NIVA TECHNICAL BRIEF

Earth Observation (EO) monitoring

Towards a standardized workflow for EO monitoring

1. Context and overview

For the new CAP (CAP 2023-2027), Paying Agencies will have to set up a new control system, called Area Monitoring System (AMS) and mainly based on the use of the temporal series of satellite images, such as Sentinel-1 or Sentinel-2 for checking and confirming the crops or other agricultural activities on the parcels.

The previous ESA project Sen4CAP already developed an integrated system to process the satellite images, derive vegetation markers and provide results on the main eligibility rules that can be checked through satellite images (e.g. crop classification, mowing detection ….). More generally, a lot of activities are going on regarding the use of Earth Observation (EO) data for the monitoring of agricultural activities. For instance, other systems have been developed mainly by commercial companies. The main problem here is that it is difficult to compare them between them, and exactly understand what the differences are.

Member States have different level experience with the Area Monitoring System. Some have started tests early on, and are running a system close to it already in parallel with the normal IACS. Others are just starting to implement the AMS directly.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 842009

With the prominent role of Earth Observation, and satellite images as part of AMS, it is timely to review and propose a more standardized way of working with this type of data. There is need for a consolidated understanding of the different systems.

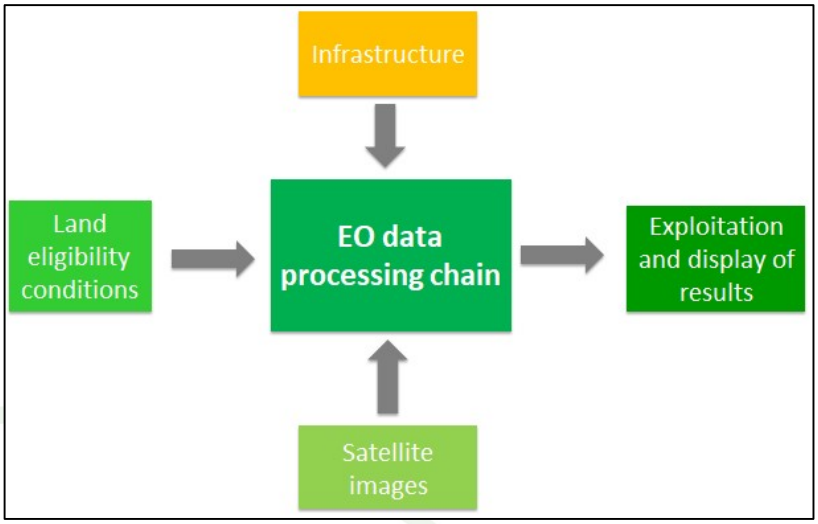

Figure 1: Overview of EO monitoring process

The EO monitoring system is driven by the necessity to control land eligibility rules and it is enabled by the availability of satellite images (mainly Sentinel1 and 2). The use if these satellite images require the development of an infrastructure. A complex EO data processing chain has then to be designed and set up in order to provide the necessary results for CAP payments.

2. Decide on a strategy for monitoring land-eligibility conditions using EO

Central to the monitoring in the CAP (consisting of different support schemes) are the land-eligibility conditions, which describe the status of the land and the activities on the land to be eligible for subsidy payments. A very first step is to identify, for each support scheme, the land eligibility conditions that have to be respected by farmers and to assess if they can be checked by EO monitoring process.

In a second step, for each eligibility condition, it is necessary to decide on the EO monitoring process to be set up and to describe it, providing where it should be conducted (its agricultural scope), when (its temporal scope) and how (the monitoring process).

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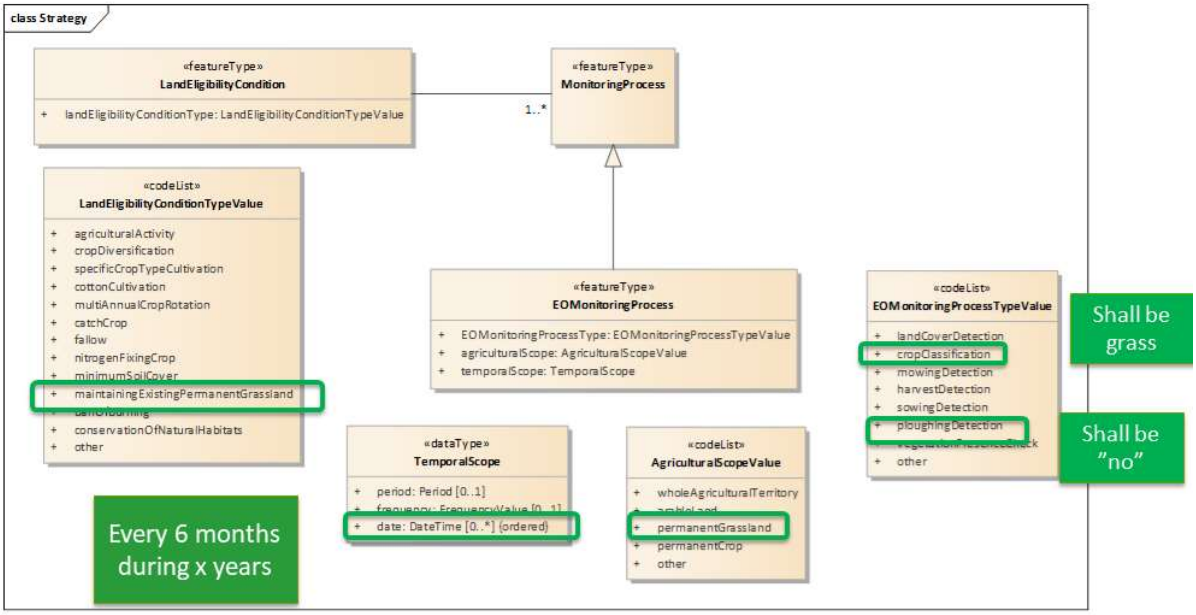

Figure 2: Potential example about maintenance of permanent grassland

Figure 2 illustrates an example. To check a land eligibility condition about maintenance of permanent grassland, the Paying Agency decides to use two EO monitoring processes: one about crop classification (with expected result being "grass") and one about ploughing detection (with expected result being "NO"). Both processes are applied on permanent grasslands (as agricultural scope) and they are performed every 6 months during a couple of years: there temporal scope may be supplied as the ordered list of planned dates.

The (basic) monitoring processes may be used to check several land eligibility conditions. For instance, crop classification is widely used as it may serve to check existence of agricultural activity, cultivation of a specific crop, crop diversification, etc.

Once fixed, the strategy is supposed to be relatively permanent. However, the temporal scope may have to be adapted to the meteorological conditions of the agricultural campaign.

3. Choose satellite images

The free availability of Sentinel-1 and Sentinel-2 images is a key enabler of the new Area Monitoring System. The Sentinel images come from ESA whose official site is Copernicus Open Access Hub (https://scihub.copernicus.eu/).

However, many issues have to be solved before getting relevant ARD (Analysis Ready Data) that can be used in the EO monitoring operations and images from other sensors may also be required.

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- **Sentinel 2**

Sentinel-2 provides optical images easy to be interpreted with rich information. They are the first candidates for EO monitoring. They suffer from the cloud issues that depend on location and are more disturbing in northern or mountainous areas.

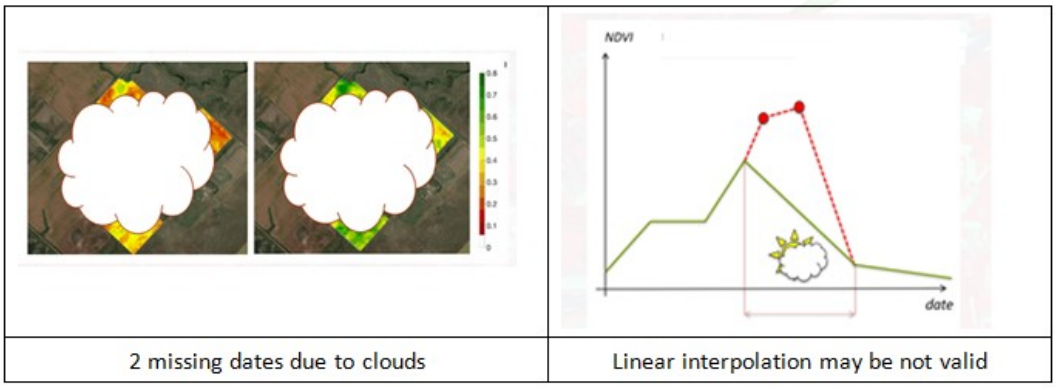

Figure 3: The risks of temporal series interpolation in case of missing observations

Regarding optical images, the main pre-processes consist in ortho-rectification and in atmospheric corrections. These pre-processes are ensured by ESA and the ESA Hub offers as free data, S-2 images at levels L1C (Top Of Atmosphere) or L2A (Bottom of Atmosphere). Paying Agencies are generally accessing L2A products; however, dealing with L1C products may be envisaged if the PA has image experts. Even for the "standardised" product L2A, there are various options for atmospheric correction according to the way to access images: for instance, the ESA hub and the Sen4CAP European project are using different cloud masks.

- **Sentinel 1**

Sentinel-1 provides radar images at resolution 30 m that are powerful but complex products, more difficult to be interpreted.

Sentinel-1 is polarised radar, whose signal may be decomposed according the polarisation of emitting and reflecting signal (horizontal/vertical). In addition, Sentinel-1 may have an ascending orbit (from South to North) or a descending one (from North to South).

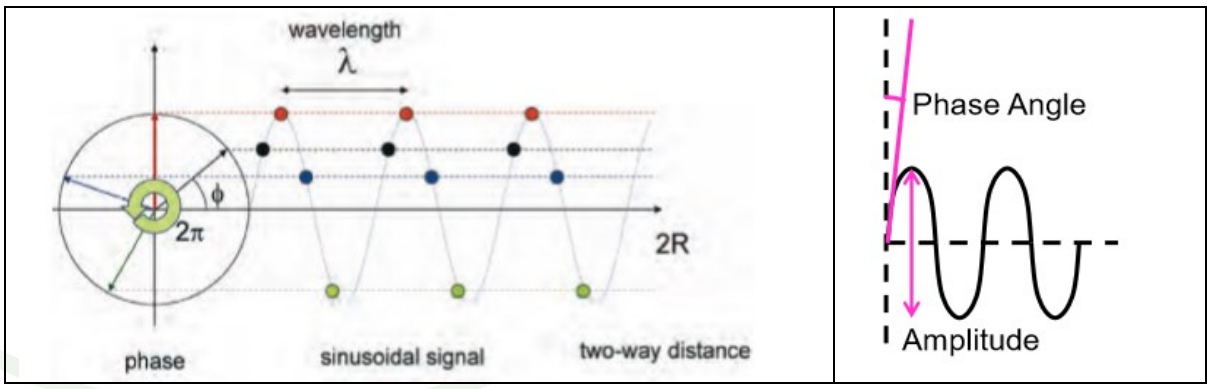

Figure3 Radar signal is a wave characterised by its amplitude and phase

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The ESA Hub offers as free data S-1 images at level L1, i.e. uncompression and coarse georeferencing are ensured. The available products are GRD (Ground Range Detected) with only the amplitude information and SLC (Single Look Complex) with also the phase information.

The more advance pre-processes (such as ground corrections using DEM) are not ensured. However, the ESA provides the SNAP tool that can be used to perform the remaining necessary pre-processes. The choice of the Digital Elevation Model used for the ortho-rectification impacts the geometric accuracy of S-1 data.

«codeList» **Sentinel1GRDMarkerValue** + amplitudeAscending + amplitudeDescending + ratioVVonVHAscending + ratioVVonVHDescending + VHAscending + VHDescending + VVAscending + VVDescending	«codeList» **Sentinel1SLCMarkerValue** + coherenceAscending + coherenceDescending
The markers usually derived from a single radar image	Markers derived from a couple of Sentinel-1 image (with phase information)

Figure 4: Markers from Sentinel-1 images

- **Access to Sentinel images: the issue**

In theory, the Sentinel images may be downloaded from the Copernicus Open Access Hub (https://scihub.copernicus.eu/), either manually or through a REST API that conforms to the Open Search/ open data search standards.

Currently, the most common method to access Sentinel data is to download the Sentinel archives on the area and period of interest, to un-compress and then to read the images.

This method has two main constraints: first, the download of Sentinel archives is time-consuming as open-data APIs are limiting the output flow and number of downloads in parallel to 2 images. The second point is that the method requires significant storage place.

There is another constraint related to the images located in long term archives (LTS). These images acquired more than a few months ago are stored on magnetic bands (or other non-direct access support) and the procedure to get them is more complex than for recent images. First, one has to make a demand to transform the images from Long Term Storage to temporary storage, accessible for download (this may take 1 day) and then one has to do the download demand itself.

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- **Images from other sensors**

The native resolution of S-2 images (10 m) or Sentinel-1 is not enough to monitor all parcels; issues occur for small parcels and also for parcels of specific shape (such as narrow parcels).

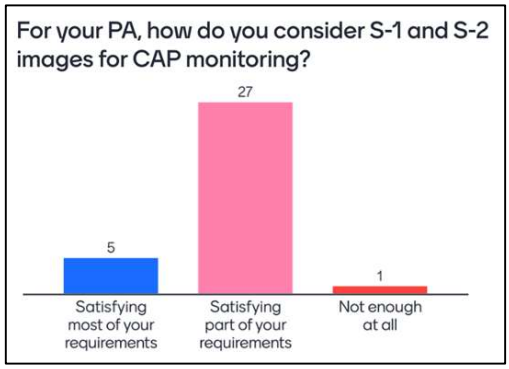

Figure 5: S-1 and S-2 not enough for CAP monitoring (poll among NIVA partners)

Using High High Resolution images such as Planet, SPOT, supra-resolution of S-2 have been mentioned as potential solutions to deal with these issues. Unfortunately, these images are not free of charge. To ensure transparency of the EO monitoring process, farmers should be offered the possibility to view the HHR images that have been used to control their parcels.

4. Set up relevant infrastructure

- **The need for infrastructure**

To cope with the issues related to access to the Sentinel images and to the big volumes of data to be processed, an infrastructure for EO monitoring is required; this infrastructure should provide quick and easy access to Sentinel data, access to data storage capabilities and computation power for the EO monitoring processes (e.g. crop classification).

The storage and handling of these big volumes of data require significant IT infrastructure investment as well as specialized employees that increase the overall cost. Extracting the information at pixel level means that users will have to get the entire image and will have to deal with huge volumes of data. Until now, this is the main available solution on the market. The investment on pre-processing and IT infrastructure may be done in the Paying Agency itself (through buying ICT material and training staff) or it may be outsourced (through buying predefined services and computation power, such as DIAS or other cloud infrastructures). It is mainly between being straightforward (lots of preliminary steps already done before PA accesses the image data) and being flexible (doing things yourself require more expertise but enable to decide on each step of the process).

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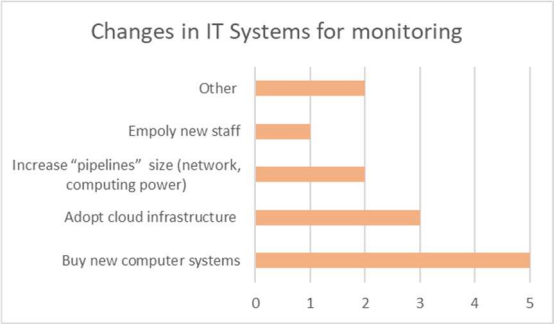

Figure 5: The significant changes in IT system required to perform EO monitoring (feed-back from PA survey)

- ## Standards and services to access EO data

Some more advanced solutions ensuring an easier access to the markers derived from satellite images have been developed. These solutions enable to get at parcel level the markers necessary for EO monitoring operations and so, to run them using reasonable volumes of data. However, the infrastructure necessary to generate the markers from the satellite images has to be paid in a way or another. In other words, the investment for infrastructure may be done by a private company offering commercial services or it may be done directly by the Paying Agency.

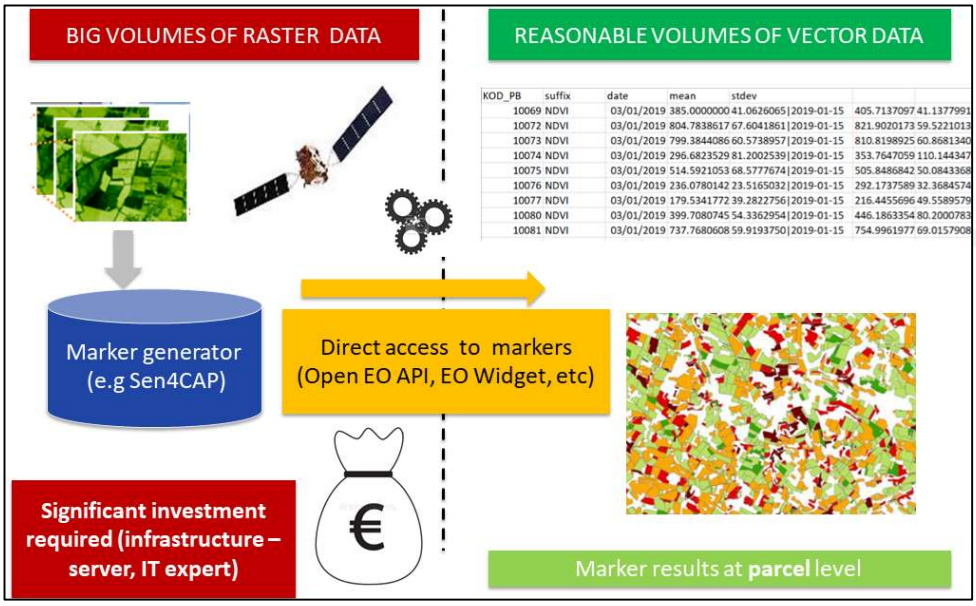

Figure 7: Markers for EO monitoring available through services

The first scenario is proposed by the EO-Widget project; this project is supported by ESA and aims to provide commercial services based on the processors developed by Sen4CAP.
The NIVA project has developed a proposal that is rather expected to work in the second scenario case. This proposal is using standardised Open EO API and is consisting in a set of micro-services based mainly on the marker database coming from Sen4CAP, but that can also

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run with any other marker generator. Until now, to benefit from these services, user has to install the Sen4CAP system (e.g. in own premises or with CREODIAS). In summary, using the NIVA Open EO APIs micro services won't relax Paying Agencies or their technical partners to install Sen4CAP (what is the main difficulty and requires strong IT infrastructure) but it will help to make workflows more automatic, more integrated.

5. Decide and run EO monitoring operations

- **IACS data preparation**

The strategy has to be implemented through concrete monitoring operations, running on real data. However, before running the EO operations themselves, it is often necessary to prepare IACS data, for instance by selecting concerned parcels or by grouping them into Features of Interest.

The NIVA Use Case "Prefilled application" (UC2) has developed a tool for "Preliminary Parcel Boundary Delineation" aiming to help farmers during their declaration. This tool is using itself satellite images.

With Sentinel-2 images (10 m resolution), the preliminary parcels boundaries may be used to detect big errors and sent as warning to farmers	With supra-resolution Sentinel-2 images (resolution 1 m), the preliminary parcels boundaries are good enough to be proposed to farmers for their declaration

Figure7: Results of NIVA Preliminary Parcel Boundary Delineation tool

In addition, UC2 has developed a method for early crop detection, based on Sen4CAP tools and a limited set of satellite images, i.e. only those available before the farmer declaration. This method enables to detect main errors about land cover or about crop seasonality

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(winter/spring crops) and may be used to send alerts to farmers and invite them to correct their declarations.

- ## Description of the EO monitoring operations

The monitoring operation has to be run at a given date and on a given area, this area being most often an administrative unit, an image tile or a bio-geographical region.

It is also necessary to describe how this EO operation (dedicated to a specific process) is conducted, by providing mainly information about the processor that is used and the source of EO data.

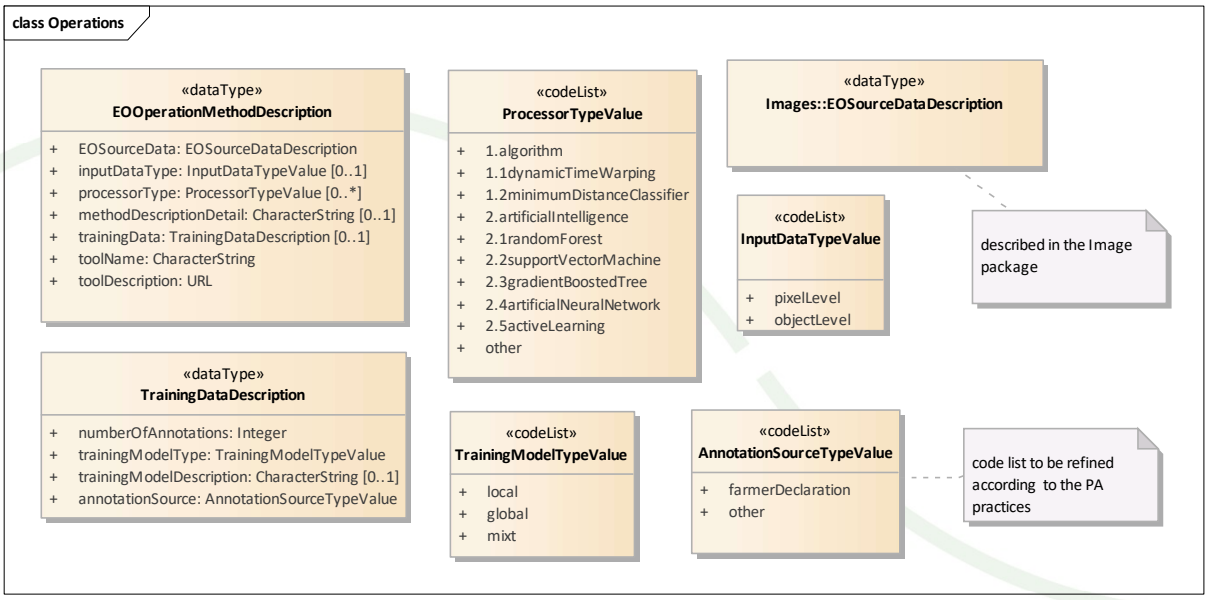

Figure 8: Description of an EO monitoring operation

Machine learning or deep learning processors are often used for EO monitoring operations. In these cases, it is also quite useful to document the characteristics of the training data.

More generally, NIVA is proposing a model called “Base types for EO monitoring” that aims to summarize in a standardized way the various choices that have to be made when designing the new AMS.

- ## Complementary NIVA tools

Using the concepts of the model “Base types for EO monitoring”, NIVA Use Case on EO Monitoring & Traffic lights has conducted a gap analysis between the requirements of NIVA partners and the tools already available on the market: Sen4CAP was already providing the most generic tools but was not solving all issues. Typically, it appeared that Mediterranean countries have specific problems, such as many small parcels or difficult detection of grasslands.

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Therefore, NIVA has investigated innovative solutions to deal with these specific issues, such as using data from other sensors (Planet) to deal with small parcels, using processes other than Random Forest (Gradient Boosted Trees) and more specific markers (e.g. moisture and water indices).

Figure 9: The issue of Mediterranean pastures

The above figure illustrates the issues met to detect Mediterranean grasslands: spatial variability within the plot, gradual transition between classes, spatial patterns involving small elements and objects. To cope with these difficulties, an advanced deep learning process using Convolutional Neural Network has been chosen.

6. Display and exploit the results

- **Results and their reliability**

Results should of course be published on each feature of interest. In case Artificial Intelligence has been used, the result is often expressed as the most likely answer with its probability (e.g. barley, 90%). The NIVA project advises to provide also some quality information for the two main impacting factors: the geometry of the feature of interest and the characteristics of temporal series, in case optical imagery has been used. The number of covered pixels and/or the proportion of the area covered by image pixels compared to the whole area may be used to express the “geometry quality” and to flag the parcels that are too small or too narrow.

The NIVA model is proposing a few examples of potential quality criteria of a temporal series: number of observations, average frequency of observations, length of the longest hole in observations. These criteria have to be adapted to the EO process. The NIVA experience has shown that this is not an easy task to get a simple quality indicator of temporal series.
In addition to the quality information to be provided on each feature of interest, it is recommended to provide also more global quality information on the whole EO monitoring process. For instance, in case of crop classification, the overall accuracy is often used.

However, the above quality information is just coming from an assessment of the EO monitoring process. Real control of the process reliability should be done by comparing the

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results from EO monitoring with independent sources, ideally with ground truth, coming for instance from On The Spot Checks or Rapid Field Visits.

- **From EO monitoring results to traffic lights**

The NIVA UC1a (EO monitoring & traffic lights) has developed a Decision Support System that can derive the traffic lights at parcel level by comparing the crop declared by farmer with the results of crop classification; the eligibility rules with their related threshold values have to be previously defined by the user.

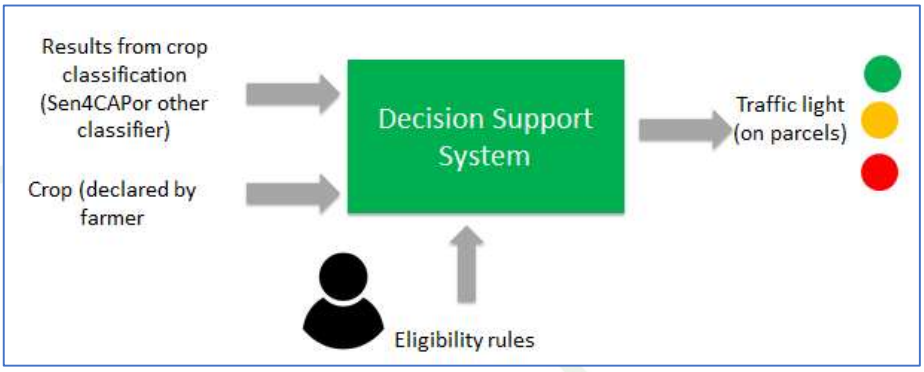

Figure 10: The principle of the Decision Support System

In addition, the NIVA Decision Support System includes also the necessary functionalities to deal with secondary evidences, such as geotagged photos or FMIS data.

7. Priorities for future development

The following priorities have been identified:

1. A common methodology for documenting EO monitoring (and more generally for the AMS) should be designed and widely used by Paying Agencies. This common and relatively detailed documentation will enable to ensure the transparency of the new system and so to build trust with farmers and with citizens (tax payers). In addition, it might be used to compare the various technical solutions between them, to identify remaining issues and to orient further innovation initiatives. In other words, benchmarks are available for common problems so that the relevant improvement of different AI and processing chains can be investigated.
2. A common understanding of fit-for-purpose across agricultural systems of different EO based monitoring chains for land eligibility conditions is required. An agreed and consolidated list of the monitorable land eligibility conditions would be a first step.

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3. The access to satellite images should be facilitated, natively at ESA hub for Sentinel images and by more flexible infrastructures that should be componentized and based on services away from current monolithic solutions. More open source components are required to build a common infrastructure.

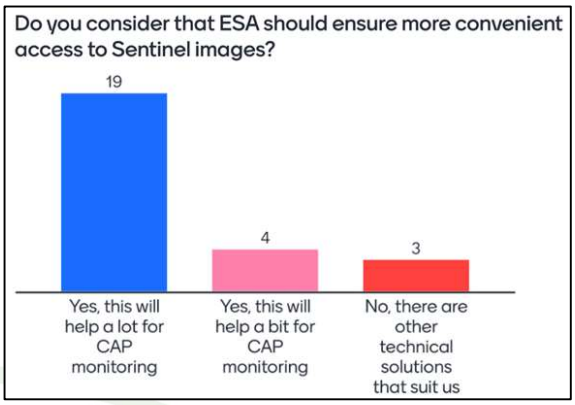

Figure 11: Easier access to Sentinel images required by NIVA partners

4. Research is conducted about the quality assessment of the new EO monitoring system. Ground truth coming from field controls is widely shared to enable researchers and IT companies to assess the reliability of their new processes.

8. Further reading

The NIVA knowledge is documented in two deliverables:

- D3.2 Common Semantic Model with a data model "Base Types for EO monitoring"; it focuses on the description of the EO data processing: D3.2 Common Semantic Model (niva4cap.eu)

- D3.5 Recommendations for standardised connections between IACS and other applications with a chapter about access and pre-process of EO data: D3.5 Recommendations for standardised connections between IACS and other applications (niva4cap.eu)

The NIVA tools (code & documentation) may be found on the NIVA GitLab: nivaeu · GitLab

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9. Background on NIVA.

Modernisation of the Common Agricultural Policy depends in no small part on ongoing digitisation of the Agricultural sector. The Integrated Administration and Control System (IACS) is the key instrument for CAP governance in each member state. Currently, implementations of IACS vary greatly between member states. New IACS Vision in Action (NIVA) delivers a suite of digital solutions, e-tools and good practices for e-governance and initiates an innovation ecosystem to support further development of IACS and to facilitate data and information flows. In NIVA a consortium of paying agencies, research institutes and private sector organisations collaborate to build the next level CAP governance tools. The project is designed to absorb the latest e-tools and digitisation trends to simplify the CAP governance, to reduce administrative burden to farmers and to close the gap between IACS data use and potential broader use.

Contributing to the implementation of the new Area Monitoring System and to wider use of Earth Observation data is among the main objectives of the NIVA project.

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