Acquire knowledge on new ICT technologies such as cloud processing and use of standards, and prepare an appropriate transition plan*
2. *R2.2 Participate in or stay informed about one of the several EU level projects on ICT developments for the CAP (e.g. DIAS, Sen4CAP)*

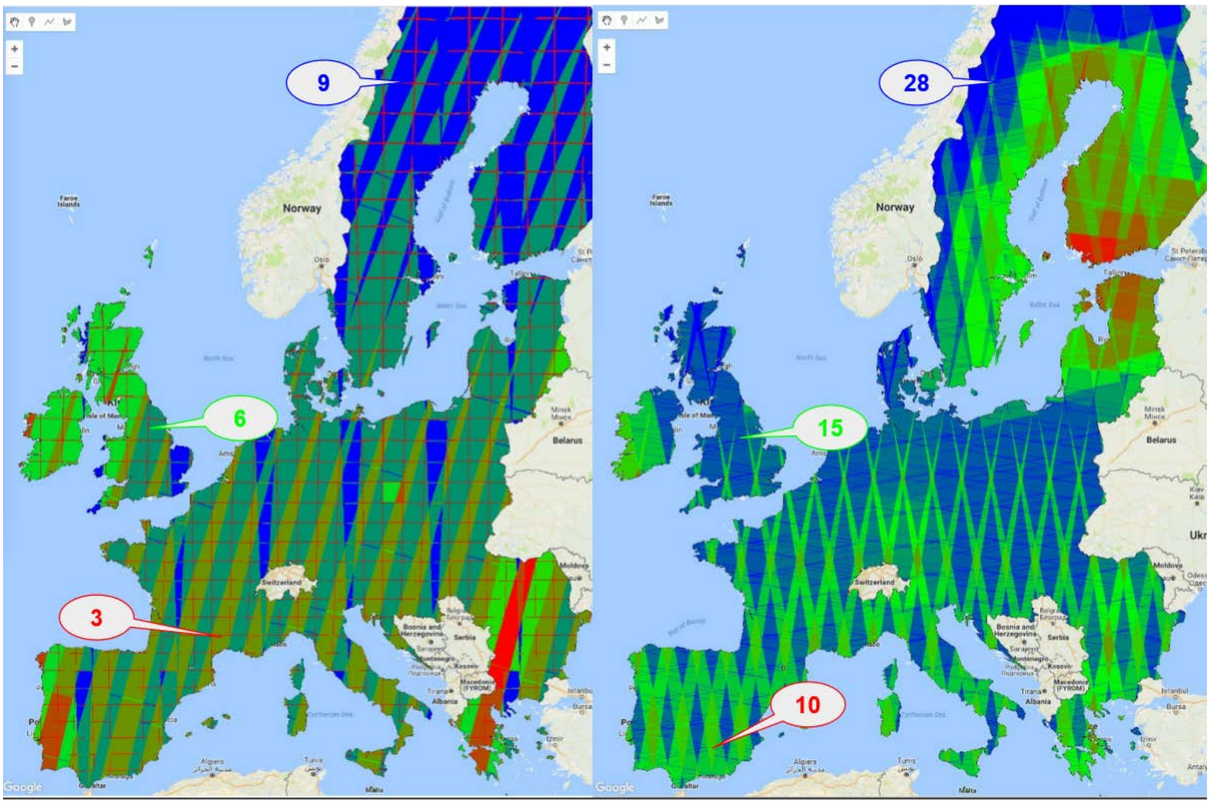


Figure 2: Actual data capture from 3 orbit cycles ((e.g. 30 days for S2, 36 days for S1) over the EU

- left: sentinel 2A optical min = 3; max = 9. Note this image availability will double soon with the availability of Sentinel 2B optical (already launched)
- right: sentinel 1A and 1B microwave: min = 10; max = 28

1.3 What and where to track?

The basis for area-related payment schemes is the land area and the land use as detailed by the declared agricultural parcel. For rural development measures, non-agricultural area can also be declared through a dedicated spatial management unit. So, depending on the scheme and its eligibility conditions, **the behaviour and condition of the agricultural parcel form** the smallest entity that will be tracked.

As the Sentinel data are not suitable for parcel delineation and area measurement in line with the current scale and precision requirements, the precondition of tracking is that the spatial extent (and the precise area value) of the agricultural parcel or unit of management is already reliably known and does not have to be derived from the Sentinel data. Hence, the full introduction of the geospatial aid application (GSAA) in combination with an LPIS with appropriate design and high quality is required (cf. Art. 17 of Regulation (EU) No 809/2014).

Sentinel data provide spatial indications of a parcel or management unit, but this depends upon the local neighbourhood of other declared parcels. There will be cases where the conclusion on the regularity of the application would depend on parcels of small size or with specific shape that cannot be processed by Sentinel data alone. For such cases, monitoring will need to include follow up actions to complete the processing. This is expected to occur in areas where the prevalent parcel size is less than the threshold of 0.5/0.3 ha; JRC analysis of LPIS populations (as a proxy to the agriculture parcel populations) suggests that this could involve some 12 percent of the EU agricultural areas. In these territories, alternative data sources to Sentinel will have to be envisaged, e.g. monitoring with sensors of higher spatial resolution (at a financial cost) or use of geotagged photographs or field inspection, depending on what the applicable legal framework will allow.

Recommended MS actions:

1. *R3.1 Optimize reference parcel and GSAA designs to ensure area management*
2. *R3.2 Investigate to what extent small agricultural parcels or parcels with a particular shape, or landscape-related characteristics require specific workarounds to be able to make conclusions on the payment in question at the level of the holding*

1.4 How to assess eligibility?

1.4.1 A tiered approach

In addition to the GSAA guiding alerts and administrative cross-checks, the monitoring process will aim at ensuring that a declared agricultural parcel complies with the eligibility conditions related to the availability of agriculture area.

The assessment will be tiered along:

- **Area of interest corresponding to the declared one**: In order to be able to conclude on the application, is the declared agricultural parcel/spatial representation of the declared area the true spatial unit of agricultural activity in the field (check the assumption of **spatial homogeneity of the parcel**); If not, can sub-parcels or parcel aggregates be identified for further processing?
- **Correct behaviour on the land**: Is the monitored land "behaving" as the scheme/measure associated with the declared agriculture parcel requires? Can the requested aid be confirmed or rejected based on the crops and activities the monitoring detects? Such observed behaviour is scheme dependent; e.g. in many cases, basic payment requires evidence of an agricultural activity, greening payment might require detection of crop type.
- **Benefit of the doubt**: Is there evidence of a non-compliance impacting on the payment within the period of monitoring? If not, the declaration is accepted as true for the scheme. For example, a permanent crop is considered present even without clear evidence of specific agricultural activity, such as pruning or mulching (depending on the detailed rules applicable in the MS); however, there should be no indication that this permanent crop is abandoned. Note that some schemes (e.g. VCS, greening) will require explicit confirmation of the declaration, the absence of counter-evidence will not offer plausible doubt.
- **Variable timing for the conclusion on the payment to the holding**: Is the monitoring process complete for the application? For each holding and scheme a verdict at dossier level can be made as soon as a sufficient number of parcels, representing a sufficient area have been confirmed. Often it will not be necessary to obtain a conclusive monitoring result for 100% of parcels. For some schemes or commitments (e.g. AEM) it might take a longer time to come up to a conclusion, as a result of the local agricultural situation and practices.
- **Early warning/Prevention of incompliances**: Can the applicant be informed on an imminent non-compliance according to the evidence collected for activities not yet conducted? If so, a reminder-notification (warning alerts) can be sent to farmers,

  "After payment care": monitoring continues to screen any scheme-specific infringements or commitments under RDP that occur later during the season (e.g. permanent grassland ploughed late in autumn); retroactive recovery should be launched upon such detection.

1.4.2 A reductive/channelling aspect

To make the monitoring procedure technically feasible use must be made of both available information as well as the observed behaviour of the declared agricultural parcel (or unit of management).

The former comes from the declaration itself as well as from other IACS registers, and allows understanding the behaviour during the monitoring period. The latter can be derived from automatically detecting a sequence of specific “markers” from the dense time series of S-1 and S-2 observations of parcels.

The assessment of **expected behaviour on the land** by these markers (2nd bullet above) is based on a reductive/channelling approach. At the start of the application year, no parcels and no application are assessed, even as information of the land is present and being gathered. Then, when the declaration makes clear which conditions need to be monitored and when monitoring sources become available, parcels are assigned codes by applying any logic that relates to the observed conditions in relation to a particular scheme/measure compliance. Parcel state can be tracked using a proposed colour-code expressed as 'traffic lights' for each scheme/measure.

1. **Black (no light),** parcel declaration not yet available, still the parcel is taken in scope because it was declared in the previous years and some multiannual commitments might apply. Furthermore, in many cases, legacy information on the unit of land can be relevant for the declaration itself.
2. **White**: parcel declaration available, but no assessment yet available (assessment results of the parcel is relevant for concluding on the compliance with the declared scheme / support measure)
3. **Blinking Yellow/Yellow**: parcel assessed and likely to make the declared scheme / support measure non-compliant due to absence of farmer action (warning alerts to farmer should be sent)
4. **Blinking blue**: expert judgement required: parcel assessed and likely to make the declared scheme / support measure non-compliant, additional information from non-monitoring sources is needed to complement the monitoring
5. **Yellow**: parcel assessed, but insufficient evidence to either explicitly confirm or reject for the declared scheme / support measure because there is no impact on payment.
6. **Green**: parcel assessed, and confirmed as compliant with the conditions of the declared scheme / support measure in question
7. **Red**: parcel assessed, and confirmed as non-compliant with the conditions of the declared scheme / support measure in question

Follow-up action and/or additional information are needed for the 'blinking light' states only.

1.4.3 A targeted aspect

A marker is defined as “something that demonstrates the existence or presence of a particular quality or feature”.

In this context of automated data processing of satellite imagery, “something” translates into an observed continuous state of data values or a change of state of the data values.

Such data values relate to raw data, calibrated data, composite indicators and any combination thereof.

The time series of these values is called “the signal” whereupon the marker is applicable.

Markers directly and solely reflect the state or behaviour of the land. They describe state and changes of the land phenomena, without presumption on particular (CAP-relevant) rules or expectations. Markers can be generically approached.

However, the conditions of a scheme imply the occurrence or absence of practices, changing or preserving the state of the land. These expectations often present a well-defined scenario in which a particular set of markers should occur. The observed sequence of applicable markers then offers a reliable indicator of the occurrence or absence of agricultural activity or agricultural practices. Scenarios are by definition locally dependent.

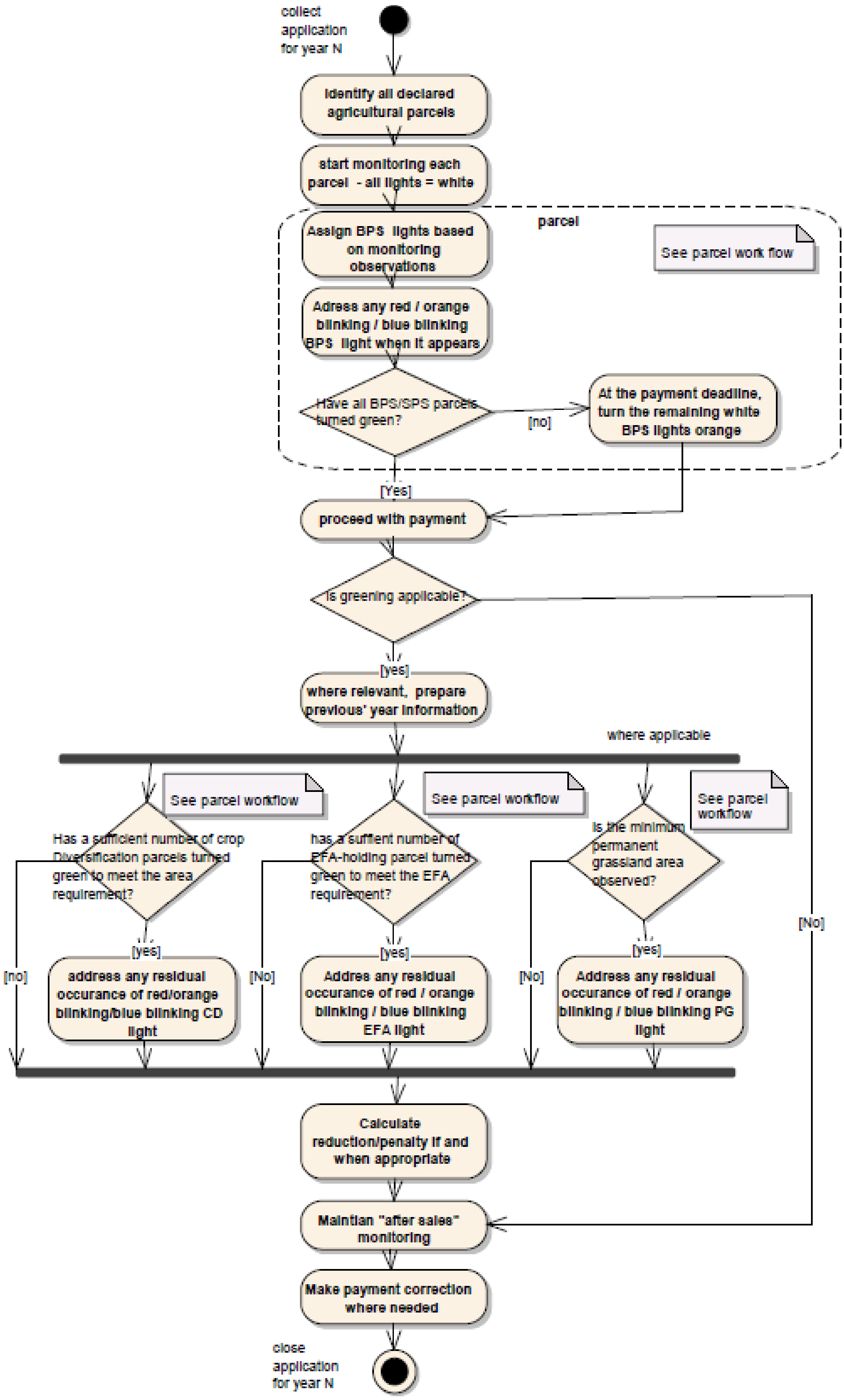
For such scenarios to be more effective, the type of agricultural area or land cover (e.g. permanent grassland) as recorded in the LPIS, will be used to pre-determine the possible agricultural activities. This helps selecting the set of markers expected to detect their presence (e.g. for mowing, not mowing, temporal events). This in turn requires the spatial disambiguation of arable land, permanent grassland and permanent crops in the LPIS.

Recommended MS actions:

1. *R4.1 Review the existing eligibility conditions adopted at national level, and assess whether the monitoring approach described above could be applicable and decide how to proceed.*
2. *R4.2 Design an appropriate workflow based on the tiered approach while considering the reductive and targeted aspects*
3. *R4.3 Identify what key markers would be picked up in the monitored land and what they represent in terms of the underlying agricultural practices*
4. *R4.4 Select which combination of markers and conditions would allow to assign a traffic light status for each declared parcel*
5. *R4.5 Identify which combination of assessed parcels enables to make a verdict on the holding*

1.4.4 A tentative workflow

The tentative workflow below offers a simplified illustration (for payment schemes only) on how these aspects could ensure the reliable processing of each application.



1.5 What is the duration of the monitoring?

Monitoring overcomes the main constraints of the current OTSC concept, where a few limited observations are taken in predefined and fixed acquisition windows. Time series of S-1 and -2 data or other relevant data, allow the continuous and territory-wide temporal capturing of the majority of agronomic phenomena. This enables establishing a more flexible workflow with the possibility to timely collect complementary evidence on the field, and this at lower cost for the organisation and to better benefit of the farmer.

The temporal continuity of monitoring has 2 further advantages:

1. a stack of image information is already available by the time the digital parcel declarations are ready for processing, allowing an immediate start of the parcel diagnosis, possibly to support the declaration process itself, and
2. the generation and analysis of markers can be largely automated and constantly upgraded based on experience from the past years. As monitoring, contrary to the OTSC, is applied to the whole territory all-year round, parcel information and behaviour from previous years can be gathered and directly integrated in the diagnosis.

In general, this continuous and systematic nature of monitoring provides a more consistent setting to integrate [machine] learning approaches as it is relatively straightforward to evaluate newly learned location specific patterns and evaluate how these impact on parcel and area diagnosis. The temporal density of the data series is a pre-condition to monitor specifically timed measures (e.g. grassland mowing, catch crop presence), which is not possible with the classical approach.

Although the monitoring is year-round, its highly automated data processing and the spread of decisions on the various holdings should offer the opportunity to spread dossier diagnosis activities over that calendar year, reducing the peak workload situation observed in the current OTSC processes.

Recommended MS actions:

1. *R5.1 Set up an e-government system to encase the monitoring algorithm and procedures*
2. *R5.2 Identify the value added from connecting parcel and holding information over the years*

1.6 When to trigger follow-up action?

1.6.1 Triggers for follow-up action

When the fulfilment of all scheme requirements of the declaration have been confirmed, it is possible to **proceed with the corresponding payment**
On the contrary, when the scheme requirements of the declaration have in part or wholly been rejected (even after original payment), administrations should **proceed with remedial action** (i.e. recalculation, penalties, recovery, yellow card issuing,...)

For cases intermediate to the two previous ones, i.e. when fulfilment of the scheme requirements is deemed unlikely but cannot be confirmed based on the monitoring data alone, **follow-up actions have to be triggered for applications where the monitoring result would affect the final payment.** If the results of monitoring do not have an impact on payment, then follow-up actions are not necessary.

In the above paragraph, these triggers are indicated by blinking lights.

1.6.2 Types of follow-up action

Different processes and techniques can be considered as follow-up actions. All aim to collect additional data or information to complete the assessment process. Possible activities are:

- An expert CAPI inspection of the considered parcel from available data sources;
- Collecting of an authenticated geotagged photo to provide evidence of the compliance with the requirement;
- The submission of scanned seed labels to evidence a specific type of crop (e.g. Durum wheat) or crop mixture (e.g. mixture as cover crop);
- Consulting other types of imagery (HR, VHR, satellite, aerial, UAV, google earth …);
- Gathering of applicable evidence from third party data sources (stakeholder sourcing)
- An inspection in the field. This follow-up action should be considered only as a 'last resort' option, that is **if** all else fails. The monitoring processing aims to reduce field visits to a very small number to minimise the burden and costs. So, among follow-up actions, field visits should be limited in number and avoided as much as possible.

1.6.3 Preventive action: reduce the need for additional data and information

Because all holdings are monitored, any collection of additional data should be considered while taking into account the cost-effectiveness of the monitoring approach when local policy options are discussed. Addressing this challenge will probably require two ex-ante considerations:

1. A careful implementation of local measures and policy choices focussed on phenomena that can be observed through monitoring in order to reduce the need for additional information.
2. A thorough rethinking of the role of farmer and inspector to make the farmer the main supplier of reliable and current data on his agricultural parcel, relieving the inspector of time consuming field activities.

Recommended MS actions:

1. *R6.1 Decide on the relevance rules for additional data and information collection*
2. *R6.2 Ensure that the preventive actions are implemented.*
3. *R6.3 Set up data catalogues, CAPI instructions and workstations for office processing*
4. *R6.4 Set up simple mechanisms that enable farmers to capture and deliver current field data*
5. *R6.5 Design an appropriate RFV action, considering the logistical constraints and other priorities*

1.7 Quality management of the monitoring approach

Given the importance of the budgets allocated to the area based aid schemes, substituting the existing OTSC mechanism with a newly developed monitoring approach inevitably raises some concern on the effectiveness of the new approach.

It is a key task of the Member States to correctly implement the CAP and to assure the new control mechanism is effective and cost-efficient. The easiest way to provide such assurance is by designing and implementing an appropriate quality policy for the monitoring system. The resulting quality management of the monitoring system is rather straightforward and comparable to any other quality management system. Among other things, it is required to

- Validate the applied monitoring methodologies that lead to the assessment of an application
- Perform quality control tests on the operational procedures and their result
- Launch remedial actions where necessary.

As part of a larger quality policy, these quality management activities should be well documented and quality awareness should a key competence of the staff involved.

To provide assurance to external stakeholders, a quality assurance framework could eventually be set up.

2 ANNEX: Examples, tools and suggestions

This Annex compiles some thoughts, discussion, examples and illustrations that are relevant for one or more of the various ideas and recommendations of the main document. It is divided into two parts: the compilation itself and a register of references to find additional information.

2.1 The concept of markers

Markers can be considered as a unique collection (combination) of property values of a data signal that evidence the existence or presence of a particular continuous state or a change of state of the land phenomenon. As explained above, the “data signal” can be the raw or calibrated DN values of the image time series (reflectance in a given wavelength range, backscattering coefficient) or a composite indicator (vegetation index, SAR coherence). The “shape” of the evolution of the signal intensity over time is the key property that defines a given marker.

Not surprisingly for the monitoring context, markers have an important temporal aspect, and general markers can be described by:

- Optional: pre-conditions (presence/absence of other markers)
- A period of occurrence (earliest and latest date)
- Optional: a minimum or maximum duration
- Conditions on start value
- Condition on end value
- Optional condition on values in between
- Optional post-conditions (presence/absence of other markers)

The figure below provides a graphical illustration of the key temporal aspects (properties) of a marker.

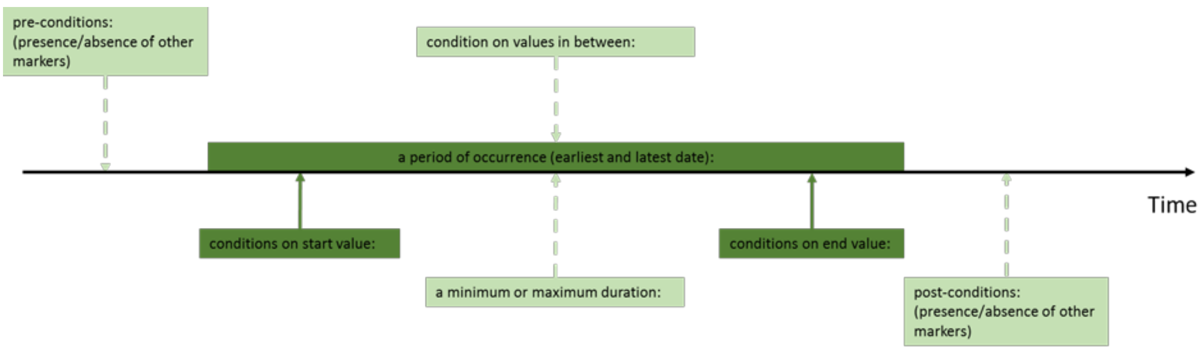


Fig. A11: General concept of a Marker

By default, markers are generic. They relate to the state of land and not the CAP-related rules. However, when they are applied in a particular locally-dependent CAP scenario, they benefit from being “parameterized”. This means that the marker properties and they values (see Fig. A11) need to be defined to adequately reflect the local conditions. This “parametrization” is performed using:

- A priori information (crop calendars, prescriptions for established local practices, farmed application, data from IACS registries)
- Statistical analysis of the image time-series within the population of agriculture parcels/units of management that are in the scope of the particular scenario

The figure below shows possible marker property values for a particular land phenomenon.

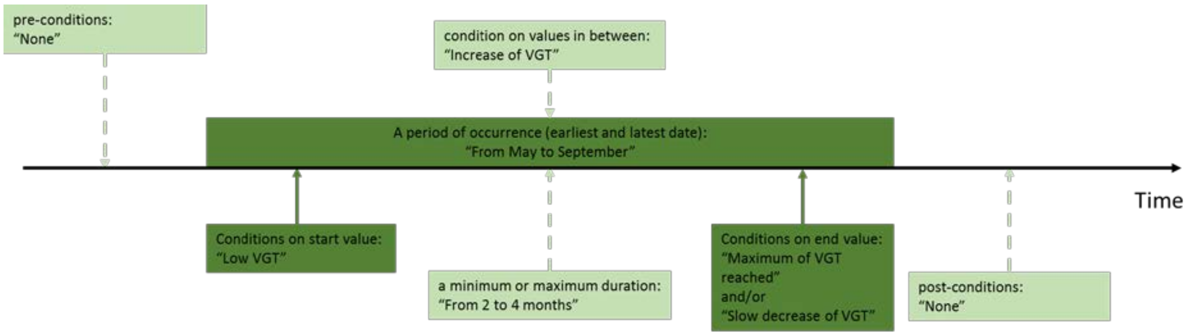


Fig. A12: Example of marker "parametrization" – plant growth

It is also important to understand that the basic feature subject to monitoring is not the image pixel itself, but the agricultural parcel or the unit of management. In our image domain, the marker property values are derived from statistical operators (mean, median, standard deviation and others) on the multitude of image pixels representing the object of monitoring. As a result, the marker property values are "data aggregates" that can be easily related to the physical properties of the land phenomenon, such as material (e.g. vegetation), appearance (herbaceous) and life cycle (temporal behaviour).

The following examples aim to illustrate the selection, parametrization and use of markers in particular scenarios, related to specific agricultural activities or agricultural practices.

2.2 Examples of ‘Markers’

2.2.1 Detection of agricultural practices

2.2.1.1 Grassland mowing

Grassland mowing is a farmer activity occurring regularly on managed grasslands that results in cutting and removal of the upper layer of grass which, after a short period, is able to regrow naturally. From the land cover perspective, this means that for a specific time-period, a substantial amount of herbaceous vegetation is absent from the land. This absence can occur almost instantly. As the roots and stems of the vegetation remain on the land, the surface is not completely bare, but partly covered. The vegetation gradually reappears and usually regains its height and cover, prior to the removal. Since mowing is often performed several times within a given year, the associated removal and regrowth of vegetation can occur more than once.

The presence and absence of vegetation is well represented by the Normalized Vegetation Index (NDVI) alone, which can play a role as a marker in this scenario. NDVI can be easily derived from Sentinel 2 only. Grassland mowing is detected by a characteristic **sharp but shallow drop of NDVI-values (averages) of the agriculture parcels with managed grassland. The drop is followed by a fast recovery**, which can be followed by other drops of the same nature during the following year.

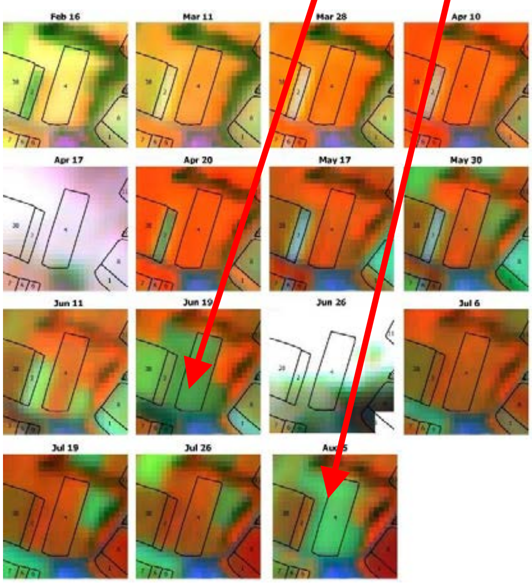
The NDVI temporal profile derived from Sentinel-2 images shows the development of the grassland with 2 **mowing** dates:

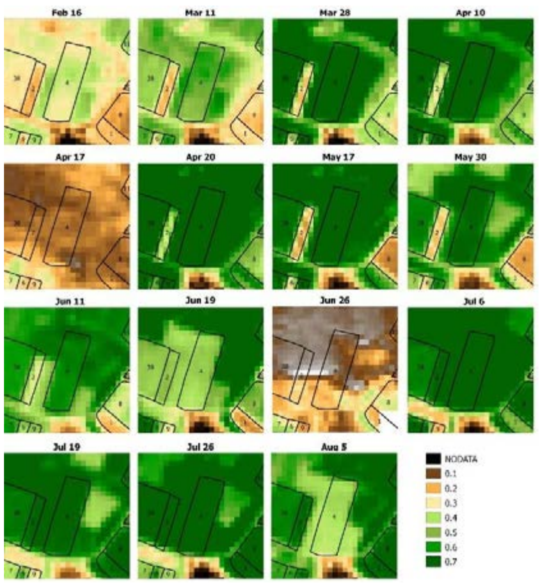
1st mowing date: between 11th June and 19th June

2nd mowing date: between 26th July and 5th August

False colour composite time series (RGB 8,11,4)

NDVI time series





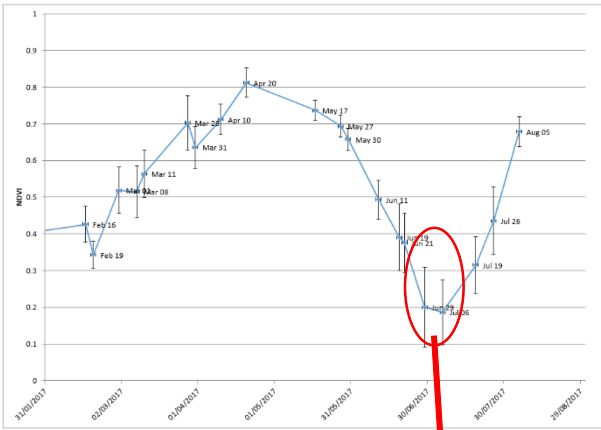
Jun 15 Aug 2

Figure A13: a case of grassland mowing

2.2.1.2 Ploughing of winter cereals stubble

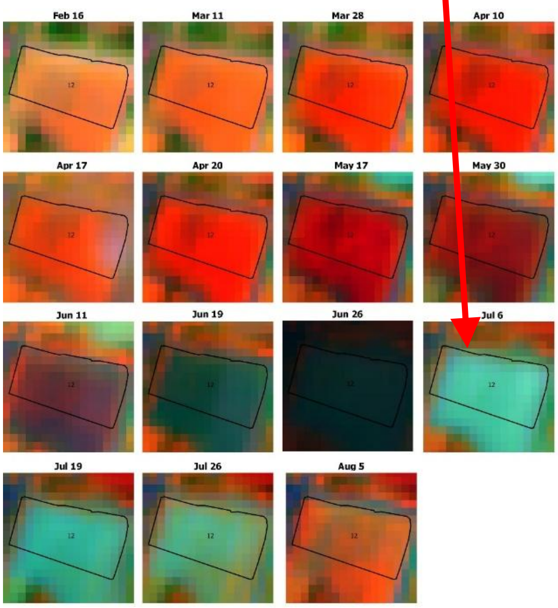
Ploughing of annual winter crops is a farmer activity occurring on arable land that results in turning up of the top layer of the soil for bringing fresh nutrients to the surface, removing of the weeds and preparation of the land for seeding (e.g. late spring crops). This event usually occurs once in a given year. From the land cover perspective, this means that for a specific period, which starts usually end of spring/beginning of summer for the major part of Europe, the soil is completely absent of vegetation. Moreover, due to the turning up of the top soil layer, the surface is marked by long trenches of more fertile and more humid soil. Often the soil is left to dry out, and is then harrowed before planting. The plants of the new crop gradually appear and cover the soil in late summer.

Here, the Normalized Vegetation Index (NDVI) alone, can play again a role as a marker in this scenario. Ploughing can be detected by a **single very deep drop of NDVI-values. The NDVI values stay very low for a while and then start gradually to increase.**

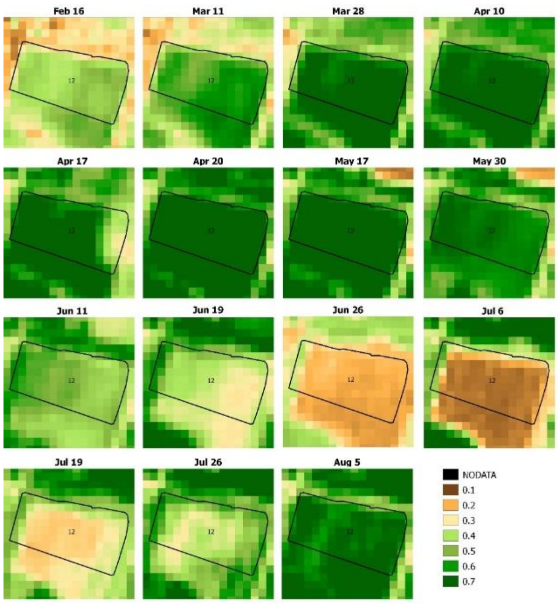


The NDVI temporal profile derived from Sentinel-2 images shows the development of the winter cereals, harvested at the end of June and **ploughed** immediately (preparing the land for maize)

False colour composite time series (RGB 8,11,4)



NDVI time series



Jun 26

Jul 6

Figure A14: a case of ploughing arable land

2.2.1.3 Robust markers in Sentinel-1

Both cases above demonstrate that each mechanical agricultural activity triggers abrupt and manifest changes in the "appearance" of the land within the parcel that are picked up by the monitoring satellites. The above detection cases relied on Sentinel 2 only, but the combination with Sentinel 1 can dramatically increase the sensitivity and robustness of the detection of such manifestations.

The graphs below demonstrate the monitoring "signatures" of agricultural land as picked up by Sentinel 1's microwave bands. The all-weather capacity of the microwave sensor ensures a predictable data capture, in contrast to the cloud free requirement of the Sentinel 2 cases above.

The 3 graphs show the monitoring results of known wheat fields in the Netherlands, France and Italy over the period January 1st - September 1st. This period yielded in 120 observations (images), i.e. on average every 2 days.

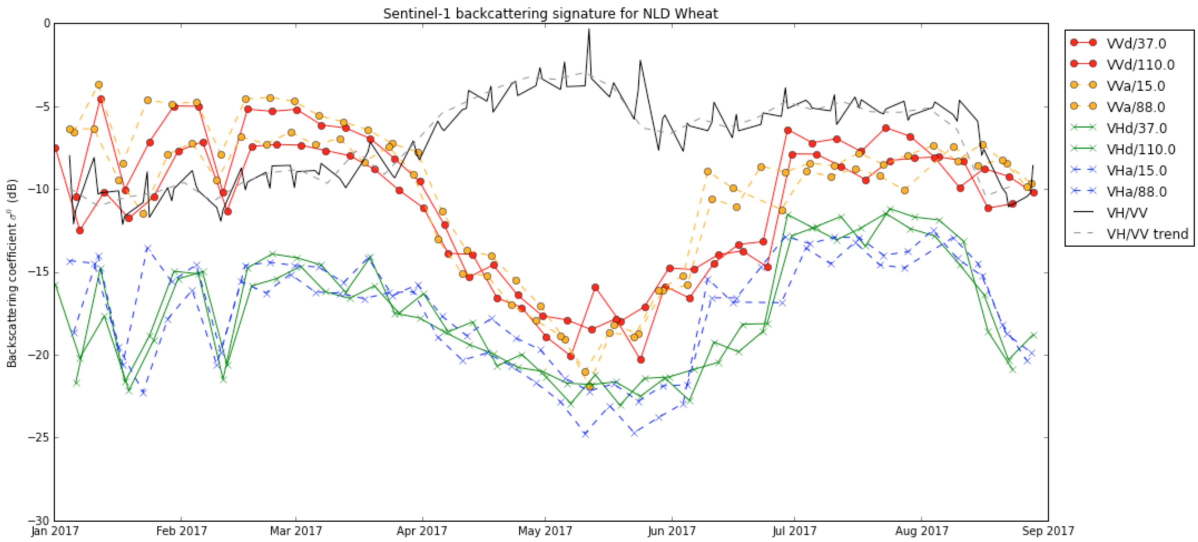


Figure A15a: microwave signatures of wheat in the Netherlands

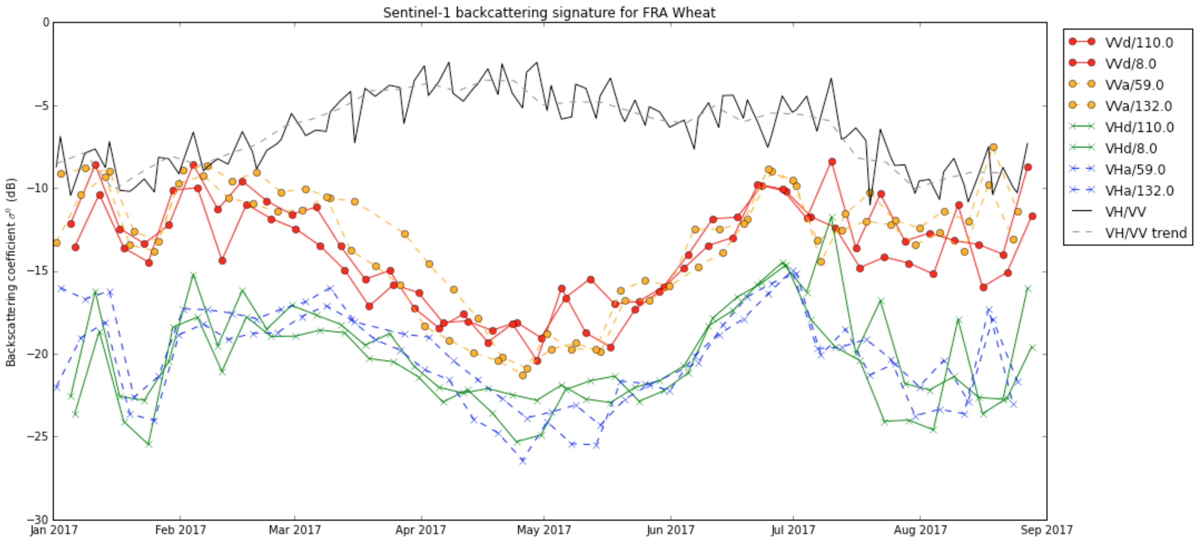


Figure A15b: microwave signatures of wheat in France

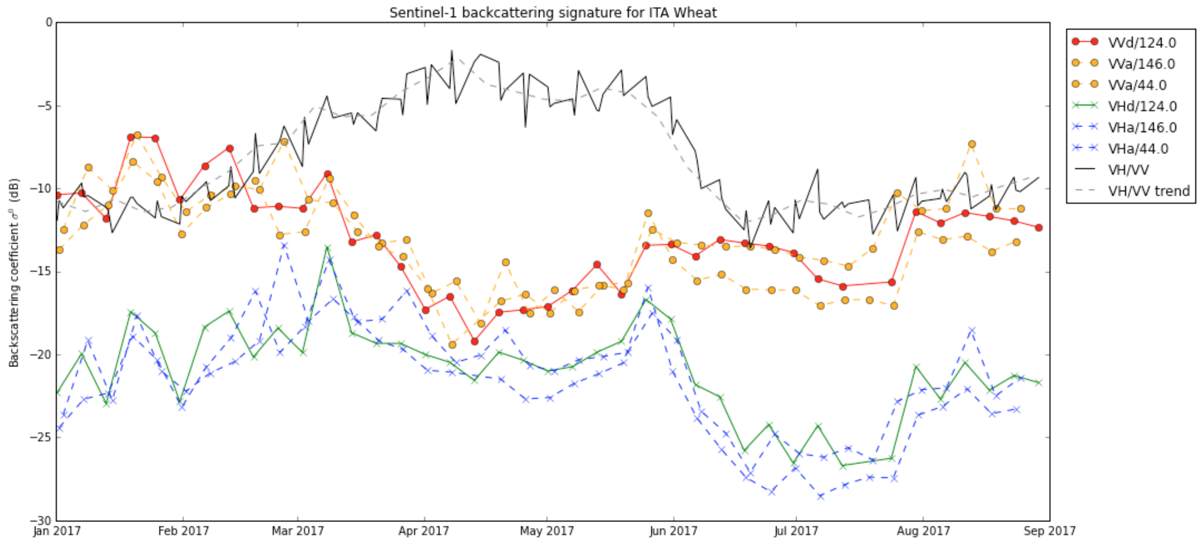


Figure A15c: microwave signatures of wheat in Italy

Comparison of the 3 graphs shows a single trend across these EU production areas, and that this trend is explained by the phenology of the wheat crop. In particular can be seen:

1. the steep drop in VV at stem elongation,
2. followed by an increase in VV after ear formation, a senescence phase and harvest.
3. a characteristic maximum in the VH/VV ratio at the breakpoint between elongation and ear formation.

In general it is scientifically documented that:

1. VH/VV ratios below -10 dB signal bare soil (or sparsely vegetated) conditions, e.g. at start of the period and post-harvest.
2. The timing, magnitude and duration of the trends depend on specific crop species and development due to varying agro-meteorological conditions, with a clear South to North sequence (earliest in Italy, latest in Netherlands). Detection of the elongation trend is possible from mid-April (Italy) to mid-May (Netherlands), i.e. even before or shortly after parcel declarations are filed.

The data collected by Sentinel-1 (being an active sensor) provides much more complex information on the physical status of the Earth cover, in comparison with Sentinel-2. Given the multi-parametric, multi-temporal, multi-dimensional data available, it is not appropriate to relate only a single variable or parameter to a particular phenomenon but rather use the multivariate observation. Thus, in the context of S1, the "**marker**" would rely on the multivariate analysis domain to come up with a more complex set of properties aiming to reflect any characteristic state or change of state of the land phenomenon.

2.3 Examples/illustration of tests / possibilities on the use-cases

2.3.1 Appropriateness of agricultural parcels for monitoring:

2.3.1.1 Verifying homogeneity of the LPIS reference parcels as a reliable representation of the agricultural parcel

The applicability of monitoring is dependent on the quality of the LPIS and the ability of the GSAA to delineate individual parcels reliably inside LPIS reference parcels that contain more than one agricultural parcel. In the figures below we show extracts from one 2012 LPIS that is available online, to demonstrate increasing difficulties that can be expected in a monitoring setup due to heterogeneous quality of the parcel reference system. The LPIS is overlaid on a Sentinel 2A image of 4 May 2016. The proximity of these extracts is so that they are all located inside this single Sentinel frame.

The first extract spans a zone that can be considered appropriate for monitoring. The LPIS reference parcels clearly represent the physical reality of the agricultural land use, with a large proportion of one-to-one correspondence between reference parcel and agricultural parcel. A clear sub-parcelling of the other reference parcels into distinct agricultural parcels could be easily achieved with the support of the GSAA.

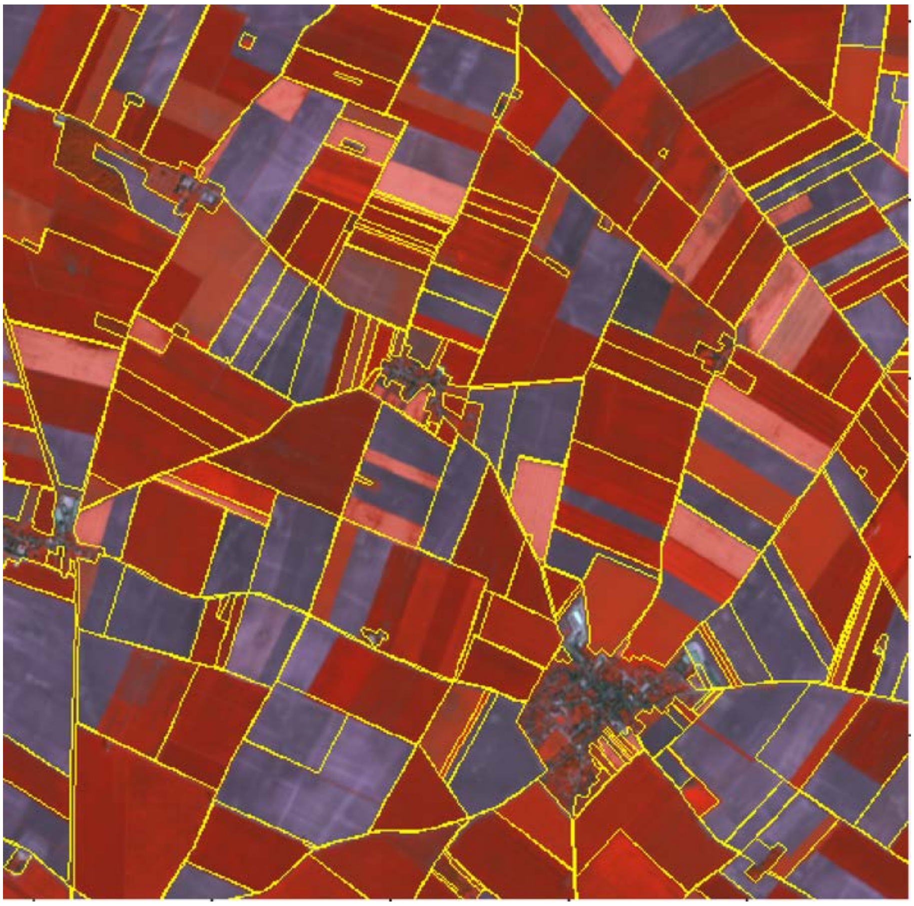


Figure A21a: LPIS extract 1: The majority of the reference parcels represents single units of management

In the second extract, the LPIS still matches the physical reality of the agricultural parcels patterns, but most reference parcels are now large and contain many individual agricultural parcels, often with irregular spatial arrangements. The LPIS condition is less than optimal as several large blocks show permanent boundaries (e.g. roads) that would allow a more appropriate subdivision, as inclusion of ineligible areas is evident even in the Sentinel-2 imagery, and as some reference parcels perimeters (e.g. in the North-

West corner) do not match the agricultural parcel boundaries. GSAA may still assist in resolving some of the larger block sub-parcelling, but the matching of monitoring results with declared parcel attributes will require additional (manual) work beyond the automatic processing stages. Improvement of the LPIS quality through the update process and appropriate remedial actions (if required by the LPIS Quality assessment) would address the identified issues.

Figure A21b: LPIS extract 2: Many reference parcels contain more several distinct units of management

In the third extract, there is no longer a simple (i.e. one-to-one, one-to-few) but rather a complex many-to-many relation between the LPIS reference parcels and the agricultural parcels. It is impossible in this case to reliably establish agricultural parcel outlines from multiple reference parcels. The LPIS no longer represents the physical reality of units of agricultural area, as the Regulation requires. Monitoring will not work in this set-up as it will require extensive, and likely imprecise, subdividing and re-grouping of both reference and agricultural parcels fragments to assess any compliance.

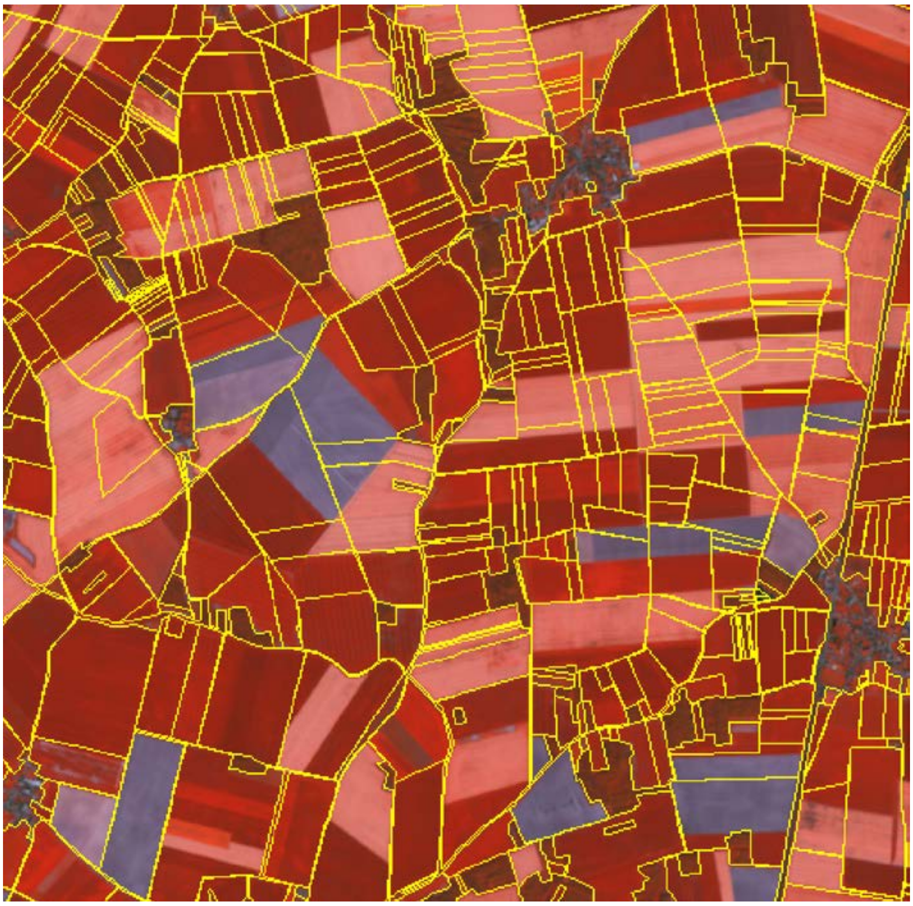


Figure A21c: LPIS extract 3: Most of the reference parcel do not represent true units of management

In 2011, JRC expressed three RP properties that any LPIS design should ideally **strive to approximate as much as possible** to support the 2009 declaration and OTSC process. (http://ies-webarchive-ext.jrc.it/mars/mars/content/download/2092/11055/file/S0_Devos_Outline.pdf slide 25 and following):

1. One spatial unit represents one applicant
2. One spatial unit is 100% eligible
3. One spatial unit represents one unit of application

The monitoring approach aspires to the exact same ideals.

The fourth extract constitutes a solution that could address the conditions of figure A21b where the LPIS still matches the physical reality of the agricultural parcels patterns, but many reference parcels contain many individual agricultural parcels. In this real world example, the GSAA assists in resolving sub-parcelling and thus makes the monitoring approach applicable.

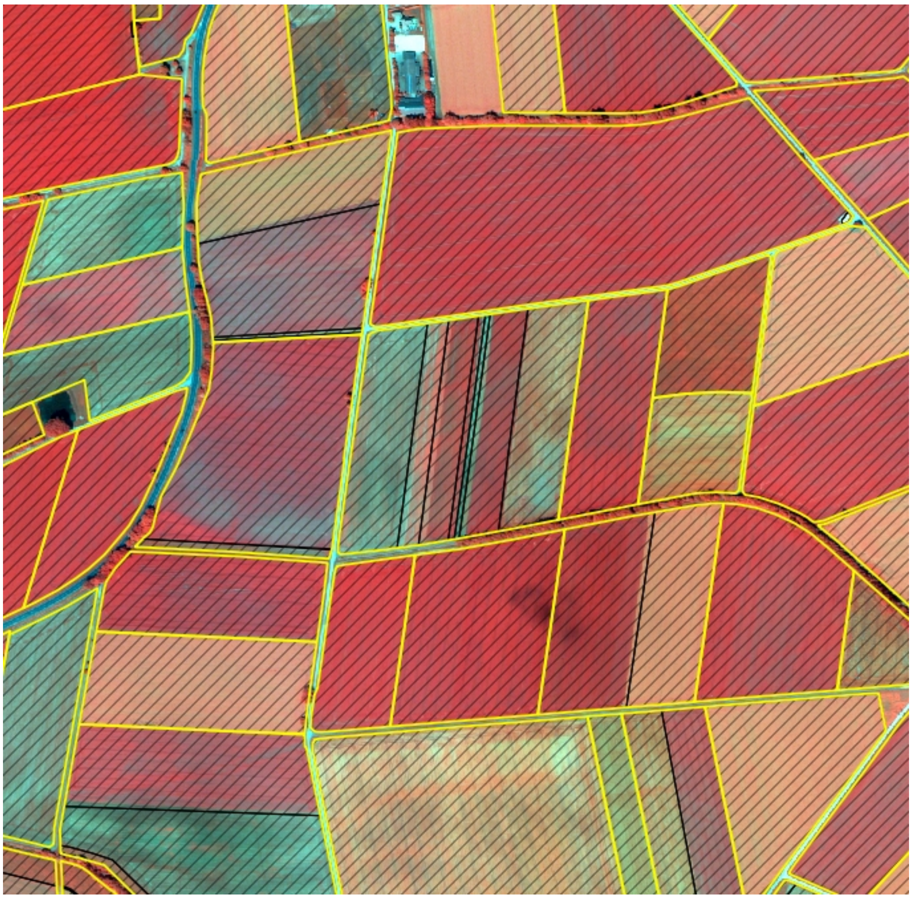


Figure A21d: LPIS and GSAA extract: The combination of parcel declared through GSAA (black boundaries) and LPIS (yellow boundaries) provides the conditions to apply monitoring

2.3.1.2 Assessing the impact of parcel area and shape on the effectiveness of the monitoring using Sentinel

Theoretical considerations on the Sentinel GSD (10m-20m) and the provisional experiences of MS tests indicate that the Sentinel family should operate well on agricultural parcels of 0.3 to 0.5 ha, depending on their shape and neighbourhood conditions.

An analysis of the impact of size/shape on the effectiveness of the monitoring with Sentinels was performed with all declared parcels of EU Member States. The basic assumption was that in order to derive meaningful information for the markers, the declared parcel/unit of management should contain at **least 20 to 30 pixels**.

For each parcel in the agricultural parcel population, a shape index is computed (the reference is 1 for a square), together with the expected maximum number of 10m pixels in the parcel (upper graph of Fig.22) and in a negative buffer of the parcel (lower graph of Fig.22). The colours correspond to a given range of numbers of pixels, with green indicating all cases where pixels are more than 30. The red line is the 0.5 ha limit.

These graphs lead to two key conclusions:

1. the area limit of 0.5 ha is indeed a good "proxy" for the usability of the Sentinel data. Except for the very complex shapes, all parcels above the 0.5 ha threshold contain a sufficient number of pixels.
2. the 0.5 ha limit is not always an obstacle, as the shape also plays an important role and a sufficient number is still achieved for smaller parcels.

The parcels with more than 5 pixels (all the dots but the dark blue ones) represent about 94% of the points in the upper graph and 76% in the lower graph. For comparison, there are 67% of parcels with more than 0.5ha. On the other end of the graph, there is expectation that less than 5 pixels (the dark blue points), might not be sufficient to provide a (rough) estimation of the parcel average value.

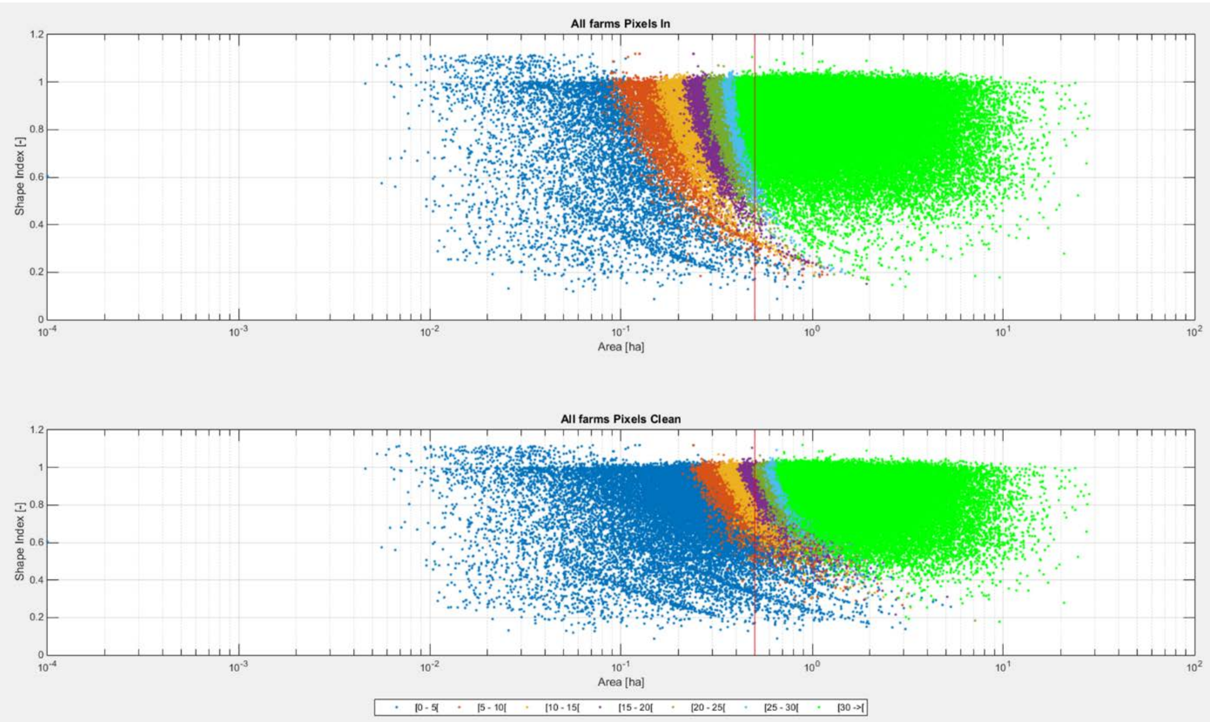


Figure A22: impact of size/shape on the effectiveness of the monitoring with Sentinels

- upper: expected maximum number of 10m pixels in the parcel (green is > 30 pixels)

- lower: expected maximum number of 10m pixels in the parcel in a negative buffer of the parcel (green is > 30 pixels)

2.3.1.3 Identifying regions potentially not suitable for monitoring using Sentinel data

Each MS considering the application of monitoring should analyse which parts of its territory have landscapes where suitable conditions occur.

Below is a simulation of such analyses at EU level based on three assumptions

1. The critical agricultural parcel size is 0.5 ha (this size should exclude any impact from shape and condition)
2. Monitoring will work in territories where approximately 90% of agricultural area is covered with agricultural parcels above the critical size.
3. In the absence of geospatial agricultural parcel data, we used the LPIS reference parcel data as the best proxy for agricultural parcels. Indeed, the Regulation states that a reference parcel should be a unit of land representing agricultural area.

The resulting map shows the areas in the EU where, under these 3 assumptions, monitoring would be appropriate. MS are advised to analyse their IACS records and GSAA data and to check applicability of the third assumption, especially:

- that for many physical or farmer block LPIS designs, any reference parcel could contain several agricultural parcels;
- that for some cadastral parcel designs, the cadastral parcels have a historic legacy and agricultural parcels could be larger by covering several reference parcels

Since the map below is derived from the data of LPIS reference parcels, it can serve only as a proxy for indicating possible areas not suitable for monitoring. Further analysis based on agriculture parcel data is required.

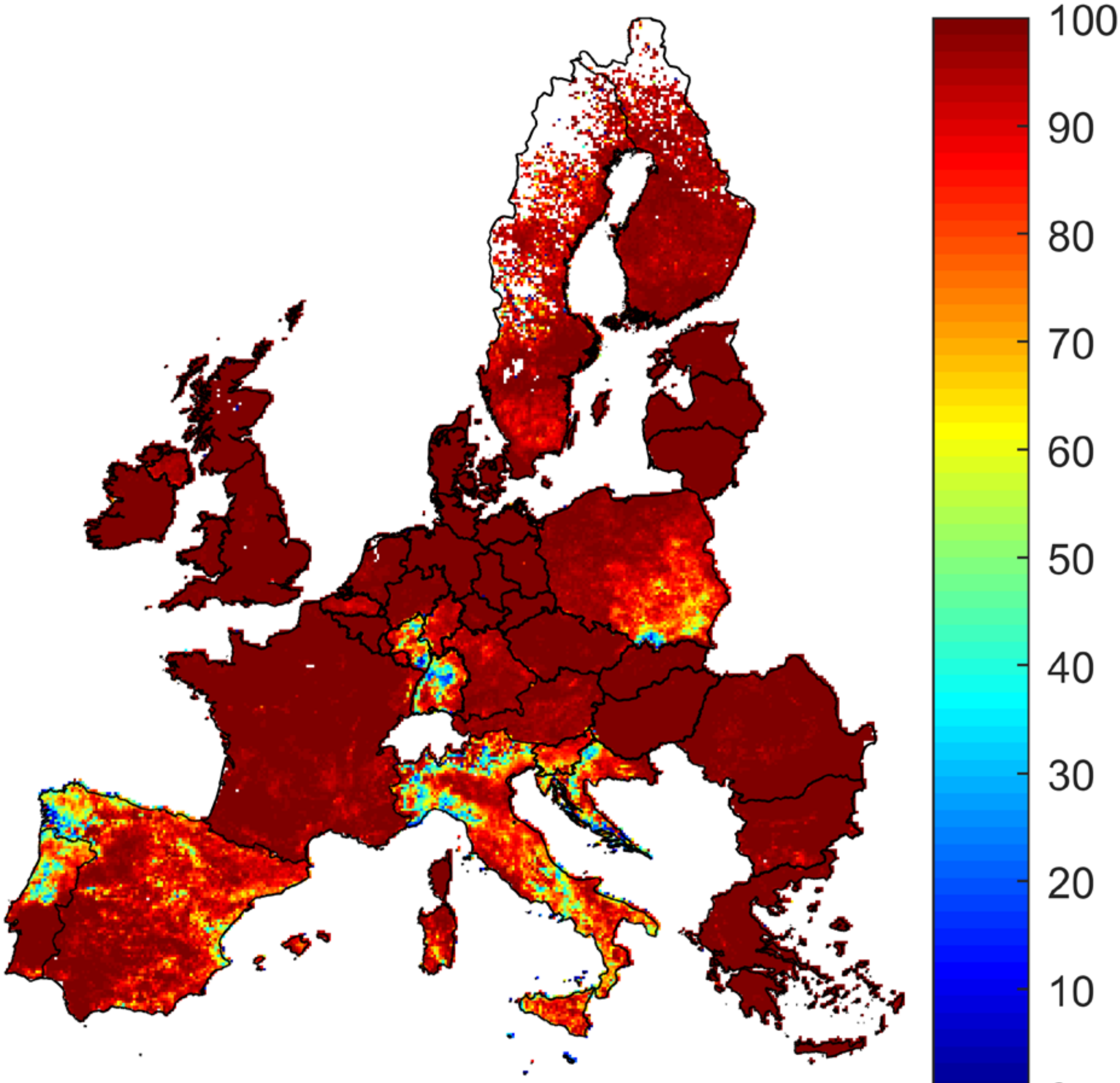


Figure A23: EU distribution of territories, based on 10km x 10km grid with the percentage of agricultural area covered by reference parcels that are bigger than 0.5 ha (blue is 0% and red is 100%), a proxy for possible non suitability for monitoring, requiring further analysis

2.3.2 Analysing the ability of the LPIS design to support GSAA

The conceptual analysis of the LPIS design offers more comprehensive information in addition to the LPIS homogeneity and the RP characteristics discussed above. The tool for such analysis is already available in the form of the TG IXIT, a key component of the LPIS Model Test Suite (MTS), part of the LPIS quality assurance framework. Briefly elaborated below is how this TG IXIT helps with the preparation for setting up the monitoring system.

TG IXIT can be regarded as a structured set of questions on the design/assembly of the LPIS reference parcel and related components such as landscape features and maximum eligible area. They are grouped into the so-called qualifiers, which correspond/reflect specific requirements set in the EU regulation in relation to LPIS and to the GSAA. The combination of choices made for these qualifiers by an EU MS can reveal the level of complexity of the given LPIS implementation and a proxy for the correspondence between the declared agriculture parcels and the unit of management represented by the LPIS reference parcels.

More specifically, IXIT can provide important information and indications on:

- the qualities of a reference parcel in GSAA terms, (provide/confirm the true extent of his/her agricultural parcels and the correct value for the maximum eligible area per scheme)
- the individual particularities of the LPIS concept applied,
- the readiness of the given LPIS implementation to fit the purpose of the "claimless system" or "click and confirm system".

The overview map below shows the approaches used by EU Member States for the creation of the initial reference parcel perimeter, expressed in the well known RP typology (2016)

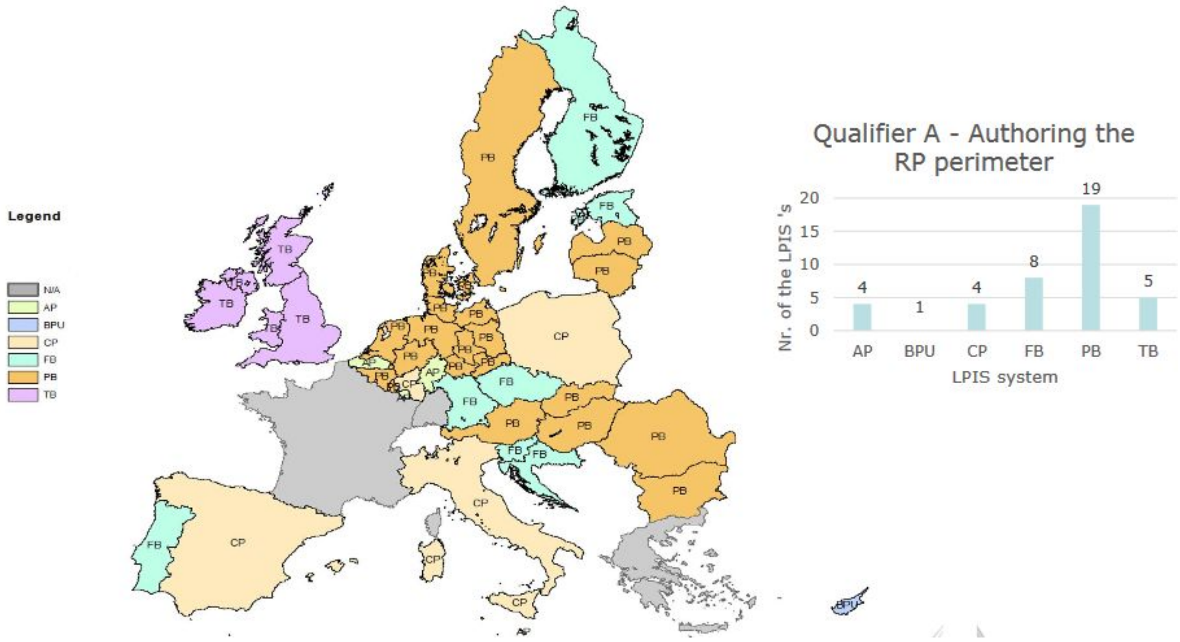


Figure A24: LPIS reference parcel types in 2016 (source: MTS)

For example, for an EU MS that has LPIS implementation ready and 'fit for purpose', we would expect the following outcomes from IXIT:

1. The unit of land representing agricultural area is directly provided/located by the farmer in an unambiguous way at the level of the single crop/management practice.
2. The RP was created through delineation or confirmation on the basis of the information provided by a geospatial aid application
3. The maximum eligible area is directly derived from this delineation and immediately confirmed by the reference information in the GSAA

2.3.3 Improving the signal to noise ratio for less than perfect parcels

Monitoring will rely on mass automation to extract only relevant information from the stack of images to come with a reliable decision. Although fuzzy logic and big data processing are still under development, the decision algorithms can already benefit from existing procedures to separate the noise from the relevant parcel signal. Several techniques are available.

2.3.3.1 Filtering out anomalies.

Automatic outlier detection algorithms can easily help to remove noisy captures from the stack of images. The example below shows how snow, cloud and shadow can be eliminated in an automated way from an NDVI sequence, using pre-defined cloud and haze masks.

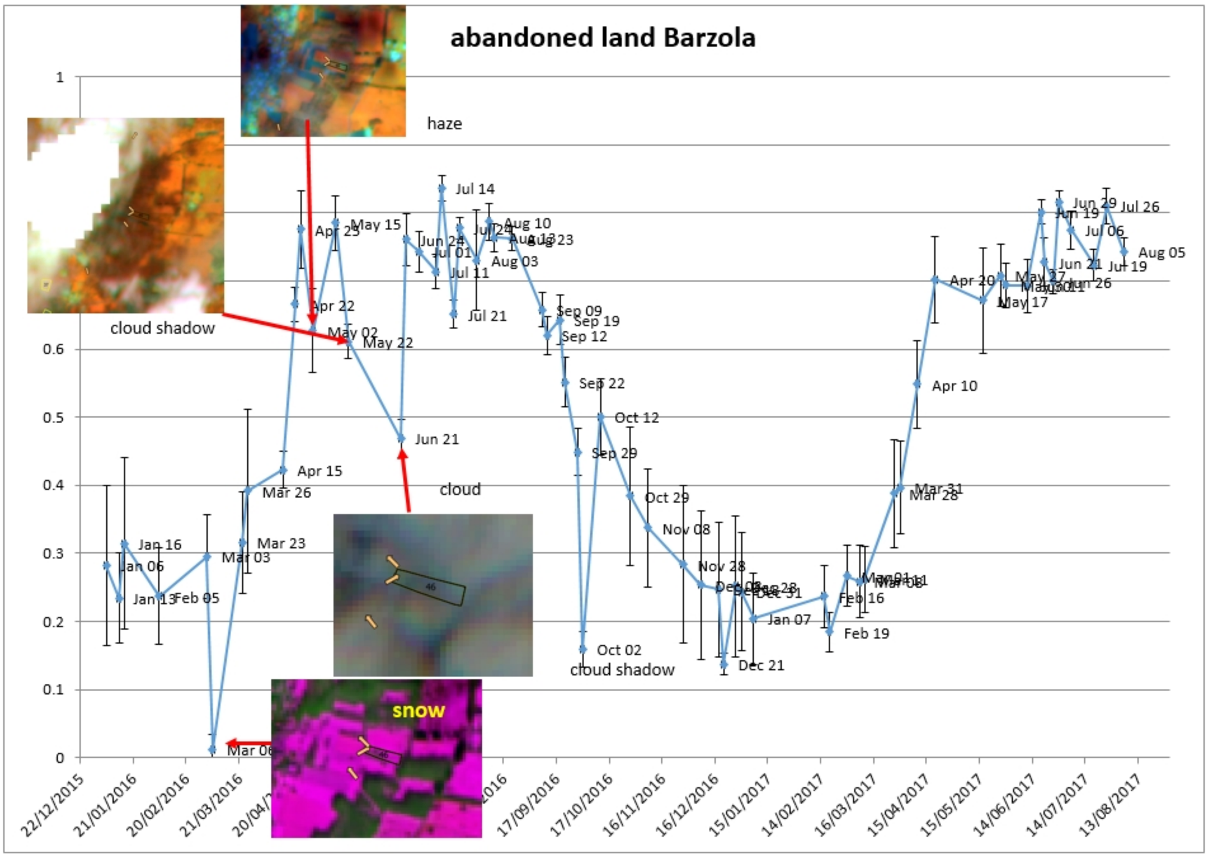


Figure A25a: complete or raw NDVI profile

The detection of such noise is greatly facilitated by including metadata and meteorological data in the processing.

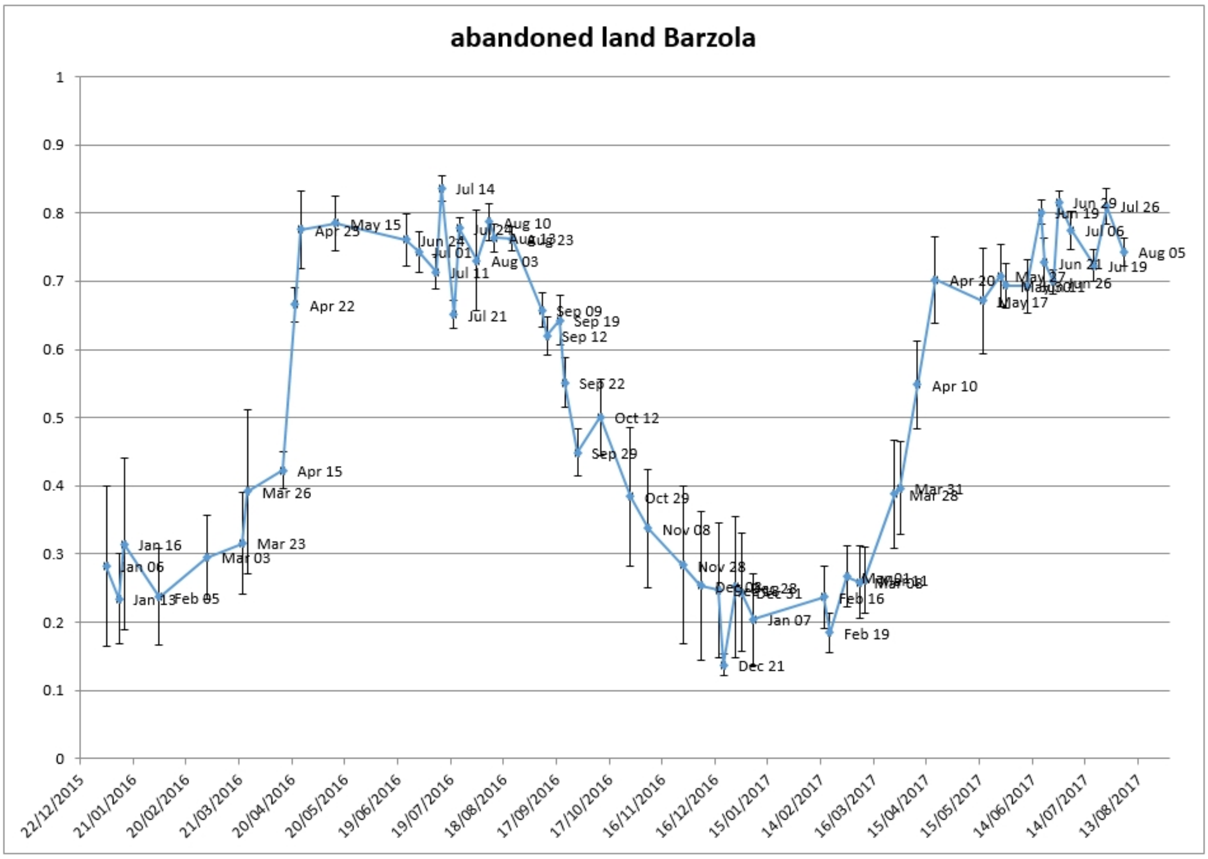


Figure A25b: relevant NDVI profile

The availability of concurrent Sentinel 1 microwave imagery will greatly 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 behaviour on the optical and microwave images will be able to provide conclusive evidence of most meteorological phenomena.

2.3.3.2 Focusing on the central area of interest.

Removing a 1 or 2 pixels from the agricultural parcel's perimeter by applying an inner buffer will ensure that only 'purer' signal/information from the 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 that could 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 pixels for calculation of the markers are slightly reduced, this leads to higher maxima, lower minima and lower standard deviation, in other words a better signal!

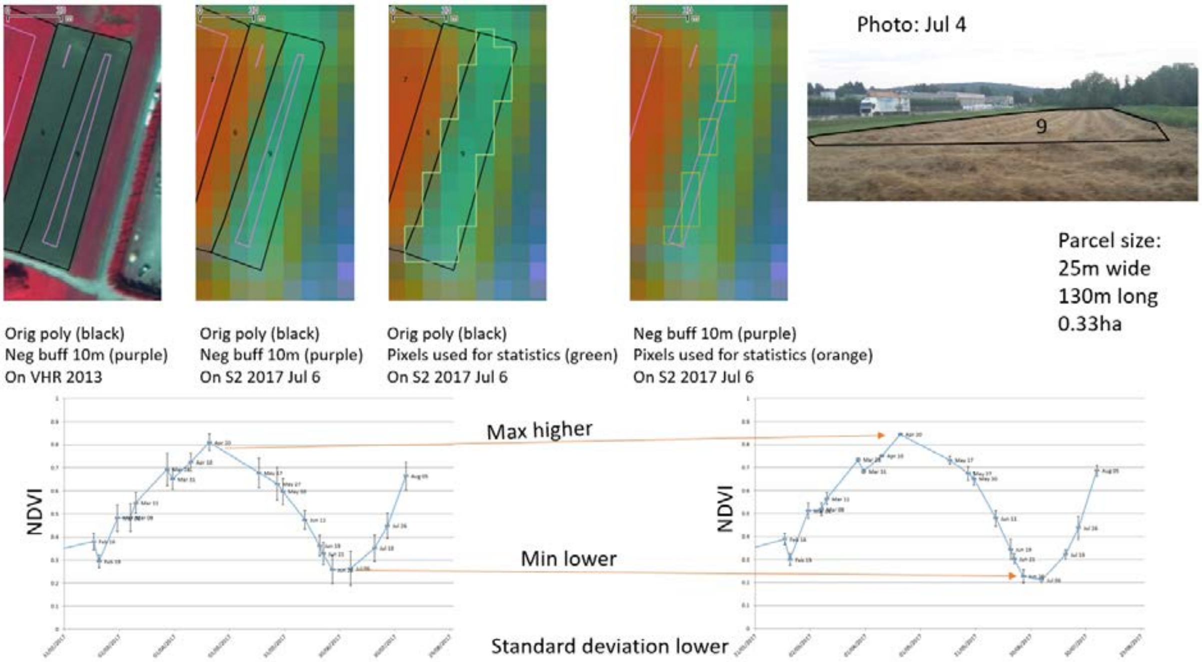


Figure A5: comparison of the NDVI profile of a complete parcel and of its center part only

2.3.3.3 How small can a parcel be to allow efficient monitoring?

In a previous section, it was stated that even 5-10 pixels could be used for an estimation of the parcel conditions. This example, corroborates this statement.

Experience from OTSC CwRS using HR imagery shows that it is usually difficult to interpret parcels smaller than 0.5ha. However, even sub-pixel parcels may show characteristic behaviour, especially when there is a contrast with larger neighbouring parcels.

Not all the noise reduction techniques might be applicable to such parcels, but additional information from the GSAA should provide elements regarding the nature of the object to come up with a conclusive verdict.

In the case below, a small stretch of land is clearly different from the neighbouring arable crop indicating a different management regime. This stretch could be unmanaged i.e. undeclared or intentional e.g. declared as EFA.

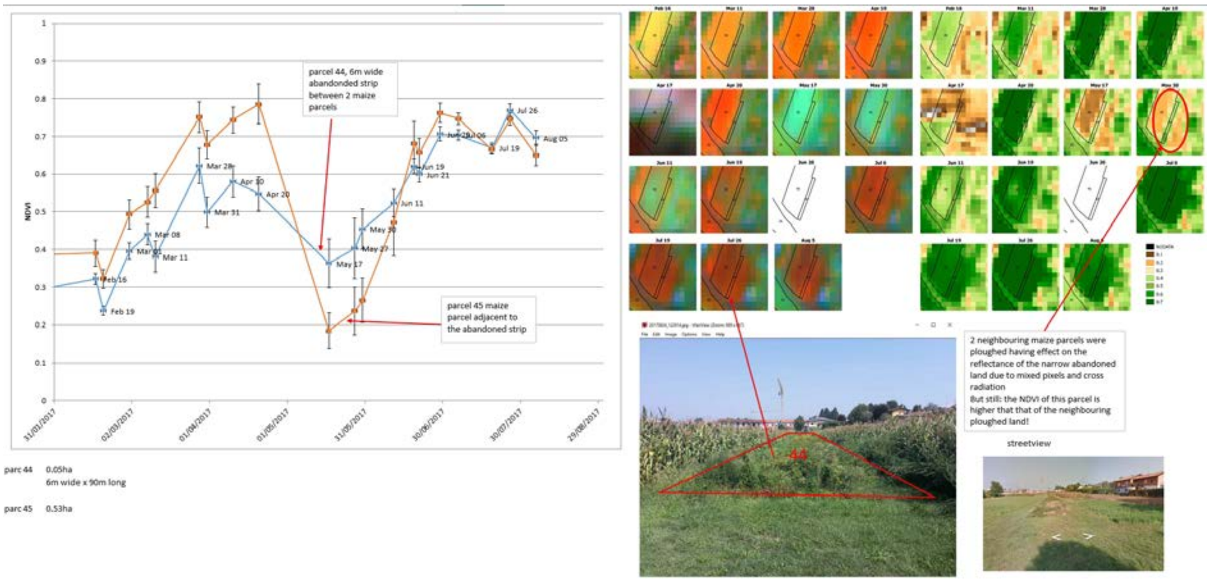


Figure A6: monitoring appearances of a 6m parcel

So even in absence of characteristic discriminating markers, the declaration could be confirmed only by the detection of the different management regime.

2.3.4 Example of holding processing through monitoring

The concept of monitoring implies a systematic inspection of all parcels declared by the holding. However, it does not necessarily require that a conclusive monitoring outcome is obtained for all agricultural parcels declared. All long as, a decision can be drawn at dossier level on the basis of the assessed number of agricultural parcels, the dossier can be categorized and closed, even if there are parcels left unresolved due to insufficient evidence or lack of assessment results.

In the example below, a holding is checked for the greening requirement related to crop diversification. The size of the holding required the presence of minimum three crops (crop groups). Six parcels were processed successfully, while four remained unresolved. However, from the processed ones, it is clear that the holding respected the crop diversification requirement - the third crop group found occupies 11% of the total arable land of the holding (>5%) and both second and third crop groups occupy 35% of the total arable land of the holding (>25%). This example also shows the relative (un)importance of individual (small) parcels (or non-compliances).

This ultimately means that the introduction of monitoring will give the opportunity to observe every agricultural parcel in an automated way, but to retain the flexibility in relation to the amount of information needed (and manual follow up) to come up with a decision at dossier level. For example, when the crop is wrongly declared but nonetheless the conditions and commitments of the scheme/support measure are fulfilled, the payment can be made.

	Crop group		AP Assessment		Trafic Light	Area Determined (ha)	Relevance for the decision at dossier level	Imapct on the payment
AP ID	Declared	Detected	Status	Categorization				
AP001	Crop group 1	Crop group 1	Assessed	Compliant		15,7	YES	YES
AP002	Crop group 3	Crop group 3	Assessed	Compliant		8,45	YES	YES
AP003	Crop group 2	Crop group 2	Assessed	Compliant		6,7	YES	YES
AP004	Crop group 1	??	Assessed	Insufficient evidence		2,15	NO	NO
AP005	Crop group 1	Crop group 1	Assessed	Compliant		22,73	YES	YES
AP006	Crop group 2	Crop group 2	Assessed	Compliant		11,85	YES	YES
AP007	Crop group 2	Crop group 1	Assessed	Non-compliant		4,2	YES	NO
AP008	Crop group 2	??	Assessed	Expert judgement required	Blinking	0,5	NO	NO
AP009	Crop group 2		Not Assessed	No results available		0,2	NO	NO
AP010	Crop group 2		Not Assessed	No results available		0,1	NO	NO
					Total	72,48		

Figure A7: impact of parcel verdicts on the application verdict for a scheme

2.3.5 Activities/practices/use on the land that manifest themselves via phenomena easy to monitor

2.3.5.1 Observing of the basic land use - grassland

In this example of the "targeted aspect" of monitoring, the analysis focuses on outliers in a specific agricultural land use class to tag a conclusive non-compliance or indicate a possible one (i.e. to switch on the blue blinking light). The particular example concerns permanent grassland where the outlier analysis consists of 2 steps:

1. identify the declared permanent grassland cases as implausible (i.e. it is most likely not (permanent) grassland).
2. find the class labels for the parcel by comparing to all cases that are not permanent grassland, i.e. add a plausibility estimate that the parcel is of another class.

For illustrating this, we selected a site where the majority of declared parcels are either grassland (both permanent (64.7%) and temporary (12.1%)) or maize (15.6%), i.e. only 7.7% of the parcels are in one of the other classes. The test area is outlined for a selected municipality, where 5041 parcels (12209 ha) have been declared. The choice of this administrative boundary is arbitrary and can be replaced by a much larger area, e.g. defined on the basis of relevant agro-ecological criteria (e.g. same soil type, crop patterns) for which known Sentinel-1 and Sentinel-2 time profiles (basis for markers) are representative.

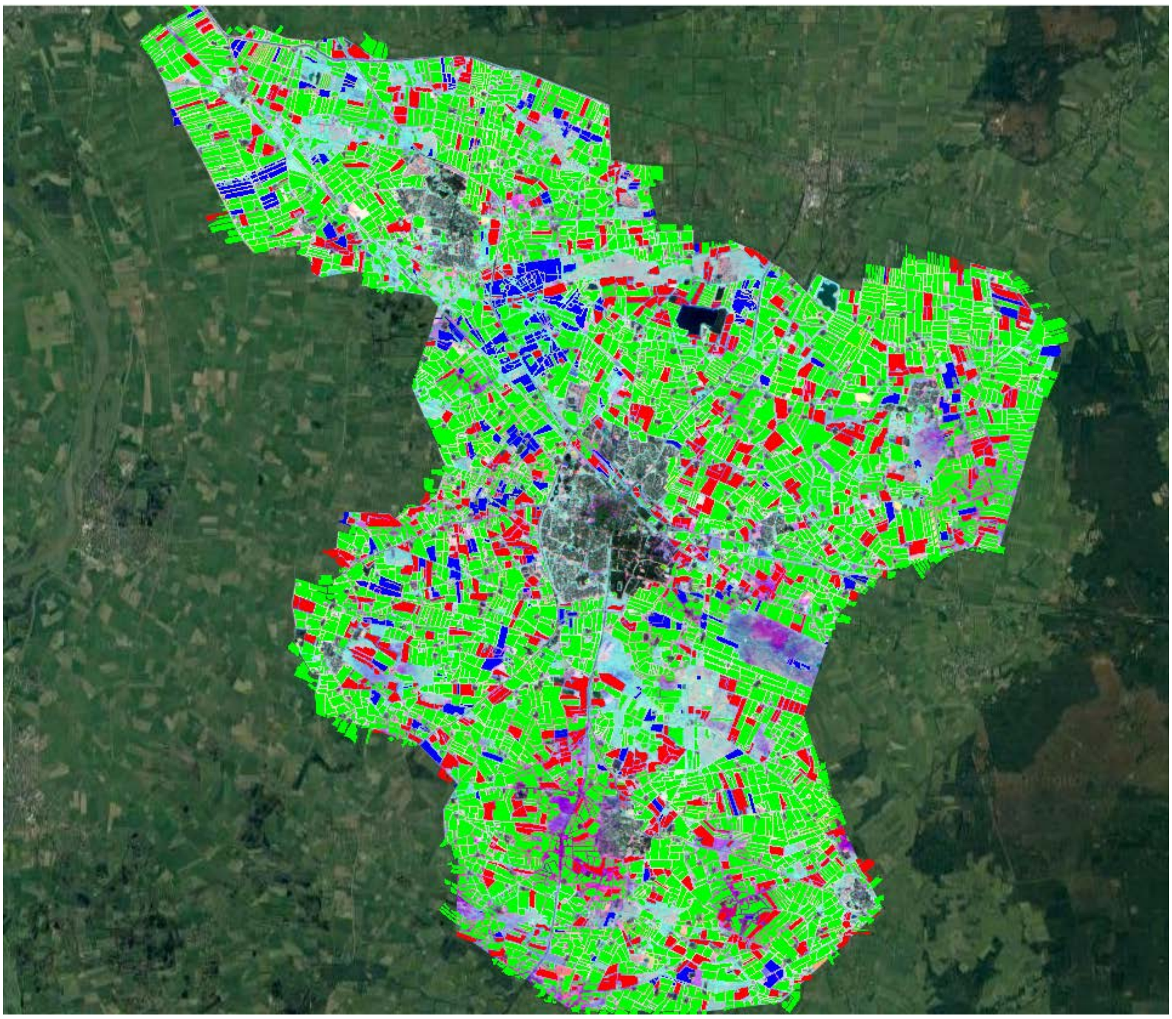


Figure A8: Declared grassland (green), maize (red) and other (blue) on the test site

In a classical remote sensing analysis approach, image classification would be applied, either to each of the available image data set, or to a stack of those images. The confusion matrix derived for the classification would then provide the most likely candidate parcels that are considered as misclassified. By running the classification several times, each time with a different (randomly) chosen subset of training data, and tracking which parcels are consistently misclassified, a high level of confidence can be reached to make a classification verdict and assign a red or, at least, blinking blue light, to those parcels.

A classification approach is suitable if the stack of images is limited and noise is not impacting too much on the data quality.

In this example, 5 relatively cloud free Sentinel-2 images are available over the test area, for the period end of March to end of August. But additionally, the site is also covered by 121 (partial) Sentinel-1 images. Using these is very challenging for a traditional classification, but modern machine learning tools are now available to handle such high-dimensional data stacks. JRC used the open source TensorFlow library to analyse the S-1 temporal profiles extracted for all grassland and maize parcels in the area.

- As noise reduction steps, we buffered the parcel boundaries with a 10 m internal buffer to avoid inclusion of boundary pixels and excluded parcels smaller than 1 ha.
- We resampled the profiles for the May-June period to a weekly interval. In TensorFlow, we chose a so-called deep neural network, and trained it with 1500 samples. The resulting model achieved an accuracy of > 99%, i.e. it manages to separate the temporal S-1 signatures in the 2 distinctive classes (grass and maize) extremely well.

- We then used the trained model to predict the class labels for the samples that were not included in the training. Thus, for each field, we obtained the probability that the model assigns either the correct or incorrect class sample. A typical result is:

Parcel_ID	Area class	Probability for 0	Probability of 1
1501	1	0.67	99.33
1502	1	1.30	98.70
1503	0	98.75	1.25
1504	1	4.56	95.44
1505	0	99.62	0.38
1506	0	98.57	1.43
...			

Provisional results!

For instance, parcel 1501, which has label 1 (= Maize) has a probability of 99.33% to be correctly assigned as class 1 (last column) and only 0.67% as class 0 (= Grass). Similarly, parcel 1503 is most likely (98.75%) to be a correct grassland case.

Of the 1939 validation parcels,

- There are only 2 grassland cases for which the probability that they are assigned to maize is higher. In fact, that probability is > 80%, i.e. these are very likely red light cases.
- By contrast, none of the maize parcels have a higher probability of being assigned to the grassland class.
- An additional 20 grassland and maize parcels have a probability < 80% (but still in the range 60-70%) of being correctly assigned. These could be cases of yellow (orange) lights, which can be resolved either by inspecting additional imagery, or select for RPV. Note that we are able to assign the green light to 1917 samples with a single run of the model!

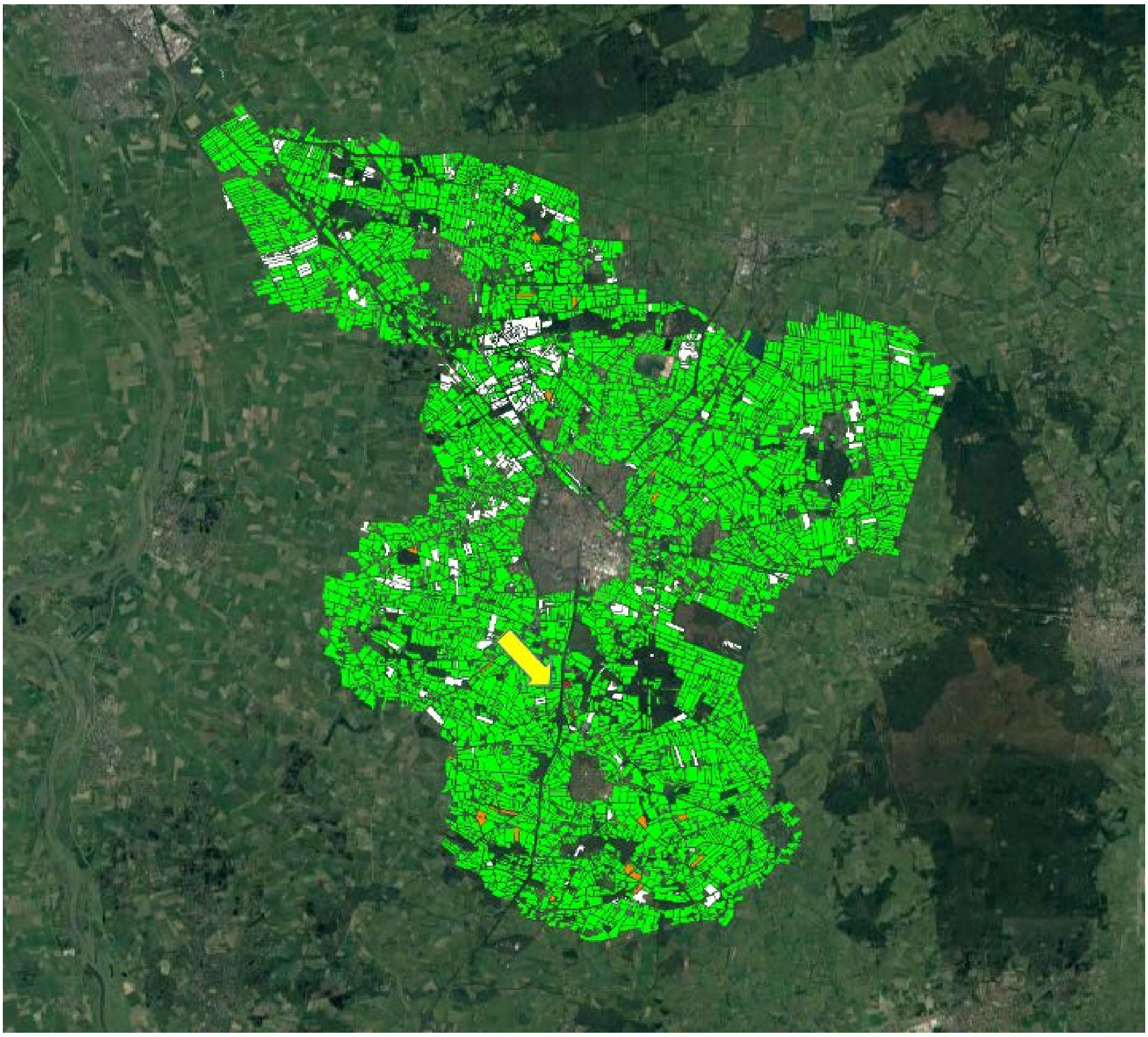


Figure A8a: Simulated traffic light assignment after the first run of the model.

In figure A8a, all grassland and maize parcels for which the class label was confirmed by the learning model are set to green. The 2 non-compliant grassland parcels are set to red (location indicated by the yellow arrow). All parcels with other crop labels which have not been included in the analysis are (still) white. The 20 grass and maize parcels which have not yet been confirmed as such are also set to yellow (orange).

The routine can be re-run with other training sample selections to ensure that all parcels are at least once used as a validation sample (this is similar as in classical classification approaches).

The parcel's time profile extraction for the large S-1 stack is fully automatic (using Google Earth Engine). The TensorFlow model (implemented in less than 50 lines of python code), including training and validation, requires only a few seconds to run for this test case. We have used only S-1 data for May and June, which demonstrates the excellent quality of these data for the purpose of monitoring and the quick availability of parcel diagnostics for timely follow up.

2.3.5.2 *Impact of eligibility conditions.*

A more sophisticated example relates to monitoring of eligibility requirements with respect to fallow land. In this particular case, an agricultural parcel was declared as land lying fallow, whose eligibility conditions (defined at national level) require that it's kept out of production for a period of at least 8 months. In addition, if the area is declared also as EFA, no mowing and any other agricultural activity should occur in the period from 1 of March to 31 of July.

Since no agronomic activities are envisaged on the land represented by this agriculture parcel, one would expect that a spontaneous growth of semi-natural vegetation will gradually occur through the year. This phenomenon will be manifested by slow progressive increase of the vegetation cover, combined by notable presence of the vegetation heterogeneity. These two characteristic can be well represented by the mean value of the NDVI within the parcel and its correspondent standard deviation.

On the figure below (left), it can be seen that these two parameters follow the expected trend typical for fallow land. First, in the spring months the NDVI gradually increases, then in the land spring-summer months (May - July) slightly decreases probably due to the increased presence of dry matter (confirmed also by the PSRI index). Note that the standard deviation of the NDVI increases during the whole period.

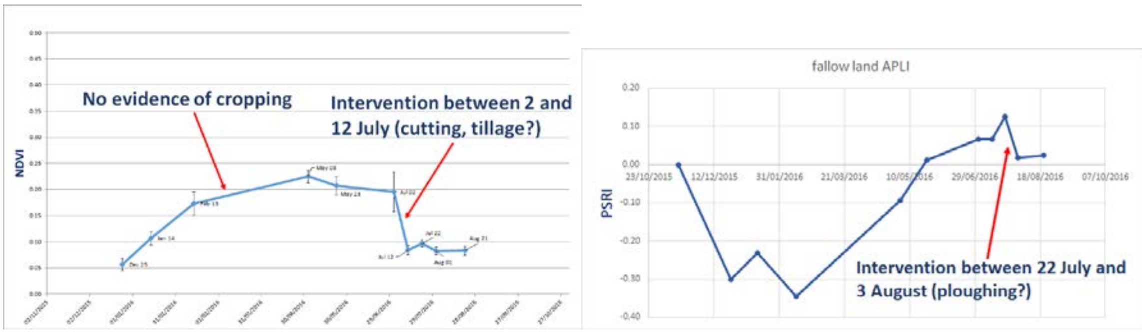


Figure A9: evidence of agricultural activity detected from markers based on NDVI and PRSI profiles

Then, there are two value drops - one in the NDVI in the period 2-22 July, combined with decrease of standard deviation; and another in the PSRI in the period 22 July - 3 August.

This can be considered as an evidence for intervention on the land, related to ploughing, provided by two independent markers:

1. disappearance of the green vegetation, due to clean-up activities and
2. drop of the dry matter (weeds, stubbles) due to the subsequent ploughing.

Here, there are two scenarios for assessment, depending on the scheme declared:

1. **declared only for BPS**: Ploughing seems to happen at the very end of the commitment period. In order to confirm whether it was conducted after the exact completion of the 8 months, the parcel can be flagged as "blinking yellow" and the farmer can be asked to provide further evidence (such as GPS track log of the harvest machine, others.). If case of absence of such evidence and in case of no impact on payment, the parcel can be flagged as "yellow" and then processed as "green", as it's considered more likely that the 8 months were respected (benefit of doubt to the farmer).

2. **declared as EFA**: Since there is substantial evidence for an intervention on the land well before 31 of July (change of NVDI value within short period), the parcel is flagged as “blinking blue” and further expert judgement is required within a short period to confirm the observed non-compliance. In the case of confirmation, the parcel is flagged as “red”. In absence of definite evidence from farmer, the parcel is flagged as “blinking blue” requiring further expert judgement.

For this particular case, a CAPI assessment and field visit confirmed the assumptions above.

The screenshot below represent the visual manifestations (as false colour composites) of the NDVI and PRSI evolution of that parcel.

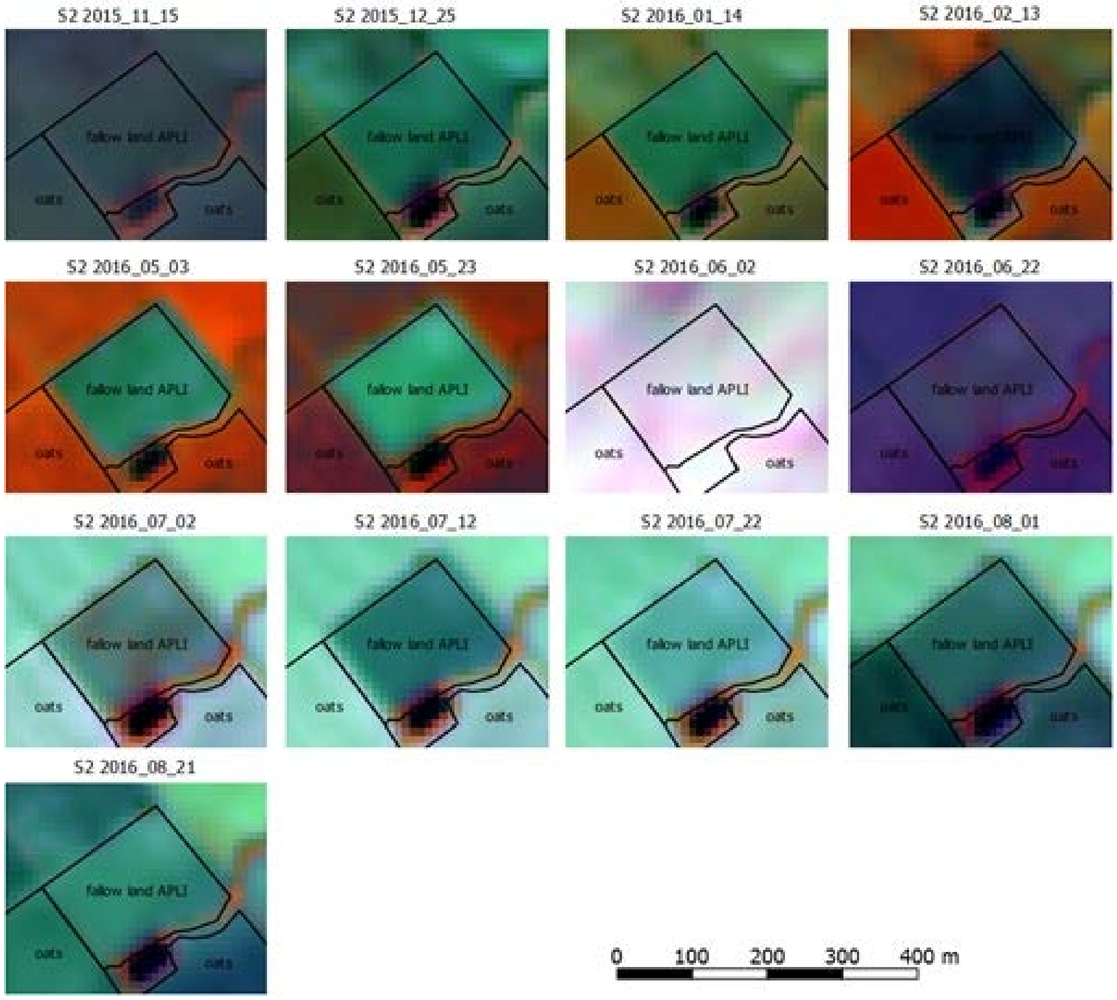


Figure A10a: False color time series

Blinking blue: the late field visit on Aug 31 evidences deep ploughing and traces of weed.

Figure A10b: late in the season field evidence

2.3.6 Assigning traffic lights as a result of monitored manifestation

2.3.6.1 The Basic procedure

The process of assigning traffic lights (i.e. assigning an eligibility status to an agricultural parcel) is based on a channelling approach; the parcel is monitored until a characteristic manifestation through the applied markers is observed that allows making a decision for the application year.

There are 2 straightforward paths to that decision on a parcel:

1. The observation of required evidence for eligibility
2. The observation of conclusive evidence for ineligibility

And there is a grey zone in-between with

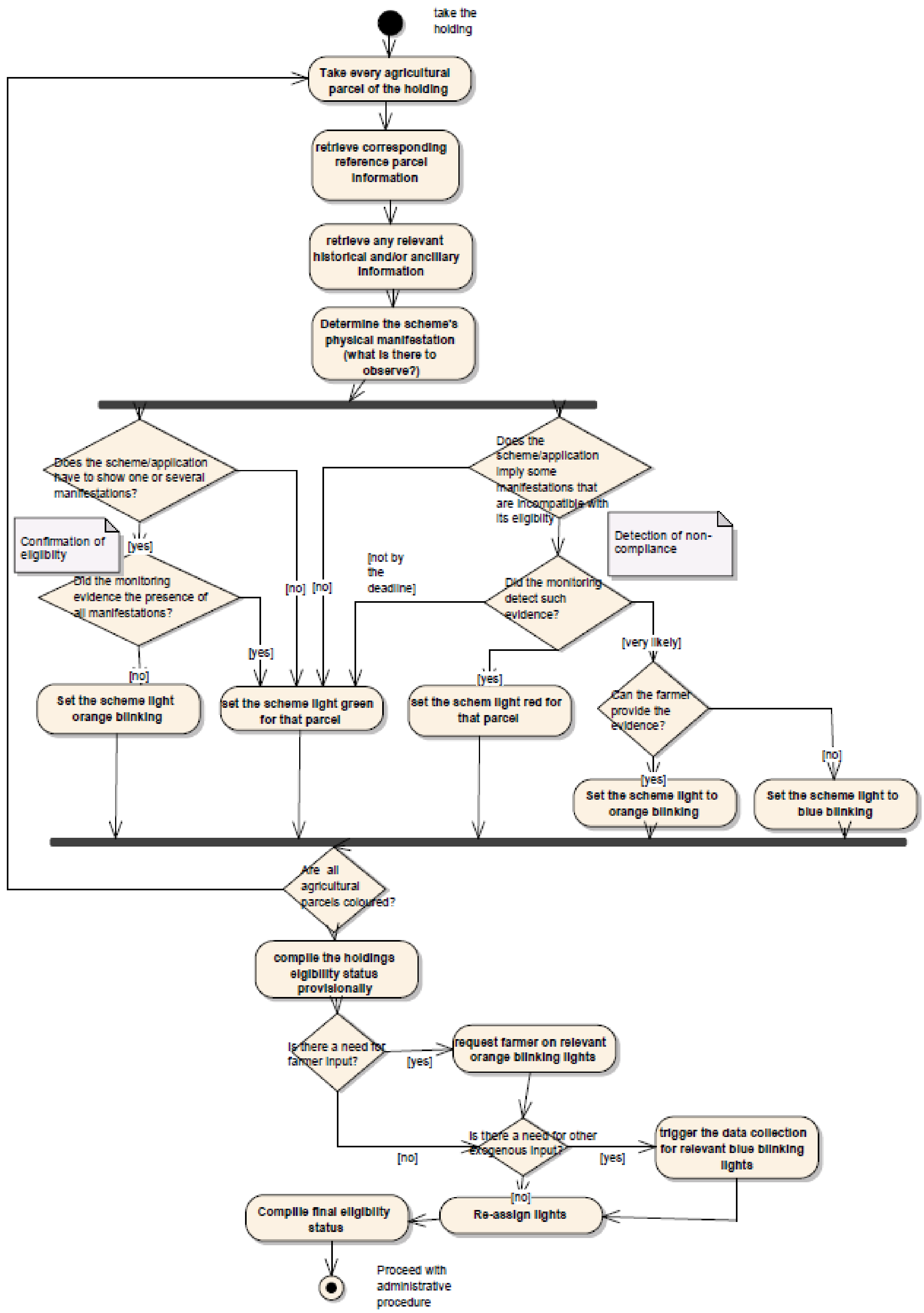
1. The observation of in-conclusive evidence on ineligibility
2. In-conclusive evidence on eligibility
3. Delayed observation of evidence on eligibility

For the channelling workload, what is required and conclusive is scheme and application dependent. For example, for BPS an agricultural activity is often required and should then be evidenced. But for EFA, parcel evidence may no longer be required as soon as the holding meets the compliance threshold. Similarly, conclusive evidence for an incorrect crop declaration may be irrelevant in cases where the crop diversification requirement is met.

Unfortunately, this dependency complicates the evaluation workflow.

The parcel workflow below illustrates how an individual parcel could be processed for a particular scheme; in simple terms what it translates into.

1. The farmer's application determines what to look for, IACS helps the interpretation.
2. If the required evidence is detected, the parcel is assigned a green light
3. If conclusive counter-evidence is detected, the parcel is assigned a red light
4. If in-conclusive counter-evidence is detected, the parcel is assigned yellow blinking light. If relevant, it triggers a request for additional information, possibly from the farmer. This information can be sufficient to re-assign a green light but if additional information does not come forward, it is assigned a blue blinking light and possibly subject to some field data collection. The result of this field activity should switch it in either red or green.
5. Any parcels that have not been assigned a red or yellow blinking light by a set deadline are assigned a yellow light, but treated as if were a green light further on.


take the holding
Take every agricultural parcel of the holding
retrieve corresponding reference parcel information
retrieve any relevant historical and/or ancillary information
Determine the scheme's physical manifestation (what is there to observe?)
Does the scheme/application have to show one or several manifestations?
Does the scheme/application imply some manifestations that are incompatible with its eligibility
Confirmation of eligiblity
[yes]
Detection of non-compliance
Did the monitoring evidence the presence of all manifestations?
[no]
[no]
[not by the deadline]
Did the monitoring detect such evidence?
[yes]
[very likely]
[no]
[yes]
Set the scheme light orange blinking
set the scheme light green for that parcel
set the schem light red for that parcel
Can the farmer provide the evidence?
[no]
[yes]
Set the scheme light to orange blinking
Set the scheme light to blue blinking
Are all agricultural parcels coloured?
compile the holdings eligibility status provisionally
Is there a need for farmer input?
[yes]
request farmer on relevant orange blinking lights
Is there a need for other exogenous input?
[no]
[yes]
trigger the data collection for relevant blue blinking lights
[no]
Compile final eligibility status
Re-assign lights
Proceed with administrative procedure

2.3.6.2 The "after payment" monitoring procedure

The "after payment" monitoring procedure is much simpler than the Basic procedure. It only looks for conclusive counter-evidence of the few selected cases that can be relevant for processing of the application, the so-called targeted approach.

E.g.

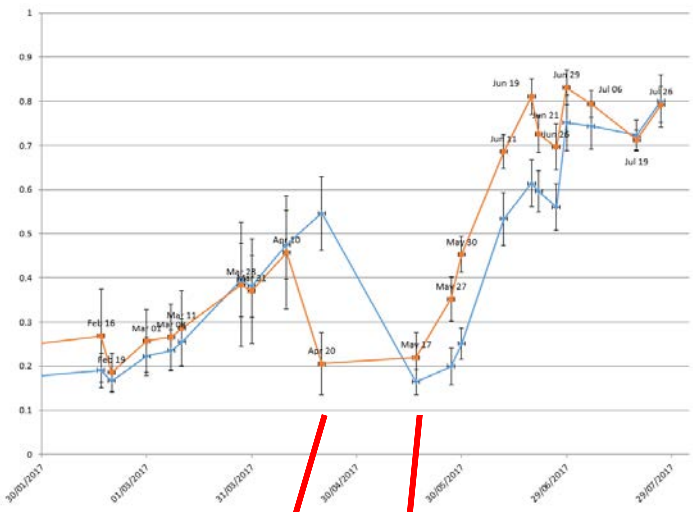
- ploughing of a permanent grassland qualified as ESPG after payment
- Non respect of the period of a cover crop.

Agricultural parcels that are not subject to such conditions are not in scope of the "after sales" monitoring.

Any detected non-compliance would trigger the parcel to be assigned a red light and be brought to the attention of the holding and the application should be re-processed well before the launch of a retro-active recovery.

2.4 Variable timing for different holdings

The wheat example already mentioned above (point 2.2.1.3) shows the varying timing of the crop phenology over different regions of Europe. There is also the time difference in the management of crop within each region, as a consequence of the specific activities of each individual farmer. Markers need to be robust enough to cope with these local differences for a given agronomic practice, in order to provide meaningful results. For example, the property value "A period of occurrence" will be set in a way to correctly reflect the period where ploughing of certain crops might occur.

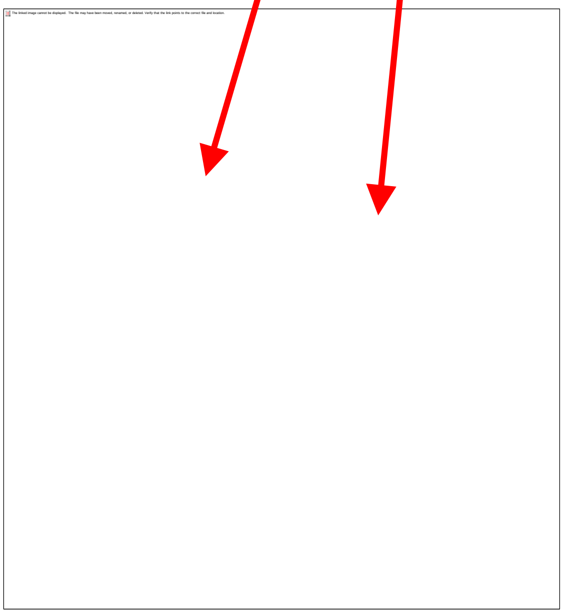


The NDVI temporal profile derived from Sentinel-2

The NDVI temporal profile derived from Sentinel-2 images shows the **ploughing of land** of two neighbouring maize parcels in North Italy with 1 month difference.

False colour composite time series (RGB 8,11,4)

NDVI time series



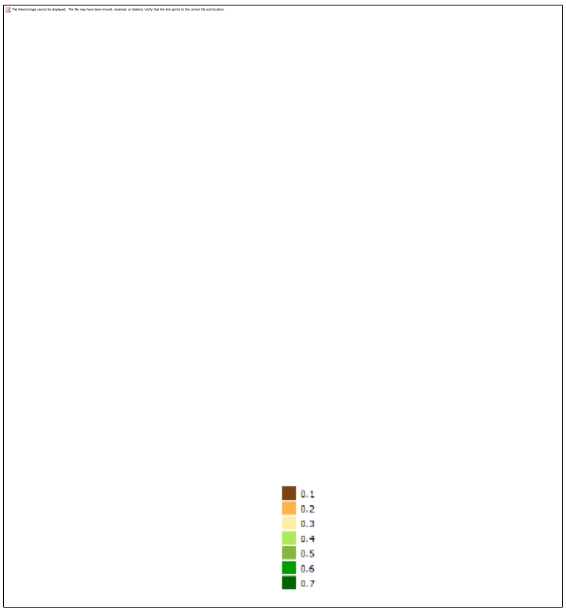


Figure A14: Two nearby maize crops with different sowing dates (20 April and 17 May)

2.5 Activation and switching of "traffic lights"

This example provides an illustration of the way different "traffic lights" are activated.

- An agriculture parcel is declared with winter wheat. At the beginning of the monitoring, the parcel is flagged as WHITE, since only the information from IACS/LPIS is extracted.
- As soon as the schemes/measures are identified and the relevant markers are selected (in this case NDVI), the monitoring of the parcel starts, the colour switches to YELLOW – the parcel is under assessment, but there are no definitive result.

The marker properties and values are set based on the crop calendar for winter crops applied in the particular agro-climatic region and the statistical information derived from the image time-series for the parcels declared with wheat in the region. The marker depicts a temporal profile of the expected NDVI mean and standard deviation within a typical parcel declared with winter wheat for the area. It implies a steady development of homogeneous vegetation coverage over the declared parcel in the spring months with a peak around the end of May. This should show an increase of the NDVI, combined with a low standard deviation due to the expected homogenous nature of the crop coverage. The same type of temporal profile (graph given below) is gradually generated from the continuous image dataflow for the parcel under monitoring.

- The comparison between these profiles (profile of monitored parcel against the reference one of the marker) reveals a significant higher value for the standard deviation of the NDVI early in the season, which indicates within-parcel heterogeneity. This can be an evidence of non-compliance, as probably only part of the parcel is cropped with winter wheat. Parcel colour is switched to BLUE BLINKING, indicating the need of expert judgement.
- Visual (CAPI) verification of the time series reveals the fact that in the beginning of February only part of the parcel is covered with a crop. Further (semi-automated) check of historic imagery from autumn of the previous year, reveals the fact that there was a (cover?) crop on the part of the parcel where winter crop was not evident (which might explain why there was a delay of the winter crop sowing). Parcel colour remain BLUE BLINKING, waiting for collection of further evidence late in the season.
- The subsequent monitoring reveals the fact that the crop emerges on the remaining part of the parcel within the expected time frame (later spring). The situation is rectified and the parcel colour switched to GREEN.

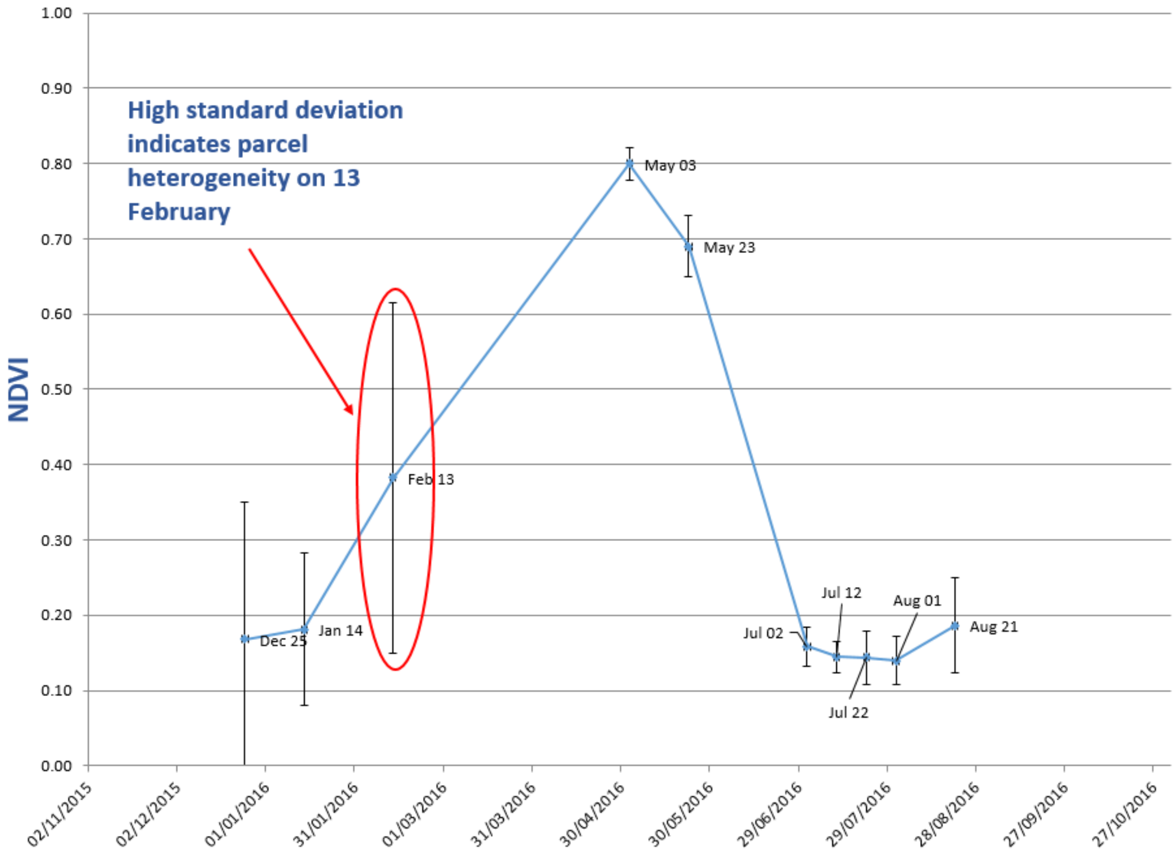


Figure A15a: NDVI profile of a heterogeneous parcel

The above NDVI values correspond to the following visual observations (false colour composite)

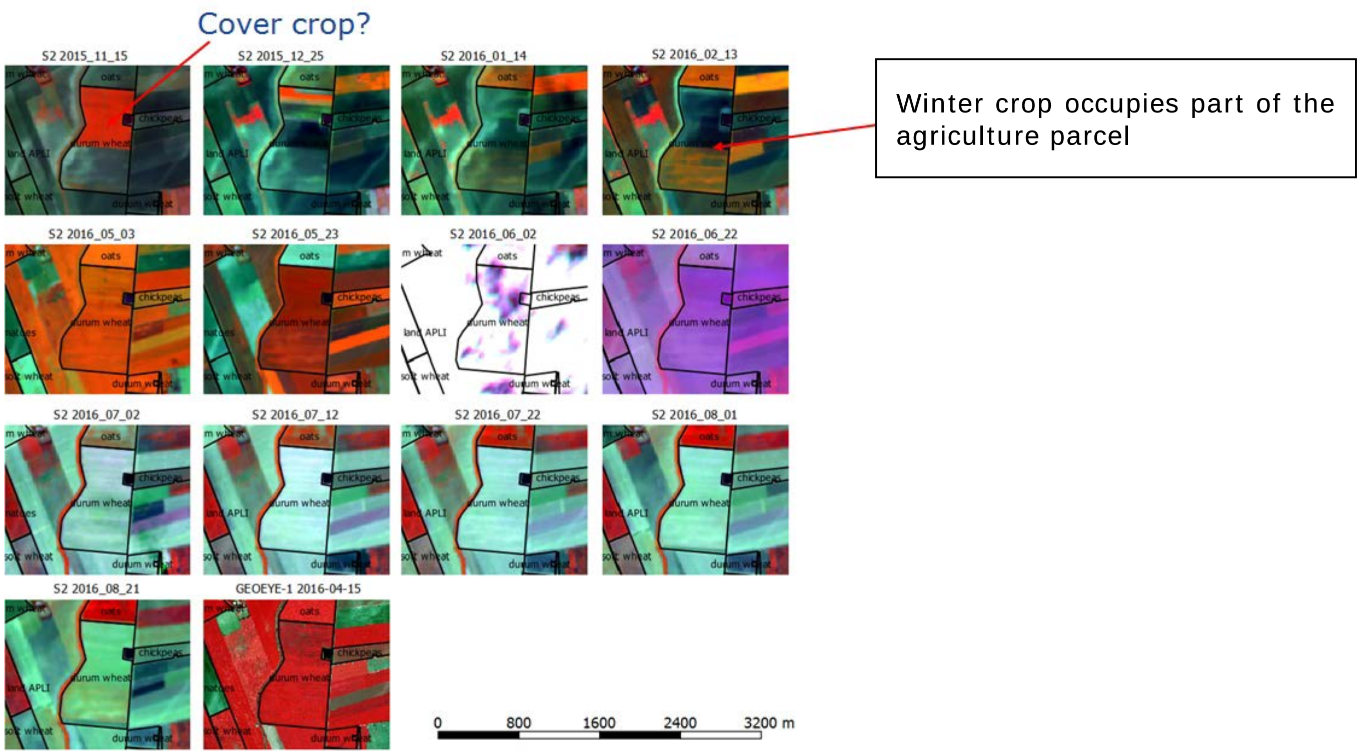


Figure A15b: Sentinel 2 images of a heterogeneous parcel

2.6 Early warning

The provision of notifications (warning alerts) to farmers about agronomic activities that they need to conduct is an important component in any design of a system that strives to increase compliance. To quote Benjamin Franklin: “An ounce of prevention is worth a pound of cure”.

2.7 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
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

List of abbreviations and definitions

AP	Agricultural parcel
BPS	basic payment scheme
CAP	Common Agricultural Policy
CwRS	Control with remote sensing
EFA	ecological focus area
IACS	Integrated Administration and Control System
GSAA	Geospatial aid application
IXIT	implementation extra information for testing
LPIS	Land Parcel Identification System
NDVI	normalised difference vegetation index
OTSC	On the spot check
RP	Reference parcel

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