Sen4CAP - Sentinels for Common Agriculture Policy

Validation Report

Milestone	Milestone 4
Authors	Sophie BONTEMPS, Laura DE VENDICTIS, Philippe MALCORPS, Cecilia SCIARRETTA, Massimo ZAVAGLI
Distribution	ESA - Benjamin KOETZ

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Table of recorded changes

Document status

Issue/Rev.	Date	Reason
0.1	29/03/2019	Creation of the document
0.2	19/07/2019	Internal review of the document
0.3	31/03/2019	Intermediate version, with 2018 validation
0.4	31/03/2020	Last version before final, for internal review
1.0	14/04/2020	Final version, with 2019 validation included
1.1	10/07/2020	Updated version, based on RIDs received from ESA
1.2	21/05/2021	Updated version after CCN2, including 2020 validation

Detailed record sheet

From version 1.0 to 1.1

RID ID	Comment	Section	Change
1	p. 31: table 4-4, Italy (7 regions)	4.2.2	No change in the document – only 5 regions are monitored in 2019 (see section 3.2 for details)
2	p.32: give indications of the timeliness of delivery in 2019 for each country	4.2.4	Text updated + new table 4-5 with all delivery dates for each country
3	p.40: give indications of the start of delivery in 2019 for each country	4.4.4	Information provided
4	P.55: provide justification for proposed grouping from the user perspective or agronomic view instead only from the EO temporal signature. This applies to other countries as well.	5.2 (intro) 5.2.x.4	Intro of Section 5.2 + sub-sections revised
5	Chapter 5: validation of catch crop is done at the level of individual markers – in table 5-111 validation is done at compliance level, please provide an explanation how the accuracy of the detection of a catch crop, nitrogen fixing crop and fallow land was derived	5.4.7	Paragraph added just before the table to explain it

6	Chapter 6.2.2 – please discuss when a sufficient accuracy is been reached in the season or at least above a certain threshold e.g. 0.8 for 5 countries in June. Timeliness was always of importance to PA…	6.2.2	Sentence added on this topic in the analysis
7	Page 140: Please comment on the low performance of mais / mais ensilage – this sounds to me rather a USE driven classification than something we can actually separate	6.2.2	Comment added before the series of graphics
8	Page 144: please add the area of land cover which are not monitored and indicate the % remaining which Sen4CAP cannot classify (because of field size/shape). The same for NDL. This is essential to clarify as not directly related to the EO capacity! If I interpret the figure 6-13 correctly basically in this case only RO remains to have issues with S1/2 resolution e.g. >5% area not monitored.	6.2.3.1	All section revised to clarify this topic
9	P. 171: Can you please comment/justify the low precision in Lithuania?	6.3.4.3 and 6.3.7	Explanations provided in the section
10	P. 178: Please replace the table 6-33 with accumulated accuracies and leave out the total as it is not giving any additional information.	6.4.1.8	Table (now Table 6-36) replaced
11	Chapter 6.4.2 – please clarify and add the sample number on which the validation is based – currently the results in the tables are all based on relative terms	6.4.2	Information added in the introduction of the section Tables captions updated throughout the section
12	Chapter 6.4.2 – please give some indication on why the performance on nitrogen crops and fallow land are so different between Spain and CZE e.g. much worse for CZE	6.4.2.3	Explanation provided for nitrogen fixing crops and fallow land
13	Chapter 6.4.2 – what about the validation in the rest of the countries beside ESP, CZE – please add at least on compliancy level in each country where these agricultural practices have been applied.	6.4.2	Clarification brought in the introduction of the section
14	Chapter 6.4.3: The summary of the agricultural practices validation is incomplete and not sufficient – please add an evaluation of all practices with overall accuracy for each country and interpretation of the results (e.g. sufficient accuracy reaching a certain benchmark), including recommendation to improve	6.4.3	Summary updated

15	Overall recommendation: Include an Executive Summary with a 2 page overview of the performances for the main products – crop type/diversification, grassland mowing, harvest detection, agricultural practices (catch crop, nitro, fallow) with overall accuracy and statement of maturity/robustness from the EO perspective		Added

From version 1.1 to 1.2

RID ID	Comment	Section	Change
NA	NA	6.3.7	New section to reflect the validation of the 2019 grassland mowing product in France (reference data received in 2020)
NA	NA	6.4.1.7	Updated section to reflect the validation of the 2019 harvest detection product in France (reference data received in 2020)
NA	NA	7	New section including the validation of the 2020 demonstration products

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Executive Summary

The Sen4CAP project aimed at providing **validated algorithms**, **products**, **workflows** and **best practices** to use **Sentinel-derived information** for the future CAP area monitoring approach.

During the first phase of the first phase of the project, a list of use cases was identified with the pilot Paying Agencies (PAs), along with relevant Earth Observation (EO) markers and products. A benchmarking was performed to identify the markers and methods that performed best and the first version of the Sen4CAP processing system was implemented. The second phase of the project consisted in the demonstration of these algorithms and workflows by running the developed Sen4CAP processing system at national scale in the pilot countries during two successive seasons (2018 and 2019). This demonstration was done on CREODIAS, with one virtual machine configured for each pilot country.

While in 2018 all products were generated at the end of the season, in 2019 they were processed and generated continuously along the season, as soon as the subsidy applications were provided by the PAs. In Spain (Castilla y León), Lithuania and the Netherlands, a near-real time processing was achieved along the season. In total, **more than 16 million of parcels were assessed** each year, covering around **600.000 km²**. Independent and scientifically-sound validation were performed in 2018 and 2019 for all products.

Crop type maps were generated on a monthly basis between May and September. Each map was validated using a sub-sample of the subsidy applications provided by the PAs, which was not used to calibrate the classification model (i.e. independent dataset). In **2018**, **the Overall Accuracy (OA) ranged from 71 % to 95 %** (Czech Republic, Spain and the Netherlands having an overall accuracy higher than 80%). Improvements brought to the classification chain in **2019** (legend refinement, better selection of calibration dataset, stratification, etc.) allowed **increasing the accuracy in all the countries (between +3% and +9%)**. The OA was higher than 90% in Czech Republic, France (Ain and Normandie) and Netherlands and higher than 80% in Spain (Castilla y León) and Lithuania.

In both years, F-Score, producer's and user's accuracy were analyzed for the 15 main crops. On this basis, recommendations were made to **group together crop types** characterized by **similar phenology and crop calendar** if they belong to the **same high-level crop group** (i.e. grassland and legumes, cereals, winter cereals and spring/summer cereals).

In all the countries, the OA reaches a plateau in July and continues to slightly increase. Depending on the country, the highest OA was achieved in August or September. As early as **June**, **five countries** have an **OA above 0.8**, and **2 above 0.9**

The classification results and conformity assessment at the parcel-level were then used to assess the compliancy of the holdings regarding crop diversification rules. Despite the fact that the rules used to conduct this exercise are not as complex and complete than the ones currently implemented in the PA's workflows, the exercise has demonstrated the relevance of Sentinel-derived information. It has shown the **limited impact of parcel size and shape** on the assessed area (0.4% to 1.3% except in Italy and Romania, with 5.2% and 7.8% respectively) and on the holdings assessment (lower than 5%).

The **grassland mowing products** were validated using truth data coming from (i) visual interpretation of Planet data and (ii) farmers interviews when available. In **2018**, the products in all countries were associated with a **high recall, but with a too low precision**. This conclusion led to significant adjustment of the algorithm for the 2019 demonstration (better identification of outliers related to cloud cover and cloud shadow, thresholds fine-tuning, decreased sensitivity to the drying). The **2019** results showed a relevant increase in precision, without decreasing the recall index, for all countries. The **recall** ranged **from 68-69%** (Spain - Castilla y León, Czech Republic) **to 88%** (Italy) while the **precision** was a bit lower (from **51 and 53%** in Romania and Spain - Castilla y León respectively to **72%** in the Netherlands and **76%** in Czech Republic).

The validation allowed identifying **two main drivers of the products accuracy**: the **parcel size** and the fact that **the mowing can be done only on a part of the parcel** (i.e. partial mowing). Logically, the algorithm performance slightly increases when considering larger parcels and parcels completely mowed. The **precision of southern countries** (Italy, Spain - Castilla y León and Romania) is a bit **lower than in the northern countries**, due to the grassland drying and grazing, both practices having a negative impact on the algorithm performance.

In 2019, for all the countries except Romania, the products were delivered **on a monthly basis from April to October**. Like for the crop type maps, the **maximum accuracy** was reached in **August or September**. In the October products, a decrease in the accuracy was observed for Lithuania (-11% in precision) and Spain - Castilla y León (-6% in recall).

Like for the **grassland mowing products**, the agricultural practices monitoring (EFA) products were validated using truth data coming from (i) visual interpretation of Planet data and (ii) farmers interviews when available.

First, the **accuracy of the harvest for the main crop** was assessed, which is a prerequisite to have an EFA crop. In both 2018 and 2019, the results showed an accuracy **above 70% (if one-week difference between real and detected event is considered) and above 80% (for two-week difference)** in all countries except for Spain. The results are rather consistent among individual countries, confirming that the method is robust and works well in different conditions.

The **validation of agricultural practices crop monitoring** was done through individual markers used for the evaluation of the respective EFA practice. Again, the results showed very good overall performance (**overall accuracy higher than 80%**) and consistency, despite a diversity of regulations and agricultural practices amongst the pilot countries.

The **main drivers** of the algorithm performance identified are the **parcel size** (higher accuracy for larger parcels), the **parcel homogeneity** (homogeneous parcel cover and application on entire parcel were assumed) and **Sentinel time series density** (gaps in EO time series having negative impact on the quality of the results).

In **2020**, the Sen4CAP system was run a third time for 3 countries: **Czech Republic, Lithuania and Romania** and the validation of the EO products was repeated following the same protocol as in 2018 and 2019. The **same kind of results** were obtained for all products, showing the **robustness and the repeatability of the Sen4CAP system** as well as the consistency of the sentinel data between years.

The tillage detection algorithm was added in the 2020 and the validation of this new processor has been successfully run for the two pilot countries that provided reference datasets: Spain (Castilla y Leon) and Lithuania.

1. Introduction

1.1 Purpose and scope

This document is the Validation Report (VR) of the Sentinels for Common Agriculture Policy (Sen4CAP) project funded by the European Space Agency (ESA).

The overall objective for the Sen4CAP project is to provide the European and national stakeholders of the Common Agriculture Policy (CAP) validated algorithms, products, workflows and best practices for agriculture monitoring relevant for the management of the CAP. Special attention shall be given to provide evidence how Sentinel derived information can support the modernization and simplification of the CAP in the post 2020 timeframe.

The PVAR is one output of the Task 6 (WP 6000) of the Sen4CAP project, named "National Demonstration" (Figure 1-1).

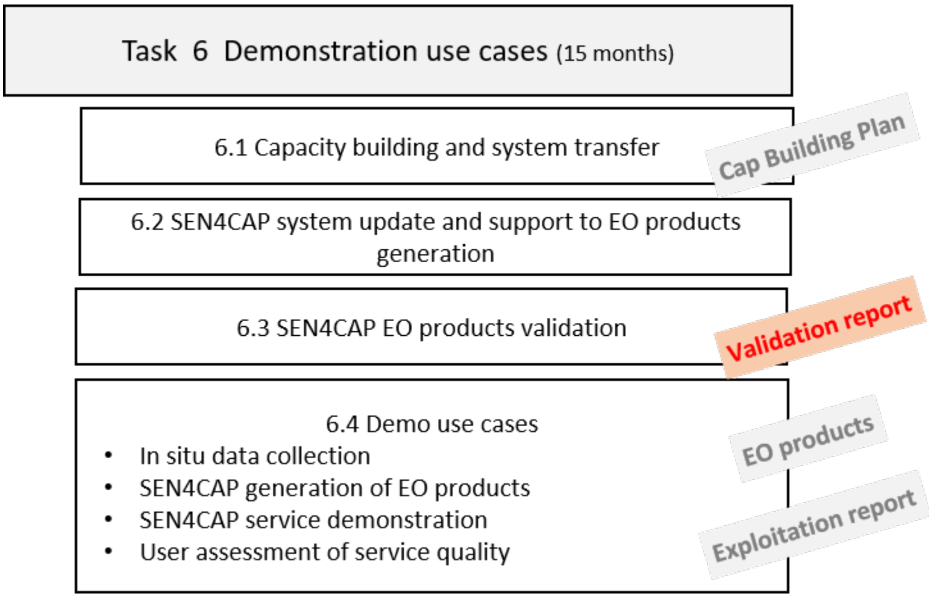


Figure 1-1. Organization of the Task 6 activities (from [AD.4])

The VR aims at:

- describing the data used for generating the demonstration products from 2018 and 2019;
- validating the fact that the Sen4CAP system generates products compliant in terms of definition, structure and content with the products specifications defined in [AD.4];
- validating the 2018 and 2019 demonstration products using common quantitative indicators.

1.2 Structure of the document

After this introduction, this document contains ***5*** sections:

- Section ***2*** summarizes the users and technical requirements associated with each product;
- Section ***3*** details the data sets gathered during the demonstration phase and used to generate the demonstration products;
- Section ***4*** assesses the compliancy of the products with regard to the technical specifications defined at the beginning of the project;
- Sections ***5*** and ***6*** quantitatively assess the demonstration products using common quantitative indicators for the years 2018 and 2019 respectively.

1.3 References

1.3.1 Applicable documents

Table 1-1. Applicable documents

ID	Title	Reference	Issue/Rev.	Date
AD.1	Statement of Work for ESA Sentinels for the common agricultural policy	EOEP-EOPS-SW-17-015	1.0	15/03/2017
AD.2	Sen4CAP User Requirement Document	Sen4CAP_URD_1.3	1.3	09/11/2017
AD.3	Sen4CAP Test Data Set	Sen4CAP_TDS_1.0	1.0	12/04/2018
AD.4	Sen4CAP Technical Specifications	Sen4CAP_TS_1.0	1.0	28/02/2018
AD.5	Sen4CAP Design Justification File	Sen4CAP_DJF_1.0	1.0	16/04/2018
AD.6	Sen4CAP Design Definition File	Sen4CAP_DDF_1.2	1.2	11/04/2019
AD.7	Sen4CAP Acceptance Test Document	Sen4CAP_ATD_1.0	1.0	09/09/2018
AD.8	Sen4CAP Qualification Review Report	Sen4CAP_QRR_1.0	1.0	11/04/2019

1.3.2 Acronyms and abbreviations

Table 1-2. List of acronyms and abbreviations

Acronym	Definition
AOI	Area Of Interest
BOA	Bottom Of Atmosphere
CAP	Common Agricultural Policy
CESBIO	Centre d'Etudes Spatiales de la BIOsphère
CNES	Centre National d'Etudes Spatiales
CS RO	CS Romania

CyL	Castilla y Leon
CZE	Czech Republic
DLR	Deutschen Zentrum für Luft- und Raumfahrt
EAA	Eligible Agriculture Area
EFA	Ecological Focus Area
EO	Earth Observation
ESA	European Space Agency
ESP	Spain
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
fCover	Fraction of vegetation cover
FN, FP	False Negative, False Positive
FRA	France
GAI	Green Area Index
GSAA	GeoSpatial Aid Applications
GST	Gisat
ITA	Italy
L8	Landsat 8
LAI	Leaf Area Index
LPIS	Land Parcel Identification System
LTU	Lithuania
LUT	Look-Up Table
MACCS	Multi-sensor Atmospheric Correction and Cloud Screening
MAJA	MACCS-ATCOR Joint Algorithm
NDVI	Normalized Difference Vegetation Index
NFC	Nitrogen Fixing Crops
NLD	Netherlands
OA	Overall Accuracy
PA	Paying Agency
ROU	Romania
S1, S1A, S1B	Sentinel-1 (A and B)
S2, S2A, S2B	Sentinel-2 (A and B)
SAR	Synthetic Aperture Radar
SenCAP	Sentinel-2 for Agriculture
SIN	Sinergise
SLC	Single Look Complex

SoW	Statement of Work
TOA	Top Of Atmosphere
TOPS	Terrain Observation with Progressive Scans
TN, TP	True Negative, True Positive
UCLouvain	Université catholique de Louvain
VR	Validation Report
WMS	Web Mapping Service

2. Technical requirements associated with the Sen4CAP EO products

The technical requirements against which the products (and the system) shall be validated were identified in [AD.2]. The technical requirements specific to the products are documented in Table 2-1. The assessment of the technical requirements related to the system is documented in [AD.7].

Table 2-1. Summary of the technical requirements related to the products (from [AD.2]

SPECIFIC REQUIREMENTS	
METHODS	
UR_Met_1	Sen4CAP methods shall do wall-to-wall or 100% coverage to allow **spatially continuous monitoring at national scale**
UR_Met_2	Sen4CAP methods shall make use of the frequent revisit cycle of Sentinel missions to allow **continuous monitoring over time**, by observing **multi crop cycles within the year** and delivering **continuous EO-derived assessment**
UR_Met_3	Sen4CAP shall **validate all involved algorithms**, products, workflows and **indicate their performance and reliability for agriculture monitoring** relevant for the management of the CAP.
UR_Met_4	Sen4CAP methods shall be **consistent over multi-year periods**
UR_Met_5	Sen4CAP methods shall allow supporting **farmers' practices**
UR_Met_6	Sen4CAP methods shall focus also on the **integrated use of both S1 and S2 data** for the CAP IACS purposes
UR_Met_7	For each developed method, the **parcel area threshold** at which the proposed monitoring approach is reliable and accurate needs to be determined
UR_Met_9	Sen4CAP methods for generating the EO products supporting the use cases should **not be site specific**, to tackle the diversity of European countries in the CAP
SYSTEM	
UR_Sys_5	Sen4CAP system shall deliver the interpretation of the processed Sentinel data **associated with a confidence index**
EO PRODUCTS	
UR_Pro_1	**<u>Cultivated crop type map</u>** 1.1 Coverage: national (for declared LPIS parcels) with statistics at national and farm levels 1.2 Time period: 2016-2019 1.3 Temporal frequency: intra-seasonal products (no clear information on the frequency but starting as soon as possible) + annual products 1.4 Delivery time: 1-2 weeks after the end of observation period 1.5 Spatial resolution: 10-20 meters (it should be possible to link the resulting information to declared LPIS parcel) 1.6 Geometric accuracy: pixel location error (it should be possible to link the resulting information to declared LPIS parcel)

	1.7 Thematic accuracy: no accuracy requirement expressed by the user; need for multi-year consistency 1.8 Thematic content: depending on the application and on the country/region 1.9 Quality flag: at least one informing about the error estimate
UR_Pro_2	**Grassland mowing** 2.1 Coverage: National over declared parcels 2.2 Time period: 2016-2019 2.3 Temporal frequency: weekly 2.4 Delivery time: one week 2.5 Spatial resolution: 20 meters (it should be possible to link the resulting information to declared LPIS parcel) 2.6 Geometric accuracy: pixel location error (it should be possible to link the resulting information to declared LPIS parcel) 2.7 Thematic accuracy: no accuracy requirement expressed by the user 2.8 Thematic content: mowing extensions, date range of the mowing 2.9 Quality flag: at least one informing about the error estimate
UR_Pro_3	**Vegetation status indicator** 3.1 Coverage: national 3.2 Time period: 2016-2019 3.3 Temporal frequency: for each acquisition + average product on a weekly basis (to have regular time steps) 3.4 Delivery time: 1-2 days after each acquisition or 1-2 days after each week (should be a fixed day) 3.5 Spatial resolution: 10-20 meters (it should be possible to link the resulting information to declared LPIS parcel) 3.6 Geometric accuracy: pixel location error (it should be possible to link the resulting information to declared LPIS parcel) 3.7 Thematic accuracy: no accuracy requirement expressed by the user 3.8 Possible variables: NDVI, LAI, GAI, fAPAR, fCover 3.9 Quality flags: at least one informing about the error estimate
UR_Pro_4	**Agricultural practices** 4.1 Coverage: National (for declared LPIS parcels) 4.2 Time period: 2016 - 2019 4.3 Temporal frequency: Intra-seasonal products (depending on the application - see section 2.7.4) 4.4 Delivery time: 1-2 weeks after the end of the observation period 4.5 Spatial resolution: 10-20m (it should be possible to link the resulting information to declared LPIS parcel) 4.6 Geometric accuracy: pixel location error (it should be possible to link the resulting information to declared LPIS parcel) 4.7 Thematic accuracy: no accuracy requirement expressed by the user 4.8 Thematic content: depending on the application (see section 2.7.4) 4.9 Quality flags: at least one informing about the error estimate

UR_Pro_5	<u>**Interactive visualization services for satellite imagery and use-case products**</u> 5.1 Services: visualization tool and application for cross-checking data provided by PAs (e.g. LPIS, declarations, etc.) with core Sen4CAP EO products identified in sections 2.7.1 to 2.7.4 5.2 Format: OGC standard compliant web services (primarily WMS) and CSV 5.3 Inputs: - S1, S2 and L8 data in various band combinations - atmospherically corrected optical data 5.4 Functionalities: - showing data on specific dates - showing data over full countries - support national geographic projections - query by LPIS parcel identifier (and similar identifier for other object types) - export data in a tabular form (assessment of the validity of declared data together with accuracy of automatically calculated data)
UR_Pro_6	All EO products shall be delivered in **WGS84 and in national projections**
UR_Pro_7	All EO products shall be delivered in a **standard and open format**, allowing **easy visualization** and **translation into alfa-numerical records** to be cross-checked with the farmer's declarations
UR_Pro_8	All EO products shall be delivered with **clear metadata** using standard formats
UR_Pro_9	EO products metadata shall provide **traceability** to identify which Sentinel imagery were used for the production
UR_Pro_10	All products shall be **validated against in-situ** data when available and **quality-controlled**

3. Dataset used for generating the demonstration products

3.1 Earth Observation dataset

Earth Observation (EO) data used for the 2018 demonstration are from both optical (Sentinel-2 (S2) and Landsat 8 (L8)) and Synthetic Aperture Radar (SAR) (Sentinel-1 (S1) sensors. Dense time series of both SAR and optical images are expected to enable to handle different data flow dynamics providing more complete information all along the growing season.

S2 and L8 data were acquired as L1 Top of Atmosphere (TOA) reflectance (S2 L1C and L8 L1T) products. They were converted to accurate Bottom-Of-Atmosphere (BOA) reflectance, with a good quality cloud mask (L2A product), based on the MACCS-ATCOR Joint Algorithm (MAJA), jointly developed by the Centre d'Etudes Spatiales de la BIOsphère (CESBIO), the French Space Agency (Centre National d'Etudes Spatiales - CNES) and the German Aerospace Center (Deutschen Zentrum für Luft- und Raumfahrt - DLR). MAJA is a joined evolution of the Multi-sensor Atmospheric Correction and Cloud Screening (MACCS) and ATCOR algorithms.

The L2A processing was applied over all available tiles on CREODIAS, with a cloud cover lower than 90%. All images were pre-processed with the same set of parameters, including the aerosol model, which is a continental one made of small particles (log normal size distribution with a modal radius of 0.2 µm, low absorption).

The SAR data pre-processing generates time series of SAR amplitude/phase and coherences. The pre-processing starts with the Single Look Complex (SLC) L1 of the S1 IW data (Terrain Observation with Progressive Scans (TOPS) mode) in order to generate (i) one stack of calibrated, co-registered and projected amplitudes and (ii) one stack of co-registered and projected 6-days coherences data. Both ascending and descending orbits have been selected in order to guarantee the full coverage of the area of interest with 6-days interferometric stacks.

3.2 Subsidy applications

Three datasets derived from yearly aid applications are required to run the Sen4CAP analyses:

- Land Parcel Identification System (LPIS) datasets
- Extract from subsidy applications (tables)
- Parcel boundaries (GeoSpatial Aid Applications - GSAA)

Note: GSAAs may be already integrated in the LPIS.

In Italy, the GSAA dataset provided by the Paying Agency (PA) covered the following regions:

- 2018: Friuli Venezia Giulia, Marche, Lazio, Campania and Puglia;
- 2019: Piemonte, Friuli Venezia Giulia, Lazio, Campania, Puglia and Calabria.

These datasets are provided by PAs. The structure, format and content of individual datasets differ significantly country by country however - as minimum – this information needs to be included:

- Parcel vector boundaries;
- Unique parcel ID;
- LPIS crop category;
- Declared crop;
- Flag to identify parcels with declared Ecological Focus Areas (EFAs) and EFAs sub-categories.

3.3 Validation data

3.3.1 Planet data interpretation

With more than 150 optical satellites in orbit, Planet is able to image anywhere on Earth daily at 3 to 5 meter resolution.

The true-colour Planet image composites are available for the Sen4CAP project for visual interpretation and in this way, the ground-truth data are obtained.

The visual interpretation is focused on the identification of harvest/clearance on arable land parcels and mowing/grazing on grassland parcels. At the same time the parcel status, such as the presence of bare soil/green vegetation cover or crop vegetation growth), is also interpreted for given reference periods.

This information is used to prepare reference datasets to validate the results of automated analysis performed by the Sen4CAP processors of grassland mowing and of EFA practices monitoring.

3.3.2 Farmers interview

In cooperation with the PAs, the farmers were approached to report the information on:

- Timing of harvest/clearance or mowing/grazing on the parcel (available for most of countries);
- Timing of other agricultural practices on the parcel during the year, e.g. the seedbed preparation, the sowing of the crop, handling of the crop residues, drying of the grass, baling of the grass, etc. (available only for few countries).

The information on the harvest/clearance or the mowing/grazing on the parcel were used for direct validation of the results of automated analysis performed by the Sen4CAP system.

The other information was first interpreted into the form of the marker values (e.g. loss/no loss of the vegetation, presence of the vegetation/bare soil) within the specific EFA periods. Then these datasets are used for validation.

4. Compliance in terms of definition, structure and content specifications

4.1 Biophysical indicator product

4.1.1 Information included in the product

The compliancy of the information included in the biophysical indicator data produced in 2018 and 2019, has been verified based on the technical specifications defined in the Sen4CAP Technical Specifications [AD.4] (Table 4-1).

Table 4-1. Information included in the biophysical indicator products

		Description	Included	Comments
REQUIRED FROM [AD.4]	RESULTS			
	1	Normalized Difference Vegetation Index (NDVI)	Yes	
	2	Leaf Area Index (LAI)	Yes	
	3	Fraction of Vegetation Cover (FCover)	Yes	
	4	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	Yes	
	QUALITY FLAGS			
	1	Pixel status: 0 = No Data / 1 = Cloud / 2 = Snow / 3 Water / 4 = Land	Yes	
	2	LAI retrieval uncertainty: Root Mean Square Error (RMSE) expressed as a function of the estimated value	No	Due to switch to last version of INRA algorithm

Compared with what was defined in [AD.4], the first difference concerns the LAI retrieval uncertainty quality flag. This flag was abandoned when updating the processor to the last version of INRA algorithm. The second difference concerns the additional use of L8 data in the products. Due to the already high temporal density of S2 data and the larger spatial resolution of L8 data (30 meters), it was decided to use only the S2 dataset for the production of the biophysical indicator products.

4.1.2 Spatial and temporal extent

As required in the Sen4CAP Technical Specifications [AD.4], the biophysical indicator products have been generated at national scale, based on the complete S2 dataset (i.e. all acquisitions) of 2018 and 2019.

4.1.3 Spatial and temporal resolution

As required in the Sen4CAP Technical Specifications [AD.4], the biophysical indicator products have been generated at 10-meter spatial resolution, for each S2 acquisition date. It was decided not to produce the weekly mosaics.

4.1.4 Delivery time

The biophysical indicator products (2018 and 2019) have been delivered 1-2 days after each acquisition, within the time limits defined in [AD.4].

4.1.5 Format projection and metadata

In 2018 and 2019, the biophysical indicator products have been delivered in WGS84-UTM projection, as raster images (GeoTIFF format), as defined in [AD.4]. A metadata file has been delivered with each product, containing all useful information (projection, spatial resolution, extent, content, no data value, etc.).

4.2 Crop Type map

4.2.1 Information included in the product

The compliancy of the information included in the crop type maps produced over the 2018 and 2019 seasons, has been verified based on the technical specifications defined in the Sen4CAP Technical Specifications [AD.4] (Table 4-2).

Table 4-2. Information included in the crop type map products

		Description	Included	Comments
REQUIRED FROM [AD.4]	RESULTS			
	1	Original parcel or block Identifier (ID)	Yes	
	2	Area of the original parcel or block	Yes	
	3	Declared crop type (expressed using the crop type coding (numeric or text) used by the PA providing the declaration)	Yes	
	4	First and second observed crop type (expressed using the crop type coding (numeric or text) used by the PA providing the declaration) which is the crop type detected by the algorithm with the first and second highest confidence	Yes	Except that the observed crop types are expressed using the Sen4CAP L4A crop code
	5	Prediction confidence of the first and second observed crop types (expressed as a percentage)	Yes	
	6	Conformity of the polygon (expressed as a numeric code and providing about the quality of the parcel or block with respect different aspects such as the size, the shape, the quality of the polygon delineation, the quality of the calibration for the associated crop type, etc.)	Yes	Area_meters, ShapeInd, GeomValid, Duplic, Overlap, S1Pix, S2Pix
	7	Compliance decision for the parcel, between the declared and observed crop types	Yes	
	QUALITY FLAGS			
	1	Original parcel or block ID	No	

	2	The total number of valid observations during the period used to generate the product	No	
	3 to 54	52 columns corresponding to the 52 weeks of the year, and for which values are incremented each time a valid observation is registered during the week. The objective is to provide information about the temporal distribution of the observations available for the classification	No	
ADDED	**RESULTS**			
	1	Conformity assessment (parcel-level)	Yes	Classif_r
	2	Crop diversification use case (holding-level): category assessment	Yes	CD_cat
	3	Crop diversification use case (holding-level): compliancy assessment	Yes	CD_diagn
	QUALITY FLAGS			
	/			

Compared with what is defined in [AD.4], the first difference concerns the expression of the first and second observed crop type in the product. It is not expressed using the original crop type coding (numeric or text) used by the Paying Agency (PA) providing the declaration dataset but the Sen4CAP L4A crop code used for the classification. The reason is that some of the original crop types are grouped together before the classification to increase the quality of the classification, because they have a very similar (or the same) phenology. For instance, it can be the case of different varieties of onions which are differentiated in the original declaration dataset but whose differentiation does not make sense. Therefore, the Sen4CAP L4A crop codes are kept in the product. It should be noted that the correspondence between each original crop type code and the Sen4CAP L4A crop code is given in a dedicated Look-Up-Table (LUT) which is written with/by the country.

The second difference concerns the generation of quality flags that inform about the number and the distribution (throughout the season) of the observations used to process the L4A crop type maps. This information has been revised during the first phase of the project based on the prototype products; and it is no more planned to follow the specifications from [AD.4].

On top of that, 3 new fields have been added to the product. They give information concerning the assessments that are done in the context of the crop diversification use case:

- Conformity assessment at the parcel-level: the results of the classification are used to assess the compliancy of the crop declaration, at the parcel-level;
- Crop diversification category assessment (holding-level): the results of the classification and the conformity assessment at the parcel-level are used to assess for each holding to which crop diversification category it belongs;
- Crop diversification assessment (holding-level): the results of the classification and the conformity assessment at the parcel-level are used to assess the compliancy of each holding regarding crop diversification rules.

4.2.2 Spatial and temporal extent

Both in 2018 and 2019, the crop type products were processed as defined in [AD.4], i.e. at national or regional (in the case of France, Italy and Spain) scale, using the complete declaration datasets. The extent and number of parcels processed in 2018 and 2019 are given in Table 4-3 and Table 4-4.

Table 4-3. Extent and number of parcels processed by site in 2018

Country	Area of interest	EO data	Total area (km²)	Number of parcels
Castilla y León (Spain)	100% of the region	S1 + S2	94,226	3,540,880
Czech Republic (full country)	100% of the country	S1 + S2	78,873	593,787
Italy (5 regions)	100% of the regions	S1 + S2	67,270	8,527,409
Lithuania (full country)	100% of the country	S1 + S2	64,897	1,153,796
Netherlands (full country)	100% of the country	S1 + S2	42,508	802,217
Romania (full country)	100% of the country	S1 + S2	238,369	6,127,057

Table 4-4. Extent and number of parcels processed by site in 2019

Country	Area of interest	EO data	Total area (km²)	Number of parcels
Castilla y León (Spain)	100% of the region	S1 + S2	94,226	102,897
Czech Republic (full country)	100% of the country	S1 + S2	78,873	597,748
France (2 departments)	100% of the regions	S1 + S2	35,862	611,074
Italy (5 regions)	100% of the regions	S1 + S2	84,770	5,718,943
Lithuania (full country)	100% of the country	S1 + S2	64,897	1,185,424
Netherlands (full country)	100% of the country	S1 + S2	37,380	806,247
Romania (full country)	100% of the country	S1 + S2	238,369	6,091,197

In 2018, the monitoring period has been settled for the 6 sites to the period from the 1st of January until the 31st of October 2018.

In 2019, using the experience gained in 2018, the monitoring period was reduced to the period from the 1st of March to the 30th of September 2019 in the countries characterized by a stronger winter: Czech Republic, Lithuania, the Netherlands and Romania. In Castilla y Leon, France and Italy, the monitoring period was settled to the period from the 1st of January to the 30th of September 2019.

4.2.3 Spatial and temporal resolution

The crop type maps are delivered at the parcel-level. It consists of an update of the attribute table from the original declaration datasets with the information presented in the point 4.2.1.

In 2018, the crop type maps were processed and delivered only once, at the end of the season. In 2019, the production was performed in a continuous mode, meaning that the product was processed and delivered several times along the season, in near-real time when it was possible. A production plan was established with each PA; generally, the crop type map was produced on a monthly-basis, from the end-of-May to the end-of-September (5 consecutive products).

4.2.4 Delivery time

In 2018, due to the large delay in the pre-processing of the S2, S1 and L8 data, the crop type maps were not delivered as planned at the end of the 2018 season (in November 2018) but once the preprocessing was finished. Once the S2, S1 and L8 pre-processed data were ready, the L4A crop type map keeps the delivery time under 10 days.

In 2019, a near-real time processing was tested when it was possible. Depending on the country, different factors affected this near-real time processing, and thus the delivery time:

- The availability of the subsidy applications layer: when the subsidy applications layer was available late in the season, it was decided with the PA to start the production with the July product, and continue the production in this order: August, September, May and June;
- The continuous upload of parcels: new functionalities had to be developed to allow the upload of parcels several times during the season with modifications, for the same site;
- The output production steps and visual checks: not all the output production steps were automatized at the beginning of the season (which is the case now), and each delivery still requires some visual checks.

Nevertheless, the best effort was given to stick as much as possible to the planning defined with each PA and to the 10 days delivery time objective. Table 4-5 shows the delivery date of all the crop type maps delivered to the PAs in 2019.

Table 4-5. Delivery date of the 2019 crop type maps to the PAs (end-of-the-month products)

Country	May	June	July	August	September
Castilla y León (Spain)	23-07-19	13-08-19	02-09-19 (v1) 15-10-19 (v2)	17-10-19	04-11-19
Czech Republic (full country)	05-12-19	05-12-19	24-10-19	16-10-19	04-11-19
France (2 departments)	13-01-20	13-01-20	21-11-19	13-01-20	13-01-20
Italy (5 regions)	04-02-20	04-02-20	15-11-19	07-01-20	04-02-20
Lithuania (full country)	07-06-19	09-08-19	25-09-19 (v1) 03-10-19 (v2)	14-10-19	28-10-19
Netherlands (full country)	23-07-19	09-08-19	26-08-19	14-10-19	25-10-19
Romania (full country)	29-01-20	30-01-20	17-12-19	18-12-19	29-01-20

4.2.5 Format, projection and metadata

The L4A crop type maps were delivered in the shapefile format, in the national projection, as requested by the PAs. As explained in the section 4.2.1, the generation of quality flags about the number and distribution (throughout the season) of the observations used for the process of the L4A crop type maps was not implemented and therefore, no additional .dbf table was produced.

No metadata was produced along with the L4A crop type maps. However, a standard README document accompanied each delivered product, in order to easily interpret the results. A QUICK USER GUIDE dedicated specifically to the crop diversification use case was also delivered with each product.

4.3 Grassland Mowing detection product

4.3.1 Information included in the product

The compliancy of the information included in the grassland mowing maps produced over the 2018 and 2019 seasons, has been verified based on the technical specifications defined in the Sen4CAP Technical Specifications [AD.4] (Table 4-6).

Table 4-6. Information included in the grassland map products

		Description	Included	Comments
REQUIRED FROM [AD.4]	RESULTS			
	1	Original parcel or block Identifier (ID)	Yes	
	2	Area of the original parcel or block	Yes	
	3	Declared crop type (expressed using the crop type coding (numeric or text) used by the PA providing the declaration)	Yes	
	4	Number of mowing events detected during the April – October period (value domain: 0, 1, 2, 3, 4)	Yes	
	5	The couple of dates representing the interval of time in which the mowing i (from 1 to 4) is observed	Yes	
	6	The confidence index, expressed as a probability ranging from 0 to 1, of the mowing i (from 1 to 4) detection - there are as many columns as mowing events observed	Yes	Except that the confidence index ranges from 0.5 to 1 for the mowing events detected by S2 or both S2 and S1, and from 0 to 0.5 for mowing events detected by S1
	7	The satellite mission (S1, S2 or both) used to detect the mowing i (from 1 to 4) - there are as many columns as mowing events observed;	Yes	
	8	A compliance flag for the parcel, between the declared practice and the mowing detection achieved by remote sensing	Yes	Except that it is a compliance flag between the national regulation and the mowing detection achieved by remote sensing
ADDED	RESULTS			
	1	Unique parcel or block Identifier (ID)	Yes (2019)	NewID
	2	Original Holding identifier	Yes (2019)	Ori_hold

4.3.2 Spatial and temporal extent

Both in 2018 and 2019, the grassland mowing detection products were processed at national scale, over the declared GSAA parcels (or over specific regions in Spain and Italy, depending on the coverage of GSAA provided).

Table 4-7. Extent and number of parcels processed by country in 2018

Country	Area Of Interest	EO input	Total area (km²)	Total parcels (nr)
NLD	100 % country	S2 + S1	7.739	404.975
CZE	100 % country	S2 + S1	10.241	323.226
LTU	100 % country	S2 + S1	8.996	492.490
ITA	100 % of the AOI (5 Regions)	S2 + S1	1.942	282.842
ESP	100 % of the AOI (Castilla Y Leon)	S2 + S1	37.184	1.288.567
ROU	100 % country	S2 + S1	26.414	2.080.995

Table 4-8. Extent and number of parcels processed by country in 2019

Country	Area Of Interest	EO input	Total area (km²)	Total parcels (nr)
NLD	100 % country	S2 + S1	10.209	501.663
CZE	100 % country	S2 + S1	10.373	336.905
LTU	100 % country	S2 + S1	8.643	532.208
ITA	100 % of the AOI (5 Regions)	S2 + S1	8.788	778.594
ESP	100 % of the AOI (Castilla Y Leon)	S2 + S1	289	11.841
ROU	100 % country	S2 + S1	33.401	1.803.910

The 2018 and 2019 monitoring period has been settled for the 6 sites to the period from the 1st of January until the 31st of October.

During the demonstration phase, the product is generated to cover the periods from April to October 2018 and 2019.

4.3.3 Spatial and temporal resolution

The products are generated at the agricultural parcel level, which has to be considered as the effective spatial resolution of the product.

In 2018, the products were delivered once, at the end of the monitoring period (October 2018). In 2019, the first delivery took place as soon as the declarations are available based on all the images acquired from the 1st of April and until this date. Then, the product was updated monthly (or be-weekly depending on user requirements) based on the subsequent satellite acquisitions.

4.3.4 Delivery time

In 2018, due to the large delay in the pre-processing of the S2 and S1 data, the grassland mowing maps were not delivered as planned at the end of the 2018 season (in November 2018) but once the preprocessing was finished. Once the S2 and S1 pre-processed data were ready, the L4B grassland mowing map keeps the delivery time under 10 days.

In 2019 the grassland mowing map kept meanly the delivery time under 5 days, once the GSAA layers were available from the PAs. In most cases, the GSAA layers were available not before the mid of the season (July, August), therefore the monthly (or bi-weekly depending on user requirements) delivery was "mimicked" providing the products ex-post, starting from May.

4.3.5 Format projection and metadata

The L4B grassland mowing maps were delivered in the shapefile format, in the national projection, as requested by the PAs.

No metadata was produced along with the L4B grassland mowing maps. However, a standard README document accompanied each delivered product, in order to easily interpret the results. A QUICK USER GUIDE dedicated specifically to the grassland mowing was also delivered with each product

4.4 Agricultural Practices monitoring product

4.4.1 Information included in the product

The compliancy of the information included in the EFA monitoring products generated over the 2018 and 2019 season, has been verified based on the technical specifications defined in the Sen4CAP Technical Specifications [AD.4] (Table 4-9).

Table 4-9. Information included in the L4C agriculture practices monitoring products

	Description		Included	Comments
REQUIRED FROM [AD.4]	RESULTS			
	1	Original parcel or block Identifier (ID)	Yes	NewID, ORIG_ID
	2	Expected start date of the harvest	Yes	H_START
	3	Expected end date of the harvest	Yes	H_END
	4	Harvest Markers	Yes	M1 – M5
	5	The week during which a harvest has been detected	Yes	H_WEEK
	6	Expected start date of the declared agricultural practice	Yes	P_START
	7	Expected end date of the declared agricultural practice	Yes	P_END
	8	EFA Markers	Yes	M6 – M10
	9	The decision on the degree of compliancy of the parcel with the practice	Yes	C_INDEX
	10	The graphics files	Yes	L4C_Graph
	QUALITY FLAGS			
	1	Original parcel or block ID	Yes	NewID

	2	An indicator of the parcel conformity (number of Sentinel-1 pixels within the parcel)	Yes	S1PIX
	3	The average number of valid and invalid observations in the time series	No	Replaced by data gaps flags
ADDED	**RESULTS**			
	1	Farm ID number	Yes	ori_hold
	2	Main crop code	Yes	MAIN_CROP
	3	Start date of the estimated period when vegetation is expected on the parcel	Yes	VEG_START
	4	Declared agricultural practice	Yes	PRACTICE
	5	Type of the declared agricultural practice	Yes	P_TYPE
	6	First and last day of the H_WEEK	Yes	H_W_START, H_W_END
	7	First day of the week when harvested or cleared conditions are observed using the Sentinel-1 data	Yes	H_W_S1
	QUALITY FLAGS			
	1	First day of the last week for which the Sentinel-1 data are available	Yes	L_WEEK
	2	Number of weeks with Sentinel-1 data missing within the whole monitoring period	Yes	S1GAPS
	3	Number of weeks with Sentinel-1 data missing in the period from H_START to H_END	Yes	H_S1GAPS
	4	Number of weeks with Sentinel-1 data missing in the period from P_START to P_END	Yes	P_S1GAPS
	5	Number of weeks with Sentinel-1 data missing in the 5 weeks period before the detected harvest/clearance	Yes	H_W_S1GAPS
	6	Reliability flag of the detected harvest/clearance H_WEEK ("1" - missing data in H_W_S1GAPS period)	Yes	H_QUALITY
	7	Reliability flag of the C-INDEX	Yes	C_QUALITY

GAPS IN THE SENTINEL-1 TIME-SERIES

The originally proposed quality flag indicating the average number of valid and invalid observations in the time series has been replaced by data gaps flags described below.

The S1 data are essential for the agriculture practices monitoring. Usually, in a week it is expected to acquire about 2-4 values (both backscatter and coherence) from different Sentinel-1 satellite paths for each parcel. If the there is no value in a whole week, the information in this week is missing ("gap" in the time-series) and the monitoring for this week cannot be provided. The gaps in the Sentinel-1 time-series have a strong negative impact on the reliability of the monitoring.

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

The missing weeks are reported for following periods:

- Year period - from the first week in the year to the last available week with the S1 data (L_WEEK). The result is reported in the attribute S1GAPS. This attribute provides an overall information about the missing weeks of the Sentinel-1 data in the whole year.
- Harvest/clearance period – from the first week when the harvest/clearance is expected on a parcel (H_START) to the last week when the harvest/clearance is expected (H_END) or, if the harvest period not yet ended, to the last available week with the S1 data (L_WEEK). The result is reported in the attribute H_S1GAPS. If the S1 data are missing in this period, the harvest/clearance week (H_WEEK) can be incorrectly detected.
- EFA practice period – from the first week of the EFA practice period (P_START) to the last week of the EFA practice period (P_END) or, if the EFA period not yet ended, to the last available week with the S1 data (L_WEEK). The result is reported in the attribute P_S1GAPS. If the S1 data are missing in the EFA practice period, the result of the compliance index (C_INDEX) can be incorrectly interpreted.
- 5-weeks period before the detected harvest/clearance week – if a harvest/clearance week (H_WEEK) is detected on a parcel, the the period of 5-weeks before the harvest/clearance week is examined. The result is reported in the attribute H_W_S1GAPS. If the S1 data are missing in this period, the harvest/clearance week (H_WEEK) can be incorrectly detected.

<u>RELIABILITY FLAGS</u>

In 2019, two quality flags were added to the results.

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

The flags warn about selected problems. The list of these flags is provided in the readme file for each product.

In 2019, the first version of the flags was provided. In this first version, the flags inform about the parcels, where the problems with the missing S1 data could affect the reliability of the detected harvest week (H_QUALITY flag "1") or the result of the compliancy index (C_QUALITY flag "1")

- H_QUALITY value "1" informs about the missing S1 data in H_W_S1GAPS period
- C_QUALITY value "1" - informs about the missing S1 data in P_S1GAPS period

4.4.2 Spatial and temporal extent

Both in 2018 and 2019, the products were generated at national scale (NLD, CZE, LTU, ROU) over the declared GSAA parcels or over specific regions (CyL, ITA and FRA – only 2019) depending on the coverage of GSAA parcels provided.

The temporal extent is defined by the year of the monitoring and the country-specific temporal rules which are part of the EFA practice definition. The extent and the number of parcels processed in 2018 and 2019 are given in Table 4-10 and

Table 4-11. The tables also include the information about the number of parcels that were not analysed due to their size or unavailability of EO time series.

Table 4-10. Detailed statistics about extent and number of parcels processed by site and per practice in 2018

HARVEST SUMMARY 2018									
COUNTRY	Total parcels		Parcels not analysed						
			Total		No S1 pixel included		Time series not available		
	(n°)	(ha)	% n°	% area	n°	%	n°	%	% of small parcels (1-3 S1 pixels)
CZE	153 262	1 538 008	8,9%	0,6%	4 920	3,2%	8 734	5,7%	41,6%
CyL	1 602 518	2 629 614	29,0%	3,1%	269 477	16,8%	195 000	12,2%	34,6%
LTU	549 050	1 768 004	23,1%	1,5%	112 011	20,4%	14 717	2,7%	95,9%
NLD	165 747	548 553	5,6%	0,5%	5 171	3,1%	4 058	2,4%	18,7%
ROM	3 570 752	6 286 953	36,5%	10,8%	1 179 078	33,0%	124 715	3,5%	92,0%
ITA	742 552	919 286	17,6%	6,1%	103 548	13,9%	27 104	3,7%	95,2%

CATCH CROPS SUMMARY 2018									
COUNTRY	Total parcels		Parcels not analysed						
			Total		No S1 pixel included		Time series not available		
	(n°)	(ha)	% n°	% area	n°	%	n°	%	% of small parcels (1-3 S1 pixels)
CZE	9 507	106 981	4,7%	0,4%	121	1,3%	327	3,4%	36,7%
CyL	not monitored								
LTU	9 140	64 010	5,5%	0,4%	435	4,8%	70	0,8%	97,1%
NLD	52 660	224 670	11,1%	0,7%	1 712	3,3%	4142	7,9%	3,7%
ROM	38 436	322 626	10,9%	1,1%	3 880	10,1%	323	0,8%	90,7%
ITA	not monitored								

NITROGEN FIXING CROPS SUMMARY 2018									
COUNTRY	Total parcels		Parcels not analysed						
			Total		No S1 pixel included		Time series not available		
	(n°)	(ha)	% n°	% area	n°	%	n°	%	% of small parcels (1-3 S1 pixels)
CZE	14 704	101 035	14,9%	1,1%	698	4,7%	1490	10,1%	45,6%
CyL	195 891	380 321	25,2%	2,2%	28 504	14,6%	20906	10,7%	35,7%
LTU	14 325	52 533	8,2%	0,8%	1 007	7,0%	168	1,2%	91,1%
NLD	not monitored								
ROM	124 684	291 866	23,4%	5,8%	26 356	21,1%	2 804	2,2%	89,6%
ITA	362 900	363 381	17,9%	7,5%	50 630	14,0%	14 367	4,0%	96,6%

FALLOW LAND SUMMARY 2018									
COUNTRY	Total parcels		Parcels not analysed						
			Total		No S1 pixel included		Time series not available		
	(n°)	(ha)	% n°	% area	n°	%	n°	%	% of small parcels (1-3 S1 pixels)
CZE	3 247	9 869	26,8%	5,0%	357	11,0%	513	15,8%	45,6%
CyL	455 359	567 800	37,2%	5,2%	95 752	21,0%	73807	16,2%	32,0%
LTU	25 362	70 123	12,1%	1,5%	2 669	10,5%	392	1,5%	95,4%
NLD	not monitored								
ROM	not monitored								
ITA	283 647	106 836	16,1%	12,8%	37 623	13,3%	7 983	2,8%	95,7%

Table 4-11. Detailed statistics about extent and number of parcels processed by site and per practice in 2019

HARVEST SUMMARY 2019										
COUNTRY	Total parcels		Parcels not analysed							
			Total		No S1 pixel included		Time series not available			
	(n°)	(ha)	% n°	% area	n°	%	n°	%	% of small parcels (1-3 S1 pixels)
CZE	215 095	2 152 272	6,7%	0,3%	12 955	6,0%	1 384	0,6%	96,3%
CyL	57 762	198 227	15,4%	0,9%	7 420	12,8%	1 502	2,6%	95,1%
LTU	537 950	1 758 529	23,6%	1,5%	107 679	20,0%	19 275	3,6%	90,5%
NLD	162 660	536 424	6,3%	0,6%	9 229	5,7%	1 072	0,7%	94,9%
ROM	3 513 534	6 338 953	44,4%	10,2%	1 440 364	41,0%	119 888	3,4%	94,8%
ITA	698 787	936 352	36,9%	3,2%	235 219	33,7%	22 894	3,3%	95,7%
FRA	231 777	1 087 229	5,9%	4,3%	5 663	2,4%	7 980	3,4%	10,3%

CATCH CROPS SUMMARY 2019									
COUNTRY	Total parcels		Parcels not analysed						
			Total		No S1 pixel included		Time series not available		
	(n°)	(ha)	% n°	% area	n°	%	n°	%	% of small parcels (1-3 S1 pixels)
CZE	9 994	106 712	1,5%	0,1%	130	1,3%	17	0,2%	100,0%
CyL	not monitored								
LTU	12 953	102 137	4,1%	0,5%	443	3,4%	84	0,6%	95,2%
NLD	53 846	232 049	10,2%	0,6%	5 251	9,8%	221	0,4%	95,5%
ROM	37 614	327 169	11,9%	1,0%	4 054	10,8%	407	1,1%	71,3%
ITA	not monitored								
FRA	37 975	230 574	3,1%	2,6%	287	0,8%	893	2,4%	6,8%

NITROGEN FIXING CROPS SUMMARY 2019									
COUNTRY	Total parcels		Parcels not analysed						
			Total		No S1 pixel included		Time series not available		
	(n°)	(ha)	% n°	% area	n°	%	n°	%	% of small parcels (1-3 S1 pixels)
CZE	15 814	103 403	6,4%	0,3%	852	5,4%	164	1,0%	95,1%
CyL	11 056	38 014	16,4%	0,9%	1 529	13,8%	287	2,6%	94,1%
LTU	25 972	92 864	8,6%	0,8%	1 790	6,9%	449	1,7%	95,3%
NLD	not monitored								
ROM	148 689	314 155	27,5%	6,1%	37 477	25,2%	3 349	2,3%	93,2%
ITA	177 263	220 670	35,3%	3,3%	55 548	31,3%	6 945	3,9%	95,9%
FRA	not monitored								

FALLOW LAND SUMMARY 2019									
COUNTRY	Total parcels		Parcels not analysed						
			Total		No S1 pixel included		Time series not available		
	(n°)	(ha)	% n°	% area	n°	%	n°	%	% of small parcels (1-3 S1 pixels)
CZE	2 865	7 712	14,1%	1,5%	352	12,3%	53	1,8%	100,0%
CyL	15 409	35 194	24,8%	2,1%	3 170	20,6%	652	4,2%	95,4%
LTU	17 273	43 564	12,7%	1,8%	1 897	11,0%	300	1,7%	97,7%
NLD	not monitored								
ROM	not monitored								
ITA	230 594	110 103	67,0%	10,5%	144 512	62,7%	9 880	4,3%	95,2%
FRA	not monitored								

4.4.3 Spatial and temporal resolution

All products were generated at the agricultural parcel level, which has to be considered as the effective spatial resolution of the product. Parcels which are not covered by at least 1 S1 pixel cannot be monitored

In 2018, the product was delivered once, at the end of the monitoring period. In 2019, the monitoring was carried out on a weekly basis, with the first delivery taking place as soon as the declarations are available based on all the images acquired until this date. Then, the product was updated until the end of the period of required compliancy according to the national EFA definition.

4.4.4 Delivery time

In 2018, due to the large delay in the pre-processing of the S2, S1 and L8 data, the L4C EFA monitoring results were not delivered as planned at the end of the 2018 season (in November 2018) but once the preprocessing was finished. As soon as the S2, S1 and L8 pre-processed data are ready, the L4C EFA monitoring results keep the delivery time under 1 week.

In 2019, the EFA monitoring has been successfully run for all pilot countries. In four countries (CZE, CyL, LTU and NLD) the monitoring has been run in continuous mode within which the harvest and EFA monitoring provide updated results every week. The remaining three countries (ROU, ITA and FRA) have been served by a one-time delivery due to the late provision of EFA application data. A summary is provided below:

- CZE: continuous delivery from October;
- CyL: continuous delivery from October;
- LTU: continuous delivery from June;
- NLD: continuous delivery from August;
- ROU: one delivery in October, one delivery in December (at the end of season);
- ITA: one delivery in December (at the end of season);
- FRA: one delivery in December (at the end of season).

4.4.5 Format projection and metadata

The L4C agricultural practices monitoring results were delivered in the CSV and shapefile format, in the national projection, as requested by the PAs. The quality flags are described in section 4.4.1.

No metadata was produced along with the L4C EFA monitoring results. However, a standard README document accompanied each delivered product, in order to easily interpret the results. A QUICK USER GUIDE dedicated specifically to the agricultural practices monitoring was also delivered with each product.

5. Quantitative validation of 2018 EO products

5.1 Biophysical indicator product

No validation dataset was available to assess the accuracy of the biophysical indicators.

5.2 Crop Type map

As required in [AD.4], each L4A crop type map was validated according to international standards, i.e. with an independent dataset. During the classification, a part of the declared parcels provided by the PA is used for the calibration of the model, while another part is kept for the validation. This validation dataset is used to calculate a confusion matrix, from which the validation values described in Table 5-1 are derived.

Table 5-1. L4A crop type validation values

Validation value	Description	Formula
Overall Accuracy (OA)	It gives the overall accuracy of the classification	$\frac{Well\ classified\ parcels}{Total\ validation\ parcels}$
Kappa	It gives the indication on how much better the classification is compared to a random model	$\frac{OA - random\ accuracy}{1 - random\ accuracy}$
Producer's accuracy (by crop type)	It gives for each crop type the chance that a crop which is that crop type in reality is classified as such	$\frac{Well\ classified\ parcels}{Parcels\ in\ reality}$
User's accuracy (by crop type)	It gives for each crop type the chance that the classified crop on the map is this crop type in reality	$\frac{Well\ classified\ parcels}{Classified\ parcels}$
F-Score (by crop type)	It combines both producer's and user's accuracies in a single value	$2 \cdot \frac{PA \cdot UA}{PA + UA}$

For each site, the **OA and Kappa** values of the classification are first given in a table. Then, these values are represented in a figure along with the **F-Score of all crop types** included in the classification. In this figure, the crop types are ranged by their area.

Concerning the **confusion matrices**, it was decided not to show the entire ones given the fact that they are not easily interpretable due to the large number of classified crop types. Instead, the results focus on the **15 main crop types** (ranged by area). For these main crop types, the **three first classes with which they are most confused** are provided, considering both **producer's** and **user's accuracy** values. It is particularly interesting for the crop types that have a low accuracy.

Using these confusion matrices, all the crop types with an **accuracy below 0.8 are listed** with the crop types that they are confused with, if the percentage of confused parcels is above a specific threshold. Because the producer's accuracy values are in this case generally higher than the user's accuracy values, this threshold has been defined to 10% for the producer's accuracy and to 5% for the user's accuracy. From these thresholds, the levels of confusion between two crop types were defined as shown in Table 5-2. On top of that, when crop types are characterized by the same confusion patterns, they are grouped together to facilitate the analysis and avoid redundancy.

Table 5-2. Defined level of confusion between 2 crop types in the producer's and user's analysis

Confusion between crop types	Producer's accuracy analysis	User's accuracy analysis
Low	**10-25 %**	**5-10 %**
Moderate	**25-50 %**	**10-25 %**
Strong	**50-75 %**	**25-50 %**
Very strong	**+ 75 %**	**+ 50 %**

Based on this analysis, **recommendations** are made to **group together crop types** that are confused with each other, if they are characterized by **similar phenology and crop calendar**, and if they belong to the **same high-level crop group**. Indeed, because of these similarities and the fact that they are confused with each other, the results of the classification in these crop types are less accurate and can lead to a wrong conformity assessment at the parcel-level. It is why we recommend these groupings. Because we consider only the 15 main crops in the analysis, only 4 high-level crop groups were observed and proposed as groupings: **grassland and legumes**, **cereals**, **winter cereals** and **spring/summer cereals**. These recommendations should be revised by the PAs to define if these groupings make sense in their local and in the CAP contexts and the analysis should be extended to the whole list of crop types.

Finally, the results of the crop diversification use case are provided. In this use case, a conformity assessment of the declared crop type is done at the parcel level, using the results of the classification. This parcel-based assessment is then used to assess the compliancy of each holding regarding crop diversification rules.

5.2.1 Spain - Castilla y Leon

5.2.1.1 Overall accuracy, Kappa and F-Score

The OA and Kappa values of the classification from the end of the season are provided in Table 5-3. These indices are also illustrated in Figure 5-1, in addition to the F-Scores of the individual crop types included in the classification.

Table 5-3. OA and Kappa values for end-of-season crop type map in CyL 2018

Overall Accuracy	Kappa
81.83%	77.96%

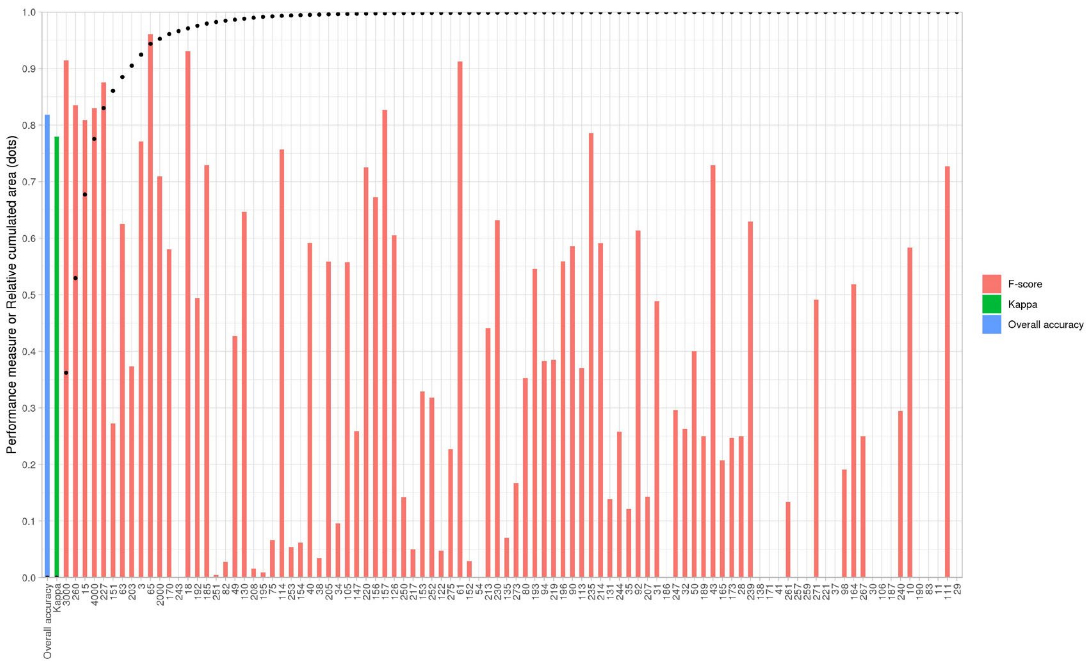


Figure 5-1. OA, Kappa and F-Score values for end-of-season crop type map in CyL 2018

5.2.1.2 Producer’s accuracy

Producer’s accuracy matrix is provided in Table 5-4 for the 15 main crop types included in the end-of-season classification. For each crop type, the table identifies the three crop types with which there are most confused, and it gives the corresponding percentage of confused parcels.

Table 5-4. Producer's accuracy matrix for end-of-season crop type map in CyL 2018

CTnumL4A	CTL4A	Declared parcels	Well classified	Producer accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	GRASSLAND	295578	287966	0.974	FALLOW LAND WITH GR	1.1	BARLEY	0.5	WHEAT WHEAT	0.5	0.5
260	WHEAT WHEAT	232072	206094	0.888	BARLEY	7.2	GRASSLAND	2.1	FALLOW LAND WITH GR	1.1	0.8
15	BARLEY	181475	158785	0.875	WHEAT WHEAT	8.7	GRASSLAND	1.6	FALLOW LAND WITH GR	1.5	0.7
4000	FALLOW LAND WITH GI	152409	125846	0.826	GRASSLAND	9.9	BARLEY	2.4	SUNFLOWER	2.0	3.1
227	SUNFLOWER	63006	56151	0.891	FALLOW LAND WITH GR	7.5	GRASSLAND	1.2	BARLEY	0.9	1.3
151	OAT	36494	6416	0.176	WHEAT WHEAT	40.4	BARLEY	19.8	GRASSLAND	13.4	8.8
63	COMMON VETCH	27757	16325	0.588	BARLEY	16.6	WHEAT WHEAT	9.7	GRASSLAND	7.2	7.7
203	RYE	26837	6283	0.234	WHEAT WHEAT	28.9	BARLEY	25.5	GRASSLAND	14.6	7.6
3	ALFALFA	20865	14215	0.681	GRASSLAND	15.9	BARLEY	5.3	FALLOW LAND WITH GR	3.4	7.3
65	CONVENTIONAL/TRAN	26822	25543	0.952	SUNFLOWER	1.6	GRASSLAND	0.8	WHEAT WHEAT	0.6	1.8
2000	PERMANENT CROP	16919	9596	0.567	GRASSLAND	22.2	FALLOW LAND WITH GR	17.6	SUNFLOWER	1.7	1.8
170	PEAS	7650	3386	0.443	BARLEY	29.4	FALLOW LAND WITH GR	8.8	COMMON VETCH	7.2	10.3
243	TRITICALE	7481	3	0.000	WHEAT WHEAT	67.7	BARLEY	16.2	GRASSLAND	8.0	8.1
18	BEET	5412	5010	0.926	SUNFLOWER	3.0	CONVENTIONAL/TRANS	0.7	BARLEY	0.5	3.2
192	RAPE	4353	1440	0.331	BARLEY	37.7	WHEAT WHEAT	14.4	GRASSLAND	5.8	9.0

The crop types with a producer’s accuracy below 0.8 are listed below with the crop types with which they are most confused:

- Oat, Rye and Triticale (producer accuracy = 0,176; 0,234; 0,000):
  - Strong/moderate confusion with “Wheat” and “Barley”, low confusion with “Grassland”;
  - “Oat, Rye and Triticale” could be grouped with “Wheat” and “Barley” because they have a similar phenology;
- Common vetch (producer accuracy = 0,588):
  - Low confusion with “Barley”;
- Alfalfa (producer accuracy = 0,681):

  - Low confusion with “Grassland”;
  - It could be included in the grassland group because it has a similar phenology;
- Permanent crop (producer accuracy = 0,567):
  - Low confusion with “Grassland” and “Fallow land with grass”;
  - Such confusion was expected due to the variable part of grassland areas in the permanent crops as well as the “permanent” presence of vegetation throughout the season;
- Peas (producer accuracy = 0,443):
  - Moderate confusion with “Barley”;
- Rape (producer accuracy = 0,331):
  - Moderate confusion with “Barley” and “Wheat”.

5.2.1.3 User’s accuracy

User’s accuracy matrix is provided in Table 5-5 for the 15 main crop types included in the end-of-season classification. For each crop type, the table identifies the three crop types with which they are most confused, and gives the corresponding percentage of confused parcels.

Table 5-5. User’s accuracy matrix for end-of-season crop type map in CyL 2018

CTnumL4A	CTL4A	Classified parcels	Well classified	User accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	GRASSLAND	334448	287966	0.861	FALLOW LAND WITH GR	4.5	OAT	1.5	WHEAT WHEAT	1.4	6.5
260	WHEAT WHEAT	261451	206094	0.788	BARLEY	6.0	OAT	5.6	RYE	3.0	6.6
15	BARLEY	211131	158785	0.752	WHEAT WHEAT	7.9	OAT	3.4	RYE	3.2	10.3
4000	FALLOW LAND WITH GI	150982	125846	0.834	SUNFLOWER	3.1	GRASSLAND	2.1	PERMANENT CROP	2.0	9.4
227	SUNFLOWER	65261	56151	0.860	FALLOW LAND WITH GR	4.7	POTATO	2.2	CHICKPEA	0.9	6.2
151	OAT	10599	6416	0.605	VETCH AND OAT MIXTU	8.9	GRASSLAND	7.2	WHEAT WHEAT	6.8	16.6
63	COMMON VETCH	24473	16325	0.667	RED PEA	7.5	OAT	5.8	VETCH AND OAT MIXTU	2.6	17.4
203	RYE	6830	6283	0.920	FALLOW LAND WITH GR	1.9	WHEAT WHEAT	1.5	TRITICALE	1.4	3.2
3	ALFALFA	16019	14215	0.887	GRASSLAND	2.2	COMMON VETCH	1.6	SANFOIN	1.5	6.0
65	CONVENTIONAL/TRAN	26356	25543	0.969	FALLOW LAND WITH GR	0.5	POTATO	0.5	WHEAT WHEAT	0.5	1.6
2000	PERMANENT CROP	10143	9596	0.946	FALLOW LAND WITH GR	2.1	ALFALFA	0.9	SUNFLOWER	0.5	1.9
170	PEAS	4016	3386	0.843	LENTIL	2.6	COMMON VETCH	2.4	FALLOW LAND WITH GR	2.3	8.4
243	TRITICALE	4	3	0.750	BARLEY	25.0	AROMATIC GRASS SPEC	0.0	AROMATIC GRASS SPEC	0.0	0.0
18	BEET	5356	5010	0.935	CARROT	1.3	ALFALFA	1.0	POTATO	0.6	3.6
192	RAPE	1472	1440	0.978	FALLOW LAND WITH GR	0.3	FALLOW LAND WITH GR	0.3	BARLEY	0.3	1.3

The crop types with a user’s accuracy below 0.8 are listed below with the crop types with which they are most confused:

- Wheat (user accuracy = 0,788):
  - Low confusion with “Barley” and “Oat”;
- Barley (user accuracy = 0,752):
  - Low confusion with “Wheat”;
- Oat (user accuracy = 0,605):
  - Low confusion with “Vetch and oat mixture”, “Grassland” and “Wheat”;
- Common vetch (user accuracy = 0,667):
  - Low confusion with “Red pea” and “Oat”;
- Triticale (user accuracy = 0,750):
  - Moderate confusion with “Barley”;
  - These 2 cereals could be grouped together because they have a similar phenology.

5.2.1.4 Recommendations for future

Crop types that are confused with each other and that could be grouped together because of their similar phenology and crop calendar, and because they belong to the same high-level crop group (PA to confirm that such grouping makes sense in the CAP context):

- CEREALS: Wheat, Barley, Oat, Rye and Triticale;
- GRASSLAND AND LEGUMES: Grassland and Alflalfa.

Crop types that require specific attention to increase their accuracy: Common vetch, Peas and Rape.

5.2.1.5 Crop diversification use case

The results of the conformity assessment at the parcel-level and the crop diversification assessment at the holding-level, based on the end-of-season crop type map, are given in Figure 5-2 and Figure 5-3.

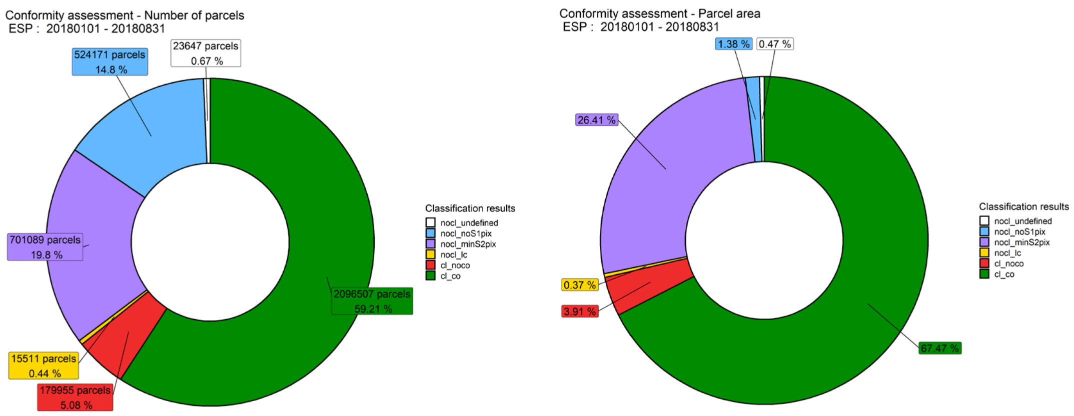


Figure 5-2. Conformity assessment at the parcel level in CyL 2018

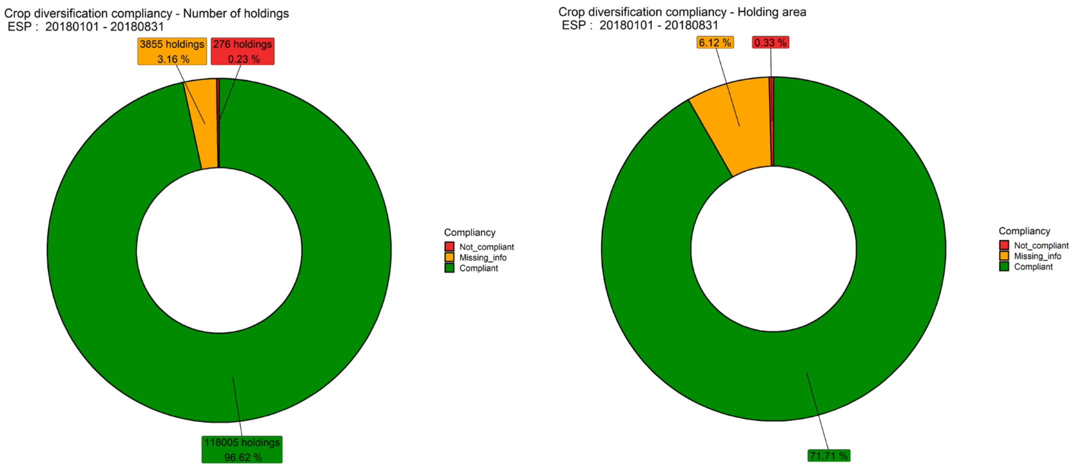


Figure 5-3. Crop diversification assessment at the holding level in CyL 2018

5.2.2 Czech Republic

5.2.2.1 Overall accuracy, Kappa and F-Score

The OA and Kappa values of the classification from the end of the season are provided in Table 5-6. These indices are also illustrated in Figure 5-4, in addition to the F-Scores of the individual crop types included in the classification.

Table 5-6. OA and Kappa values for end-of-season crop type map in CZE 2018

Overall Accuracy	Kappa
88.69%	79.98%

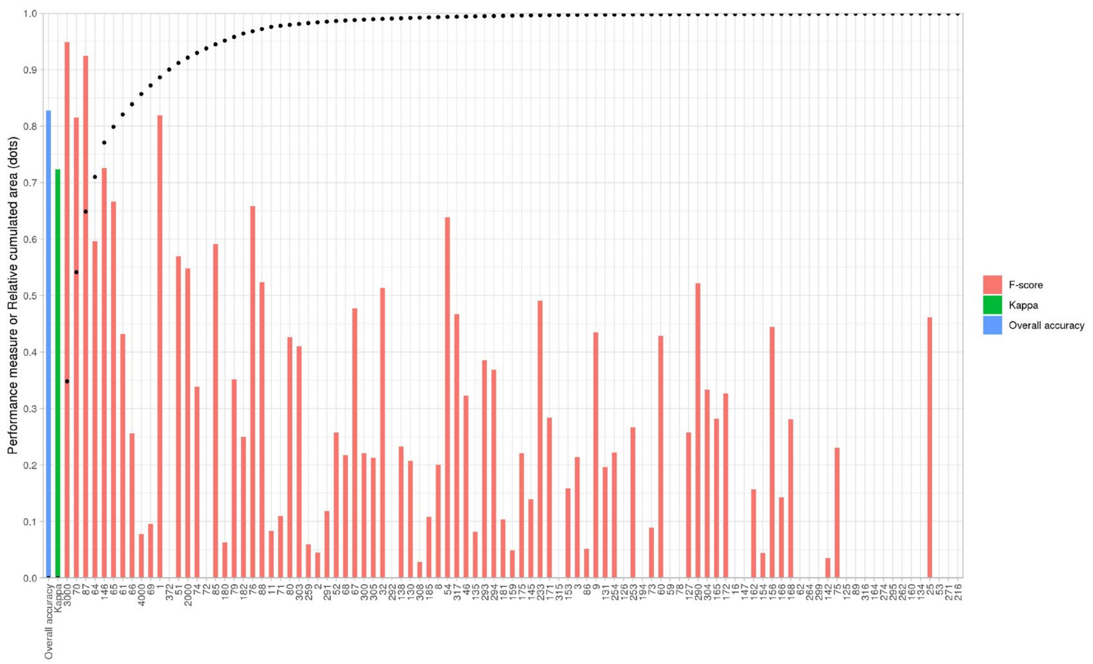


Figure 5-4. OA, Kappa and F-Score values for end-of-season crop type map in CZE 2018

5.2.2.2 Producer's accuracy

Producer's accuracy matrix is provided in Table 5-7 for the 15 main crop types included in the end-of-season classification. For each crop type, the table identifies the three crop types with which they are most confused and gives the corresponding percentage of confused parcels.

Table 5-7. Producer's accuracy matrix for end-of-season crop type map in CZE 2018

CTnumL4A	CTL4A	Declared parcels	Well classified	Producer accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	Grassland	231711	230161	0.993	Spring barely	0.1	Winter wheat	0.1	Unknown crop	0.1	0.4
70	Winter wheat	41841	40518	0.968	Grassland	1.3	Spring barely	0.7	Unknown crop	0.5	0.7
87	Winter rapeseed	20710	20240	0.977	Winter wheat	0.9	Grassland	0.7	Unknown crop	0.2	0.5
372	Unknown crop	13215	1976	0.150	Grassland	32.1	Winter wheat	25.0	Spring barely	14.0	13.9
64	Spring barely	12517	11152	0.891	Unknown crop	3.6	Grassland	3.0	Winter wheat	1.8	2.5
146	Maize	11996	11407	0.951	Grassland	1.8	Unknown crop	0.6	Sorghum	0.5	2.0
2000	Permanent fruit	10000	5033	0.503	Grassland	47.9	poppy	0.6	Unknown crop	0.3	0.9
65	Winter barely	5606	3195	0.570	Winter wheat	38.5	Grassland	2.7	Spring barely	0.7	1.1
61	Lucerne	5410	1085	0.201	Grassland	73.7	Spring barely	1.3	Unknown crop	0.9	4.0
69	Spring wheat	3421	371	0.108	Spring barely	61.3	Winter wheat	10.2	Unknown crop	7.5	10.2
66	Oat	3405	744	0.219	Spring barely	46.8	Grassland	13.4	Unknown crop	8.2	9.7
4000	Fallow land	2526	62	0.025	Grassland	64.6	Maize	7.2	Unknown crop	4.4	21.3
72	Winter triticale	2142	3	0.001	Winter wheat	90.0	Grassland	4.9	Winter barely	1.5	3.5
51	Pea	1694	968	0.571	Grassland	10.7	Spring barely	8.4	Unknown crop	4.7	19.1
74	Winter rye	1360	492	0.362	Winter wheat	47.5	Winter barely	6.2	Grassland	5.8	4.3

The crop types with a producer's accuracy below 0.8 are listed below with the crop types with which they are most confused:

- Unknown crop (producer accuracy = 0,150):
  - Moderate confusion with “Grassland” and “Winter wheat”;
  - It **should** not be included anymore in the classification because it can be any crop;
- Permanent fruit (producer accuracy = 0,503):
  - Moderate confusion with “Grassland”;
  - Such confusion was expected due to the possibly high part of grassland areas in the permanent fruit plantations as well as the “permanent” presence of vegetation throughout the season like the grassland areas
- “Winter barley”, “Winter triticale” and “Winter rye” (producer accuracy = 0,570; 0,001; 0,362):
  - Very strong confusion between “Winter triticale” and “Winter Wheat”;
  - Moderate confusion between “Winter barley” / “Winter rye” and “Winter wheat”;
  - These 4 crop types **could** be grouped together because they have a similar phenology;
- Lucerne (producer accuracy = 0,201):
  - Strong confusion with “Grassland”;
  - It **could** be included in the grassland group because it has a similar phenology;
- “Spring wheat” and “Oat” (producer accuracy = 0,108; 0,219):
  - Moderate / strong confusion with “Spring barley”;
  - These 3 crop types **could** be grouped together because they have a similar phenology;
- Fallow land (producer accuracy = 0,025):
  - Strong confusion with “Grassland”;
  - Such confusion was expected due to the fact that fallow land are made of grass species and due to the “permanent” presence of vegetation throughout the season like the grassland areas;
- Pea (producer accuracy = 0,571):
  - Low confusion with “Grassland”.

5.2.2.3 User's accuracy

User's accuracy matrix is provided in Table 5-8 for the 15 main crop types included in the end-of-season classification. For each crop type, the table identifies the three crop types with which they are most confused and gives the corresponding percentage of confused parcels.

Table 5-8. User's accuracy matrix for end-of-season crop type map in CZE 2018

CTnumL4A	CTL4A	Classified parcels	Well classified	User accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	Grassland	247888	230161	0.928	Permanent fruit	1.9	Unknown crop	1.7	Lucerne	1.6	2.0
70	Winter wheat	49961	40518	0.811	Unknown crop	6.6	Winter barely	4.3	Winter triticale	3.9	4.1
87	Winter rapeseed	20750	20240	0.975	Unknown crop	1.5	Winter wheat	0.3	Grassland	0.1	0.6
372	Unknown crop	3960	1976	0.499	Spring barely	11.2	Oat	7.0	Spring wheat	6.5	25.4
64	Spring barely	17937	11152	0.622	Spring wheat	11.7	Unknown crop	10.3	Oat	8.9	6.9
146	Maize	12889	11407	0.885	Unknown crop	4.0	Grassland	1.0	Oat	0.7	5.8
2000	Permanent fruit	5333	5033	0.944	Grassland	1.8	Unknown crop	1.7	Lucerne	0.7	1.4
65	Winter barely	3480	3195	0.918	Winter rye	2.4	Unknown crop	1.8	Grassland	1.4	2.6
61	Lucerne	1144	1085	0.948	Grassland	2.0	Unknown crop	1.8	Lucerne-grassland mix	0.3	1.1
69	Spring wheat	486	371	0.763	Oat	7.0	Unknown crop	5.3	Spring barely	4.7	6.7
66	Oat	928	744	0.802	Unknown crop	9.4	Spring wheat	4.3	Spring barely	2.4	3.7
4000	Fallow land	84	62	0.738	Grassland	10.7	Pea	6.0	Lucerne	2.4	7.1
72	Winter triticale	4	3	0.750	Winter wheat	25.0	sugar beet	0.0	sugar beet	0.0	0.0
51	Pea	1157	968	0.837	Unknown crop	3.8	Grassland	1.7	Spring barely	1.6	9.2
74	Winter rye	564	492	0.872	Unknown crop	5.5	Winter triticale	4.6	Winter wheat	1.1	1.6

The crop types with a user's accuracy below 0.8 are listed below with the crop types with which they are most confused:

- Unknown crop (user accuracy = 0,499):
  - Moderate confusion with "Spring barley" and "Oat";
  - It **should** not be included anymore in the classification because it can be any crop;
- Spring barley (user accuracy = 0,622):
  - Moderate confusion with "Spring wheat", "Unknown crop";
  - Low confusion with "Oat";
  - These 3 crop types ("Spring barley", "Spring wheat" and "Oat") **could** be grouped together because they have a similar phenology;
- Spring wheat (user accuracy = 0,763):
  - Low confusion with "Oat" and "Unknown crop"
  - See before for the grouping;
- Fallow land (user accuracy = 0,738):
  - Confusion with "Grassland";
  - Such confusion was expected due to the fact that fallow land are made of grass species and due to the "permanent" presence of vegetation throughout the season like the grassland areas;
- Winter triticale (user accuracy = 0,750):
  - Strong confusion with "Winter wheat";
  - These 2 crop types **could** be grouped together because they have a similar phenology.

5.2.2.4 Recommendations for future

"Unknown crop" should be excluded from the classification because it can be anything.

Crop types that are confused with each other and that could be grouped together because of their similar phenology and crop calendar, and because they belong to the same high-level crop group (PA to confirm that such grouping makes sense in the CAP context):

- WINTER CEREALS: Winter wheat, Winter barely, Winter triticale and Winter rye;
- SPRING/SUMMER CEREALS: Spring barley, Spring wheat and Oat;
- GRASSLAND AND LEGUMES: Grassland and Lucerne.

Crop types that require specific attention to increase their accuracy: Permanent fruit, Fallow land and Peas.

5.2.2.5 Crop diversification use case

The results of the conformity assessment at the parcel-level and the crop diversification assessment at the holding-level, based on the end-of-season crop type map, are given in Figure 5-5 and Figure 5-6.

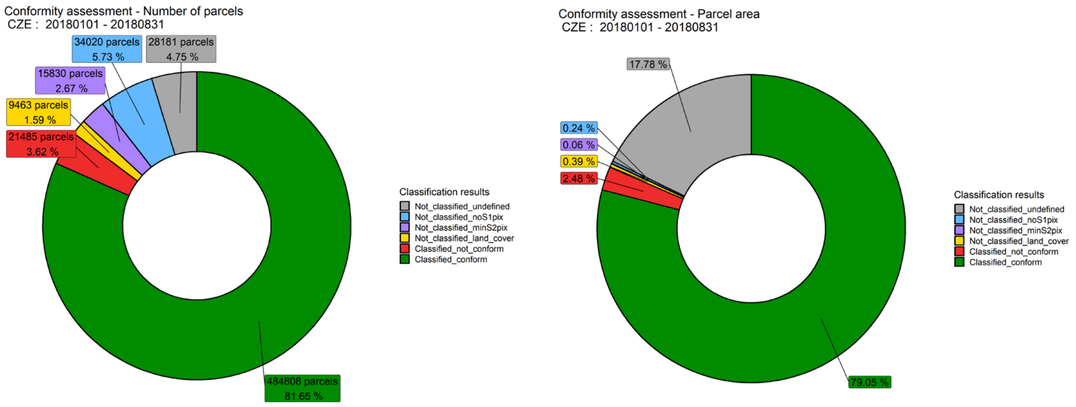


Figure 5-5. Conformity assessment at the parcel level in CZE 2018

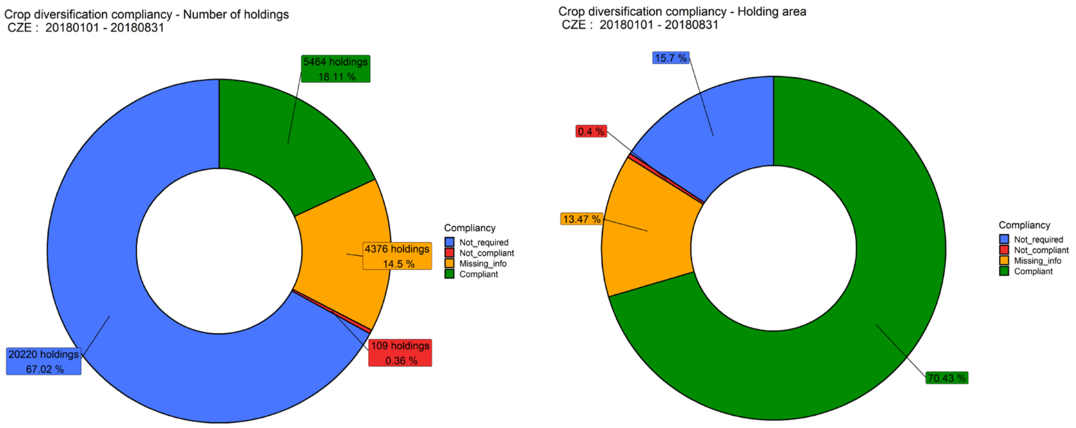


Figure 5-6. Crop diversification assessment at the holding level in CZE 2018

5.2.3 Italy

5 regions were provided by the PA, which were grouped in 2 strata: Campania and Puglia in stratum 1 and Friuli, Marche and Lazio in stratum 2. Results are provided for these 2 strata separately

5.2.3.1 Overall accuracy, Kappa and F-Score

The OA and Kappa values of the classification from the end of the season over strata 1 and 2 are provided in Table 5-9 and Table 5-10. These indices are also illustrated in Figure 5-7 and Figure 5-8, in addition to the F-Scores of the individual crop types included in the classification.

Table 5-9. OA and Kappa values for end-of-season crop type map in ITA - Campania and Puglia, 2018

Overall Accuracy	Kappa
75.04%	62.09%

Table 5-10. OA and Kappa values for end-of-season crop type map in ITA - Friuli, Marche and Lazio, 2018

Overall Accuracy	Kappa
69.69%	63.67%

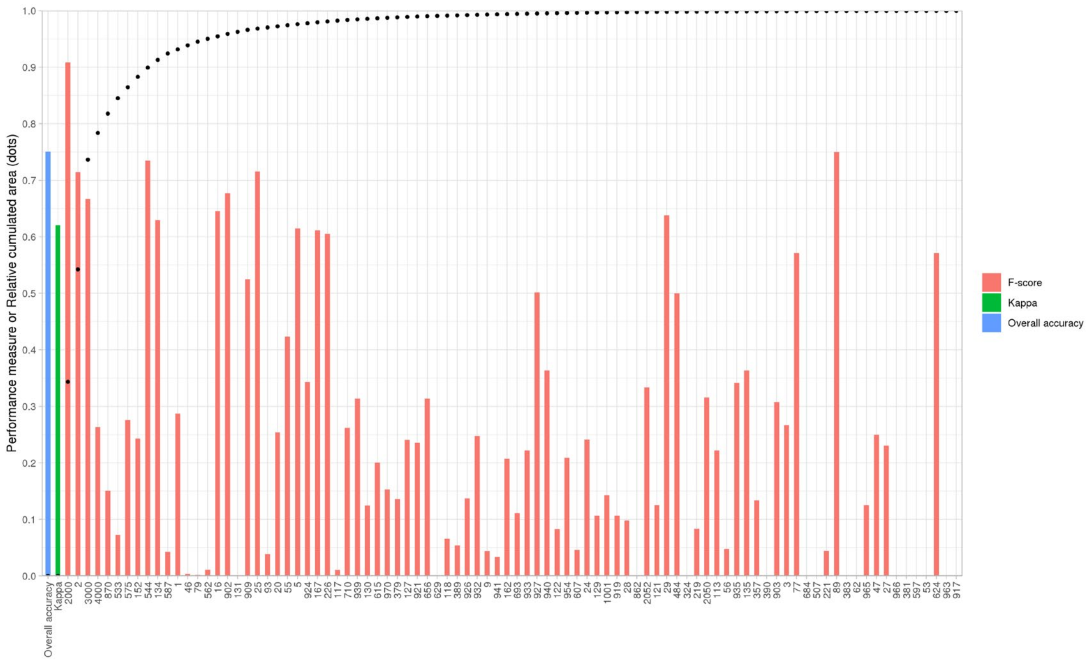


Figure 5-7. OA, Kappa and F-Score values for end-of-season crop type map in ITA - Campania and Puglia, 2018

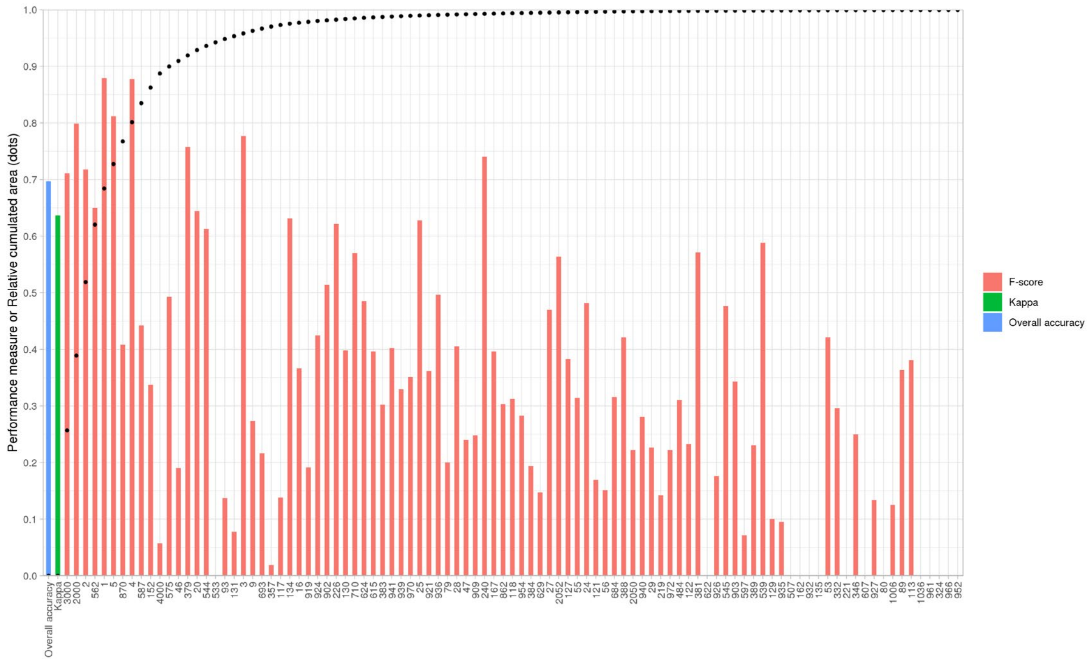


Figure 5-8. OA, Kappa and F-Score values for end-of-season crop type map in ITA - Friuli, Marche and Lazio, 2018

5.2.3.2 Producer’s accuracy

Producer’s accuracy matrices for strata 1 and 2 are provided in Table 5-11 and Table 5-12for the 15 main crop types included in the end-of-season classification. For each crop type, the tables identify the three crop types with which they are most confused and gives the corresponding percentage of confused parcels.

Table 5-11. Producer's accuracy matrix for end-of-season crop type map in ITA - Campania and Puglia, 2018

CTnumL4A	CTL4A	Declared parcels	Well classified	Producer accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
2000	PERMANENT CROPS	152086	140602	0.924	GRASSLAND	6.4	FALLOW	0.5	DURUM WHEAT	0.5	0.2
3000	GRASSLAND	45400	36478	0.803	PERMANENT CROPS	11.7	DURUM WHEAT	6.0	FALLOW	0.8	1.2
2	DURUM WHEAT	31571	28899	0.915	GRASSLAND	4.1	PERMANENT CROPS	2.5	FALLOW	0.8	1.1
4000	FALLOW	13252	2394	0.181	PERMANENT CROPS	36.8	GRASSLAND	23.1	FALLOW	18.1	3.9
533	OAT	6745	259	0.038	DURUM WHEAT	45.8	GRASSLAND	36.6	PERMANENT CROPS	9.0	4.8
870	BARLEY	6152	512	0.083	DURUM WHEAT	69.1	GRASSLAND	15.9	PERMANENT CROPS	4.2	2.5
152	CLOVER	4918	742	0.151	GRASSLAND	60.8	DURUM WHEAT	17.8	PERMANENT CROPS	3.6	2.7
575	FAVA BEAM	3322	549	0.165	DURUM WHEAT	49.6	GRASSLAND	17.2	PERMANENT CROPS	8.6	8.1
587	SOFT WHEAT	3001	65	0.022	DURUM WHEAT	74.3	GRASSLAND	17.1	PERMANENT CROPS	4.1	2.3
544	CHICKPEA	2295	1669	0.727	DURUM WHEAT	10.0	PERMANENT CROPS	8.1	GRASSLAND	3.8	5.4
46	LOIETTO LOGLIO	2183	4	0.002	GRASSLAND	68.8	PERMANENT CROPS	12.5	DURUM WHEAT	8.1	10.4
134	TOMATO	1902	1273	0.669	PERMANENT CROPS	14.5	GRASSLAND	5.5	DURUM WHEAT	4.4	8.7
562	ALPHA -ALPHA	1799	10	0.006	GRASSLAND	70.6	PERMANENT CROPS	19.1	DURUM WHEAT	5.2	4.5
1	MAIZE - CORN	1770	392	0.221	GRASSLAND	38.0	PERMANENT CROPS	23.4	DURUM WHEAT	5.5	11.0
131	VEGETABLES	1410	0	0.000	PERMANENT CROPS	49.0	GRASSLAND	15.5	FALLOW	11.3	24.2

The crop types with a producer’s accuracy below 0.8 are listed below with the crop types with which they are most confused (Campania and Puglia):

- Fallow (producer accuracy = 0,181):
    - Confusion with “Permanent crops” and “Grassland”;
    - Such confusion was expected due to the fact that fallow land are made of grass species and due to the “permanent” presence of vegetation throughout the season like the grassland areas;
- “Oat”, “Barley” and “Soft wheat” (producer accuracy = 0,038;0,083; 0,022):

- Moderate or strong confusion with “Durum wheat”;
- These 4 crop types **could** be grouped together because they have a similar phenology;

- “Clover”, “Loietto loglio” and “Alfa-alfa” (producer accuracy =0,151; 0,002; 0,006):
  - Moderate or strong confusion with “Grassland”;
  - These 4 crop types **could** be grouped together because they have a similar phenology;
- Fava bean (producer accuracy =0,165):
  - Moderate confusion with “Durum wheat”;
- Chickpea (producer accuracy =0,727):
  - Low confusion with “Durum wheat”;
- Tomato (producer accuracy =0,669):
  - Low confusion with “Permanent crops;
- Maize (producer accuracy =0,221):
  - Moderate confusion with “Grassland”;
  - Low confusion with “Permanent crops”;
- Vegetables (producer accuracy =0):
  - Moderate confusion with “Permanent crops”;
  - Low confusion with “Grassland”.

CTnumL4A	CTL4A	Declared parcels	Well classified	Producer accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	GRASSLAND	42102	36491	0.867	PERMANENT CROPS	4.2	ALPHA -ALPHA	4.2	DURUM WHEAT	1.5	3.4
2000	PERMANENT CROPS	39246	29243	0.745	GRASSLAND	21.4	ALPHA -ALPHA	2.2	DURUM WHEAT	0.6	1.3
562	ALPHA -ALPHA	17385	10798	0.621	GRASSLAND	26.6	PERMANENT CROPS	4.6	DURUM WHEAT	2.4	4.3
2	DURUM WHEAT	13173	12199	0.926	GRASSLAND	4.0	ALPHA -ALPHA	1.1	PERMANENT CROPS	0.5	1.8
1	MAIZE - CORN	10544	9084	0.862	GRASSLAND	4.9	SOYBEAN	2.6	SUNFLOWER	1.4	4.9
4	SOYBEAN	6892	6176	0.896	MAIZE - CORN	3.0	GRASSLAND	2.7	BARLEY	1.4	3.3
870	BARLEY	5956	1724	0.289	DURUM WHEAT	46.0	GRASSLAND	14.9	ALPHA -ALPHA	3.5	6.7
4000	FALLOW	5467	168	0.031	GRASSLAND	51.9	PERMANENT CROPS	14.5	ALPHA -ALPHA	11.3	19.2
587	SOFT WHEAT	4766	1462	0.307	DURUM WHEAT	46.3	GRASSLAND	12.3	BARLEY	4.1	6.6
5	SUNFLOWER	4689	4195	0.895	GRASSLAND	2.6	ALPHA -ALPHA	1.4	DURUM WHEAT	1.3	5.2
152	CLOVER	2460	623	0.253	GRASSLAND	59.6	DURUM WHEAT	4.7	ALPHA -ALPHA	3.4	7.0
575	FAVA BEAM	1560	537	0.344	DURUM WHEAT	33.5	GRASSLAND	20.2	ALPHA -ALPHA	2.8	9.1
46	LOIETTO LOGLIO	1252	148	0.118	GRASSLAND	60.0	ALPHA -ALPHA	8.5	PERMANENT CROPS	4.3	15.4
131	VEGETABLES	1235	51	0.041	GRASSLAND	44.6	PERMANENT CROPS	19.3	SUNFLOWER	4.7	27.3
379	CLOVER	1134	768	0.677	ALPHA -ALPHA	10.8	GRASSLAND	9.5	SUNFLOWER	4.3	7.7

Table 5-12. Producer's accuracy matrix for end-of-season crop type map in ITA - Friuli, Marche and Lazio, 2018

The crop types with a producer’s accuracy below 0.8 are listed below with the crop types with which they are most confused (Friuli, Marche and Lazio):

- Permanent crops (producer accuracy = 0,745):
  - Low confusion with “Grassland”;
  - Such confusion was expected due to the possibly high part of grassland areas in the permanent fruit plantations as well as the “permanent” presence of vegetation throughout the season like the grassland areas
- “Alfa-alfa”, “Clover” and “Loietto loglio” (producer accuracy = 0,621; 0,253; 0,118):
  - Moderate or strong confusion with “Grassland”;
  - These 4 crop types **could** be grouped together because they have a similar phenology;
- “Barley” and “Soft wheat” (producer accuracy = 0,289; 0,307):
  - Moderate confusion with “Durum wheat”;

- These 3 crop types **could** be grouped together because they have a similar phenology;
- Fallow (producer accuracy =0,031):
  - Strong confusion with “Grassland”;
  - Such confusion was expected due to the fact that fallow land are made of grass species and due to the “permanent” presence of vegetation throughout the season like the grassland areas;
- Fava bean (producer accuracy = 0,344):
  - Moderate confusion with “Durum wheat”;
- Vegetables (producer accuracy = 0,041):
  - Moderate confusion with “Grassland”.

5.2.3.3 User’s accuracy

User’s accuracy matrices for strata 1 and 2 are provided in Table 5-13 and Table 5-14 for the 15 main crop types included in the end-of-season classification. For each crop type, the tables identify the three crop types with which they are most confused and gives the corresponding percentage of confused parcels.

Table 5-13. User’s accuracy matrix for end-of-season crop type map in ITA - Campania and Puglia, 2018

CTnumL4A	CTL4A	Classified parcels	Well classified	User accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
2000	PERMANENT CROPS	157500	140602	0.893	GRASSLAND	3.4	FALLOW	3.1	DURUM WHEAT	0.5	3.7
3000	GRASSLAND	63952	36478	0.570	PERMANENT CROPS	15.2	FALLOW	4.8	CLOVER	4.7	18.3
2	DURUM WHEAT	49358	28899	0.585	BARLEY	8.6	OAT	6.3	GRASSLAND	5.5	21.1
4000	FALLOW	4940	2394	0.485	PERMANENT CROPS	16.4	GRASSLAND	7.1	DURUM WHEAT	5.1	22.9
533	OAT	408	259	0.635	DURUM WHEAT	8.1	GRASSLAND	6.4	GRASSLAND	6.4	15.6
870	BARLEY	654	512	0.783	GRASSLAND	4.4	DURUM WHEAT	4.1	OAT	4.0	9.2
152	CLOVER	1188	742	0.625	GRASSLAND	17.3	OAT	6.4	DURUM WHEAT	3.3	10.5
575	FAVA BEAM	661	549	0.831	FALLOW	3.5	DURUM WHEAT	3.3	GRASSLAND	1.7	8.4
587	SOFT WHEAT	78	65	0.833	DURUM WHEAT	9.0	CLOVER	6.4	BARLEY	1.3	0.0
544	CHICKPEA	2250	1669	0.742	FALLOW	3.8	DURUM WHEAT	3.5	LENTILS	3.2	15.3
46	LOIETTO LOGLIO	13	4	0.308	MAIZE - CORN	23.1	GRASSLAND	15.4	GRASSLAND	15.4	15.3
134	TOMATO	2142	1273	0.594	FALLOW	4.2	MAIZE - CORN	4.1	MELON	2.8	29.5
562	ALPHA -ALPHA	13	10	0.769	OAT	15.4	GRASSLAND	7.7	MAIZE - CORN	0.0	0.0
1	MAIZE - CORN	958	392	0.409	LOIETTO LOGLIO	16.4	GRASSLAND	11.4	OAT	9.6	21.7
131	VEGETABLES	0	0	NA	NA	NA	NA	NA	NA	NA	NA

The crop types with a user’s accuracy below 0.8 are listed below with the crop types with which they are most confused (Campania and Puglia):

- “Grassland” and “Fallow” (user accuracy = 0,570;0,485):
  - Confusion with “Permanent crops”;
  - Such confusion was expected was expected due to the fact that fallow land are made of grass species and due to the “permanent” presence of vegetation throughout the season like the grassland areas as well as the “permanent” presence of vegetation throughout the season;
- Durum wheat (user accuracy = 0,585):
  - Low confusion with “Barley”, “Oat” and “Grassland”;
- Oat (user accuracy = 0,635):
  - Low confusion with “Durum wheat” and “Grassland”;
- Barley (user accuracy = 0,783):
  - Diffuse confusion (no clear scheme);
- “Clover” and “Alfa-alfa” (user accuracy = 0,625; 0,769):
  - Moderate and low confusion with “Grassland”
  - These 3 crop types **could** be grouped together because they have a similar phenology;

- Chickpea (user accuracy = 0,742):
    - Diffuse confusion (no clear scheme);
- Loietto Loglio (user accuracy = 0,308):
    - Moderate confusion with “Maize” and “Grassland”;
    - It **could** be grouped with “Grassland”;
- Tomato (user accuracy = 0,594):
    - Diffuse confusion (no clear scheme);
- Maize (user accuracy = 0,409):
    - Moderate confusion with “Loietto Loglio” and “Grassland”;
- Vegetables (user accuracy = NA):
    - No classified Vegetables parcels in the validation dataset

Table 5-14. User’s accuracy matrix for end-of-season crop type map in ITA - Friuli, Marche and Lazio, 2018

CTnumL4A	CTL4A	Classified parcels	Well classified	User accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	GRASSLAND	60475	36491	0.603	PERMANENT CROPS	13.9	ALPHA -ALPHA	7.7	FALLOW	4.7	13.4
2000	PERMANENT CROPS	33951	29243	0.861	GRASSLAND	5.3	ALPHA -ALPHA	2.4	FALLOW	2.3	3.9
562	ALPHA -ALPHA	15845	10798	0.681	GRASSLAND	11.2	PERMANENT CROPS	5.5	FALLOW	3.9	11.3
2	DURUM WHEAT	20818	12199	0.586	BARLEY	13.2	SOFT WHEAT	10.6	GRASSLAND	3.1	14.5
1	MAIZE - CORN	10125	9084	0.897	SOYBEAN	2.0	GRASSLAND	1.8	ALPHA -ALPHA	1.3	5.2
4	SOYBEAN	7181	6176	0.860	MAIZE - CORN	3.8	SORGHUM	1.9	FALLOW	1.8	6.5
870	BARLEY	2490	1724	0.692	SOFT WHEAT	7.9	GRASSLAND	5.5	SOYBEAN	3.9	13.5
4000	FALLOW	378	168	0.444	GRASSLAND	16.4	PERMANENT CROPS	14.3	VEGETABLES	4.8	20.1
587	SOFT WHEAT	1848	1462	0.791	GRASSLAND	4.3	BARLEY	4.1	TRITICALE	2.8	9.7
5	SUNFLOWER	5643	4195	0.743	ALPHA -ALPHA	4.1	CHICKPEA	3.2	MAIZE - CORN	2.6	15.8
152	CLOVER	1233	623	0.505	GRASSLAND	34.7	ALPHA -ALPHA	1.6	LOIETTO LOGLIO	1.5	11.7
575	FAVA BEAM	620	537	0.866	BARLEY	2.3	DURUM WHEAT	1.5	PEAS	1.3	8.3
46	LOIETTO LOGLIO	304	148	0.487	MAIZE - CORN	23.7	NA	15.1	TRITICALE	3.6	8.9
131	VEGETABLES	81	51	0.630	GRASSLAND	9.9	MAIZE - CORN	2.5	MAIZE - CORN	2.5	22.1
379	CLOVER	893	768	0.860	CLOVER	4.9	GRASSLAND	1.9	ALPHA -ALPHA	1.5	5.7

The crop types with a user’s accuracy below 0.8 are listed below with the crop types with which they are most confused (Friuli, Marche and Lazio):

- Grassland (user accuracy = 0,603):
    - Confusion with “Permanent crops”;
    - It is expected due to the possibly high part of grassland areas in the permanent fruit plantations as well as the “permanent” presence of vegetation throughout the season like the grassland areas;
- “Alfa-alfa” and “Clover” (user accuracy = 0,681; 0,505)
    - Moderate and strong confusion with “Grassland”;
    - These 3 crop types **could** be grouped together because they have a similar phenology;
- Durum wheat (user accuracy =0,586):
    - Moderate confusion with “Barley” and “Soft wheat”;
    - These 3 crop types **could** be grouped together because they have a similar phenology;
- Barley (user accuracy = 0,692):
    - Low confusion with “Soft wheat” and “Grassland”;
- Fallow (user accuracy = 0,444):
    - Moderate confusion with “Grassland” and “Permanent crops”;
    - Such confusion was expected was expected due to the fact that fallow lands are made of grass species, the possibly high part of grassland areas in the permanent fruit plantations as well as the “permanent” presence of vegetation throughout the season;

- Loietto Loglio (user accuracy = 0,487):
    - Moderate confusion with "Maize";
- Vegetables (user accuracy = 0,630):
    - Low confusion with "Grassland".

5.2.3.4 Recommendations for future

In stratum 1 (Campania and Puglia):

- Crop types that are confused with each other and that could be grouped together because of their similar phenology and crop calendar, and because they belong to the same high-level crop group (PA to confirm that such grouping makes sense in the CAP context):
    - CEREALS: Durum wheat, Oat, Barley and Soft wheat;
    - GRASSLAND AND LEGUMES: Grassland, Clover, Loietto loglio and Alfalfa;
- Crop types that require specific attention to increase their mapping accuracy: Fava bean, Chickpea, Tomato, Maize and Vegetables.

In stratum 2 (Friuli, Marche and Lazio):

- Crop types that are confused with each other and that could be grouped together because of their similar phenology and crop calendar, and because they belong to the same high-level crop group (to be revised by the PA to define if it makes sense in their local and in the CAP contexts):
    - CEREALS: Durum wheat, Barley and Soft wheat;
    - GRASSLAND AND LEGUMES: Grassland, Clover, Loietto loglio and Alfalfa;
- Crop types that require specific attention to increase their accuracy: Permanent crops, Fallow, Grassland, Fava bean and Vegetables.

5.2.3.5 Crop diversification use case

The results of the conformity assessment at the parcel-level and the crop diversification assessment at the holding-level, based on the end-of-season crop type map, are given in Figure 5-9 and Figure 5-10 for stratum 1 (Campania and Puglia) and in Figure 5-11 and Figure 5-12 for stratum 2 (Friuli, Marche and Lazio).

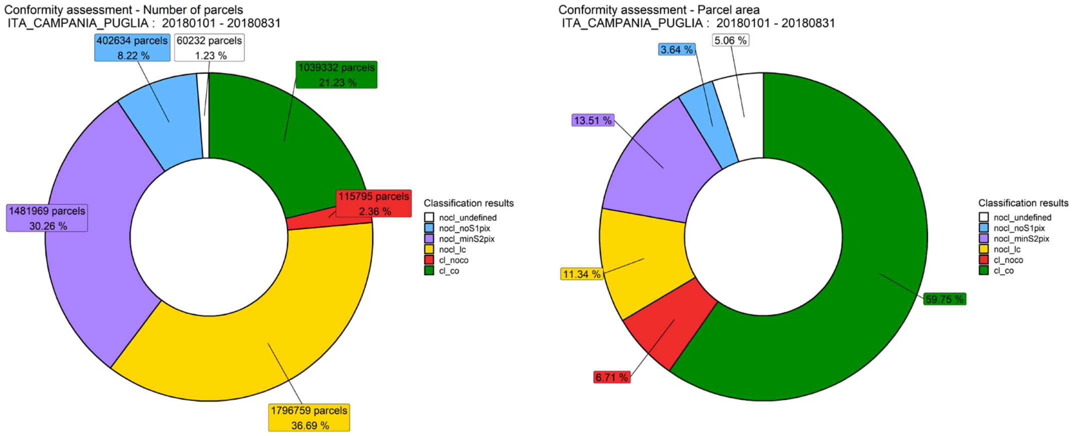


Figure 5-9. Conformity assessment at the parcel level in ITA – Campania and Puglia, 2018

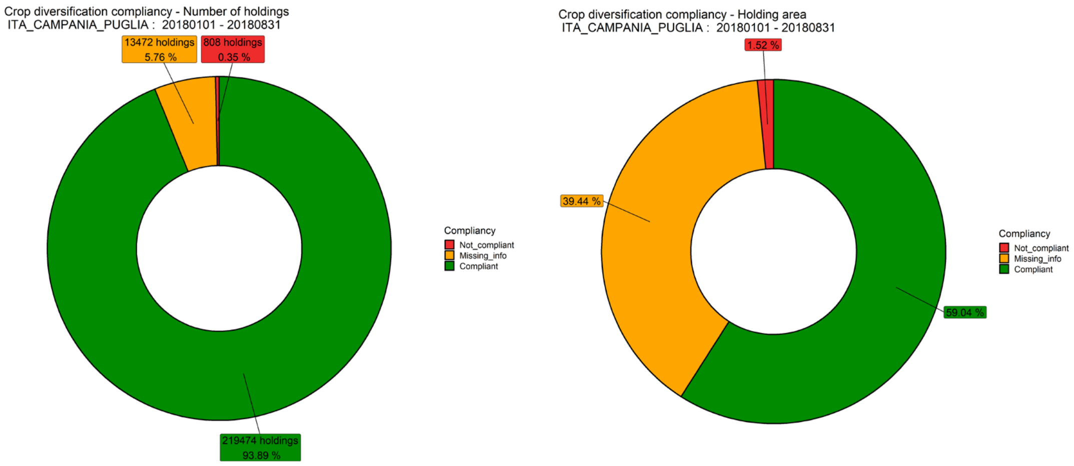


Figure 5-10. Crop diversification assessment at the holding level in ITA – Campania and Puglia, 2018

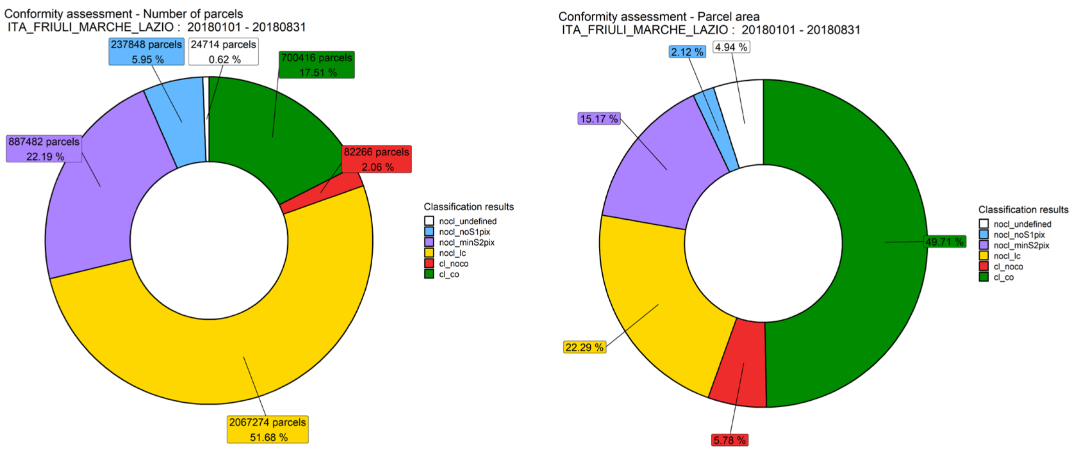


Figure 5-11. Conformity assessment at the parcel level in ITA – Friuli, Marche and Lazio, 2018

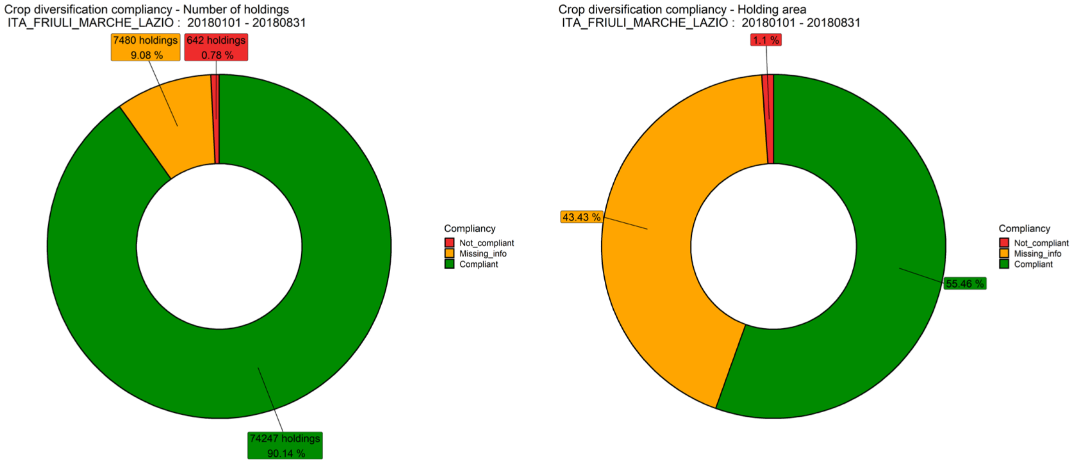


Figure 5-12. Crop diversification assessment at the holding level in ITA – Friuli, Marche and Lazio, 2018

5.2.4 Lithuania

5.2.4.1 Overall accuracy, Kappa and F-Score

The OA and Kappa values of the classification from the end of the season are provided in Table 5-15. These indices are also illustrated in Figure 5-13, in addition to the F-Scores of the individual crop types included in the classification.

Table 5-15. OA and Kappa values for end-of-season crop type map in LTU 2018

Overall Accuracy	Kappa
78.74%	71.02%

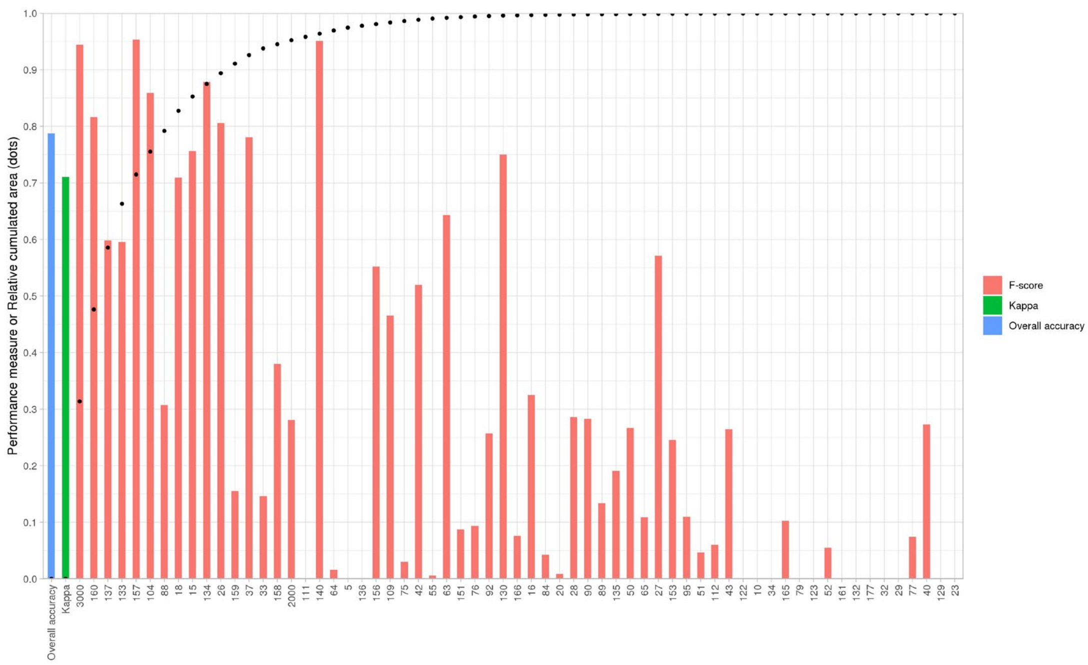


Figure 5-13. OA, Kappa and F-Score values for end-of-season crop type map in LTU 2018

5.2.4.2 Producer's accuracy

Producer's accuracy matrix is provided in Table 5-16 for the 15 main crop types included in the end-of-season classification. For each crop type, the table identifies the three crop types with which they are most confused, and gives the corresponding percentage of confused parcels.

Table 5-16. Producer's accuracy matrix for end-of-season crop type map in LTU 2018

CTnumL4A	CTL4A	Declared parcels	Well classified	Producer accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	Grass	216159	211572	0.979	Winter wheat	0.6	Spring wheat	0.6	Black fallow	0.4	0.5
160	Winter wheat	46205	43206	0.935	Spring wheat	3.5	Grass	1.8	Spring barley	0.4	0.8
137	Spring wheat	39098	33252	0.850	Spring barley	6.1	Winter wheat	4.1	Grass	1.7	3.1
133	Spring barley	31802	16282	0.512	Spring wheat	42.1	Winter wheat	2.2	Grass	1.9	2.6
18	Black fallow	18743	12284	0.655	Grass	12.3	Winter wheat	10.7	Spring wheat	5.3	6.2
88	Oats	17879	3507	0.196	Spring wheat	65.7	Spring barley	6.4	Grass	3.8	4.5
104	Peas	13452	11546	0.858	Spring wheat	4.9	Beans	2.8	Grass	1.2	5.3
157	Winter rape	8900	8573	0.963	Winter wheat	1.5	Peas	0.6	Spring rape	0.5	1.1
159	Winter triticale	8071	704	0.087	Winter wheat	80.0	Grass	4.5	Spring wheat	3.6	3.2
26	Buckwheat	7697	6545	0.850	Grass	5.7	Spring wheat	4.2	Black fallow	1.4	3.7
2000	Permanent crops	6653	1096	0.165	Grass	74.2	Black fallow	3.5	Spring wheat	2.0	3.8
109	Potatoes	5468	1937	0.354	Spring wheat	13.7	Other crops on arable l	8.1	Grass	6.7	36.1
92	Other crops on arable l	5205	882	0.169	Grass	23.9	Spring wheat	18.5	Potatoes	12.5	28.2
134	Spring rape	4956	4444	0.897	Buckwheat	2.3	Beans	1.7	Spring wheat	1.5	4.8
15	Beans	4856	4011	0.826	Spring wheat	7.4	Peas	3.1	Buckwheat	2.7	4.2

The crop types with a producer's accuracy below 0.8 are listed below with the crop types with which they are most confused:

- "Spring barley" and "Oats" (producer accuracy = 0,512; 0,196):
  - Moderate or strong confusion with "Spring wheat";
  - These 3 crop types **could** be grouped together because they have a similar phenology;
- Black fallow (producer accuracy = 0,655):
  - Low confusion with "Grass" and "Winter wheat";
- Winter triticale (producer accuracy = 0,087):
  - Very strong confusion with "Winter wheat"
  - These 2 crop types **could** be grouped together because they have a similar phenology;
- Permanent crops (producer accuracy = 0,165):
  - Strong confusion with "Grassland":
  - It is expected due to the possibly high part of grassland areas in the permanent fruit plantations as well as the "permanent" presence of vegetation throughout the season;
- Potatoes (producer accuracy = 0,354):
  - Low confusion with "Spring wheat";
  - Diffuse confusion (no clear scheme);
- Other crops on arable land (producer accuracy = 0,169):
  - Low confusion with "Grass", "Spring wheat" and "Potatoes";
  - It **should** not be included anymore in the classification because it can be any crop.

5.2.4.3 User's accuracy

User's accuracy matrix is provided in Table 5-17 for the 15 main crop types included in the end-of-season classification. For each crop type, the table identifies the three crop types with which they are most confused, and gives the corresponding percentage of confused parcels.

Table 5-17. User's accuracy matrix for end-of-season crop type map in LTU 2018

CTnumL4A	CTL4A	Classified parcels	Well classified	User accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	**Grass**	231922	211572	0.912	Permanent crops	2.1	Clover	1.3	Black fallow	1.0	4.4
160	**Winter wheat**	59659	43206	0.724	Winter triticale	10.8	Black fallow	3.4	Winter rye	3.2	10.2
137	**Spring wheat**	72077	33252	0.461	Spring barley	18.6	Oats	16.3	Agricultural mix	3.1	15.9
133	**Spring barley**	22876	16282	0.712	Spring wheat	10.4	Oats	5.0	Agricultural mix	2.6	10.8
18	**Black fallow**	15891	12284	0.773	Grass	5.5	Green fallow	1.7	Permanent crops	1.5	14.0
88	**Oats**	4969	3507	0.706	Spring wheat	8.8	Protein crops	4.6	Agricultural mix	4.2	11.8
104	**Peas**	13422	11546	0.860	Potatoes	2.3	Black fallow	1.9	Spring wheat	1.2	8.6
157	**Winter rape**	9087	8573	0.943	Black fallow	1.4	Winter wheat	0.7	Peas	0.7	2.9
159	**Winter triticale**	989	704	0.712	Winter rye	25.5	Winter wheat	1.6	Spring wheat	0.3	1.4
26	**Buckwheat**	8543	6545	0.766	Black fallow	2.4	Potatoes	2.1	Grass	1.9	17.0
2000	**Permanent crops**	1160	1096	0.945	Grass	4.2	Other crops on arable l	1.3	Aromatics	0.0	0.0
109	**Potatoes**	2855	1937	0.678	Other crops on arable l	22.8	Other vegetables	2.7	Black fallow	1.1	5.6
92	**Other crops on arable l**	1658	882	0.532	Potatoes	26.7	Other vegetables	6.5	Grass	3.0	10.6
134	**Spring rape**	5159	4444	0.861	Potatoes	4.0	White mustard	1.8	Peas	1.6	6.5
15	**Beans**	5747	4011	0.698	Peas	6.5	Potatoes	5.2	Black fallow	2.5	16.0

The crop types with a user's accuracy below 0.8 are listed below with the crop types with which they are most confused:

- Winter wheat (user accuracy = 0,724):
  - Moderate confusion with "Winter triticale";
  - These 2 crop types **could** be grouped together because they have a similar phenology;
- Spring wheat (user accuracy = 0,461):
  - Moderate confusion with "Spring barley" and "Oats";
- Spring barley (user accuracy = 0,712):
  - Moderate confusion with "Spring wheat";
- Winter triticale (user accuracy = 0,712):
  - Strong confusion with "Winter Rye";
- Buckwheat (user accuracy = 0,766):
  - Diffuse confusion (no clear scheme);
- Potatoes (user accuracy = 0,678):
  - Moderate confusion with "Other crops on arable land";
- Other crop on arable land (user accuracy = 0,532):
  - Strong confusion with "Potatoes"
- Beans (user accuracy =0,698):
  - Low confusion with Peas and Potatoes;
  - It **should** not be included anymore in the classification because it can be any crop.

5.2.4.4 Recommendations regarding crop type grouping

"Other crops on arable land" should be excluded from the classification because it can be anything.

Crop types that are confused with each other and that could be grouped together because of their similar phenology and crop calendar, and because they belong to the same high-level crop group (PA to confirm that such grouping makes sense in the CAP context):

- SPRING/SUMMER CEREALS: Spring wheat, Spring barley and Oat;
- WINTER CEREALS: Winter wheat, winter Triticale and Winter rye.

Crop types that require specific attention to increase their accuracy: Black fallow, Permanent crops, Potatoes, Buckwheat and Beans.

5.2.4.5 Crop diversification use case

The results of the conformity assessment at the parcel-level and the crop diversification assessment at the holding-level, based on the end-of-season crop type map, are given in Figure 5-14 and Figure 5-15.

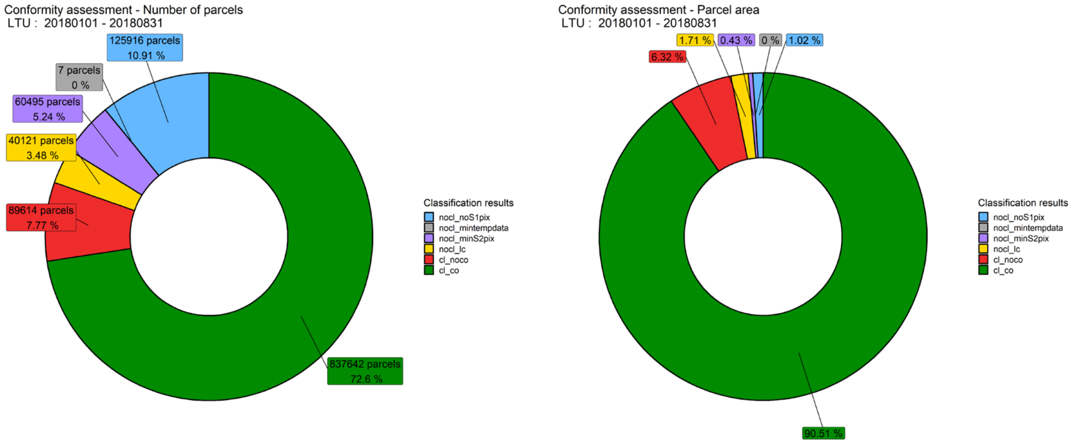


Figure 5-14. Conformity assessment at the parcel level in LTU 2018

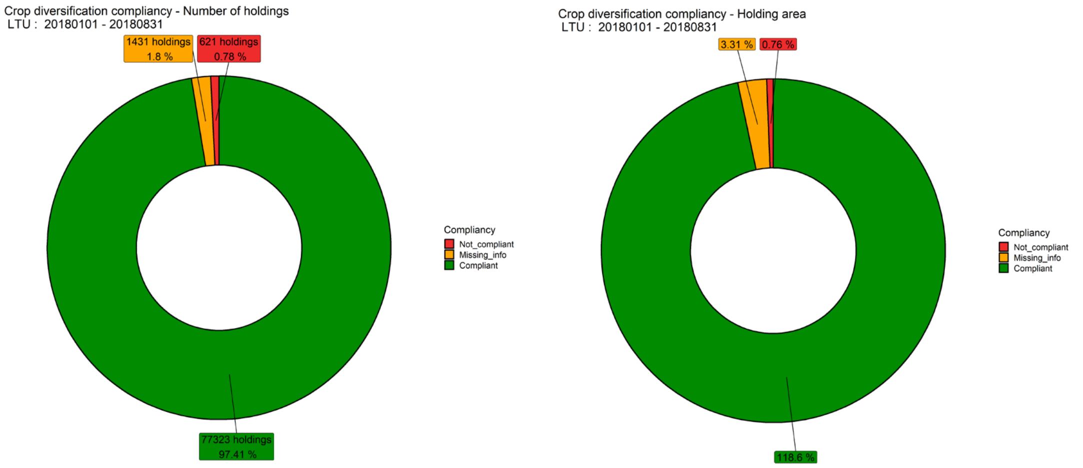


Figure 5-15. Crop diversification assessment at the holding level in LTU 2018

5.2.5 Netherlands

5.2.5.1 Overall accuracy, Kappa and F-Score

The OA and Kappa values of the classification from the end of the season are provided in Table 5-18. These indices are also illustrated in Figure 5-16, in addition to the F-Scores of the individual crop types included in the classification.

Table 5-18. OA and Kappa values for end-of-season crop type map in NLD 2018

Overall Accuracy	Kappa
94.95%	90.21%

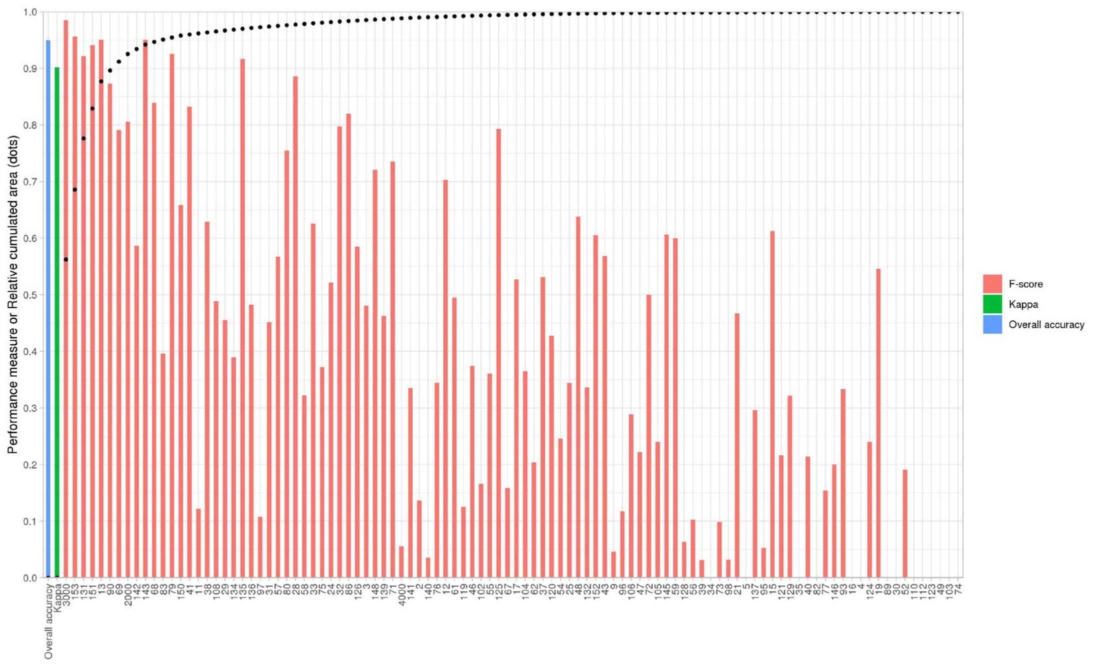


Figure 5-16. OA, Kappa and F-Score values for end-of-season crop type map in NLD 2018

5.2.5.2 Producer’s accuracy

Producer’s accuracy matrix is provided in Table 5-19 for the 15 main crop types included in the end-of-season classification. For each crop type, the table identifies the three crop types with which they are most confused, and gives the corresponding percentage of confused parcels.

Table 5-19. Producer's accuracy matrix for end-of-season crop type map in NLD 2018

CTnumL4A	CTL4A	Declared parcels	Well classified	Producer accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	Grass	223762	222460	0.994	Zea	0.2	Solanum_tuberosum	0.1	Hordeum_summer	0.0	0.3
153	Zea	41878	40729	0.973	Grass	1.3	Solanum_tuberosum	0.9	Onions	0.2	0.3
131	Solanum_tuberosum	16578	15852	0.956	Zea	2.5	Grass	0.6	Onions	0.2	1.1
151	Winter wheat	8710	8378	0.962	Triticum_summer	1.2	Grass	1.1	Hordeum_winter	0.3	1.2
13	Beets	8643	8300	0.960	Solanum_tuberosum	1.5	Zea	1.0	Grass	0.4	1.1
2000	Permanent fruit	6052	4096	0.677	Grass	23.8	Zea	2.9	Gladiolus	0.7	4.9
69	Hordeum_summer	3743	2938	0.785	Grass	6.1	Zea	4.8	Winter wheat	2.4	8.2
90	Onions	3237	3033	0.937	NA	2.8	Beets	0.6	Peas	0.5	2.4
142	Triticum_summer	2100	975	0.464	Hordeum_summer	18.6	Winter wheat	13.6	Zea	6.9	14.5
143	Tulipa	1602	1514	0.945	Hyacinthus	1.4	Grass	1.1	Narcissus	0.6	2.4
68	Hordeum_winter	1048	818	0.781	Grass	11.3	Winter wheat	6.9	Hordeum_summer	1.2	2.5
83	Medicago	837	209	0.250	Grass	58.4	Solanum_tuberosum	6.9	Zea	3.3	6.4
79	Lilium	757	686	0.906	Grass	3.3	Onions	1.1	Zea	0.8	4.2
97	Other flowers	732	44	0.060	Grass	35.5	Zea	7.1	Solanum_tuberosum	5.2	46.2
11	Avena	657	43	0.065	Grass	19.9	Hordeum_summer	17.0	Zea	11.4	45.2

The crop types with a producer’s accuracy below 0.8 are listed below with the crop types with which they are most confused:

- Permanent fruit (producer accuracy = 0,677):
  - Low confusion with “Grass”;
  - It is expected due to the possibly high part of grassland areas in the permanent fruit plantations as well as the “permanent” presence of vegetation throughout the season like the grassland areas;
- Hordeum summer (producer accuracy = 0,785):
  - Diffuse confusion (no clear scheme);
- Triticum summer (producer accuracy = 0,464):

- Low confusion with “Hordeum summer” and “Winter wheat”;
- “Hordeum summer” and “Triticum summer” **could** be grouped together because they have a similar phenology;
- Hordeum winter (producer accuracy = 0,781):
  - Low confusion with “Grass”;
- Medicago (producer accuracy = 0,250):
  - Strong confusion with “Grass”;
  - It **could** be added to the grass group because it has a similar phenology;
- Other flowers (producer accuracy = 0,060):
  - Confusion with “Grass”;
- Avena (producer accuracy = 0,065):
  - Low confusion with “Grass” and “Hordeum summer”.

5.2.5.3 User’s accuracy

User’s accuracy matrix is provided in Table 5-20 for the 15 main crop types included in the end-of-season classification. For each crop type, the table identifies the three crop types with which they are most confused, and gives the corresponding percentage of confused parcels.

Table 5-20. User’s accuracy matrix for end-of-season crop type map in NLD 2018

CTnumL4A	CTL4A	Classified parcels	Well classified	User accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	Grass	227977	222460	0.976	Permanent fruit	0.6	Zea	0.2	Medicago	0.2	1.4
153	Zea	43297	40729	0.941	Grass	1.3	Solanum_tuberosum	1.0	Hordeum_summer	0.4	3.2
131	Solanum_tuberosum	17809	15852	0.890	Zea	2.0	Grass	0.8	Beets	0.7	7.5
151	Winter wheat	9102	8378	0.920	Triticum_summer	3.1	Hordeum_summer	1.0	Triticale	0.8	3.1
13	Beets	8821	8300	0.941	Chicory	0.6	Red beetroot	0.5	Zea	0.4	4.4
2000	Permanent fruit	4122	4096	0.994	Grass	0.2	Other flowers	0.2	Zea	0.1	0.1
69	Hordeum_summer	3688	2938	0.797	Triticum_summer	10.6	Avena	3.0	Grass	1.8	4.9
90	Onions	3712	3033	0.817	Zea	1.8	Peas	1.5	Grass	1.4	13.6
142	Triticum_summer	1227	975	0.795	Winter wheat	8.4	Hordeum_summer	5.0	Avena	4.1	3.0
143	Tulipa	1584	1514	0.956	Other flowers	1.5	Hyacinthus	0.7	Grass	0.4	1.8
68	Hordeum_winter	901	818	0.908	Winter wheat	3.2	Grass	2.0	Secale	1.6	2.4
83	Medicago	219	209	0.954	Trifolium	0.9	Trifolium	0.9	Trifolium	0.9	1.9
79	Lilium	725	686	0.946	Other flowers	1.2	Permanent fruit	0.8	Gladiolus	0.6	2.8
97	Other flowers	85	44	0.518	Grass	8.2	Avena	3.5	Avena	3.5	33.0
11	Avena	52	43	0.827	Hordeum_summer	5.8	Triticum_summer	3.8	Triticum_summer	3.8	3.9

The crop types with a user’s accuracy below 0.8 are listed below with the crop types with which they are most confused:

- Hordeum summer (user accuracy =0,797):
  - Confusion with “Triticum summer”;
- Triticum summer (user accuracy =0,795):
  - Low confusion with “Winter wheat” and “Hordeum summer”;
- Other flowers (user accuracy =0,518):
  - Low confusion with “Grass”.

5.2.5.4 Recommendations for future

Crop types that are confused with each other and that could be grouped together because of their similar phenology and crop calendar, and because they belong to the same high-level crop group (PA to confirm that such grouping makes sense in the CAP context):

- SPRING/SUMMER CEREALS: Hordeum summer and Triticum summer;
- GRASSLAND AND LEGUMES: Grass and Medicago.

Crop types that require specific attention to increase their accuracy: Permanent fruits, Other flowers and Avena.

5.2.5.5 Crop diversification use case

The results of the conformity assessment at the parcel-level and the crop diversification assessment at the holding-level, based on the end-of-season crop type map, are given in Figure 5-17 and Figure 5-18.

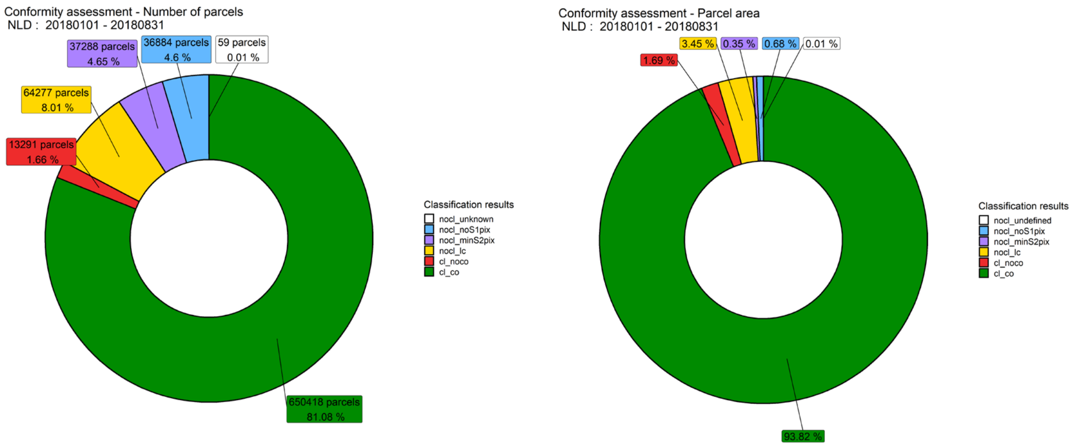


Figure 5-17. Conformity assessment at the parcel level in NLD 2018

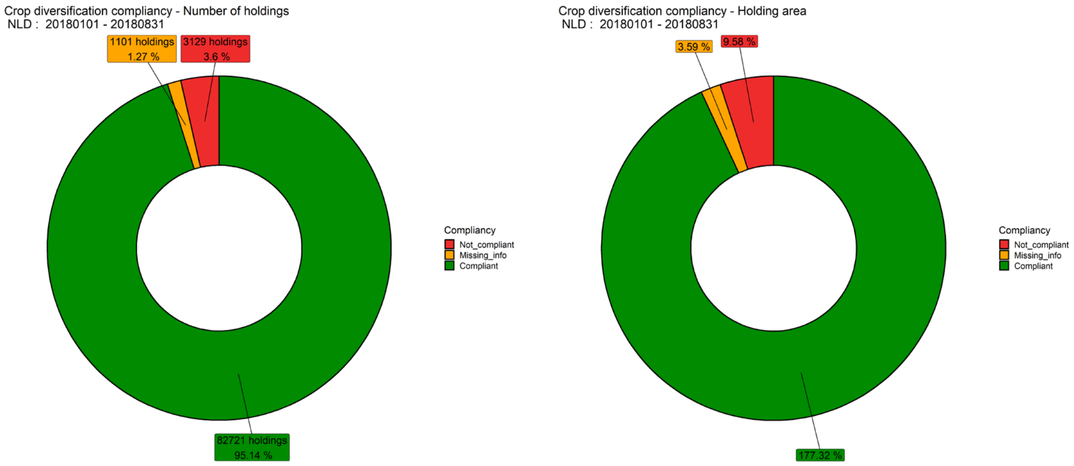


Figure 5-18. Crop diversification assessment at the holding level in NLD 2018

5.2.6 Romania

5.2.6.1 Overall accuracy, Kappa and F-Score

The OA and Kappa values of the classification from the end of the season are provided in Table 5-21. These indices are also illustrated in Figure 5-19, in addition to the F-Scores of the individual crop types included in the classification.

Table 5-21. OA and Kappa values for end-of-season crop type map in ROU 2018

Overall Accuracy	Kappa
64.91%	55.56%

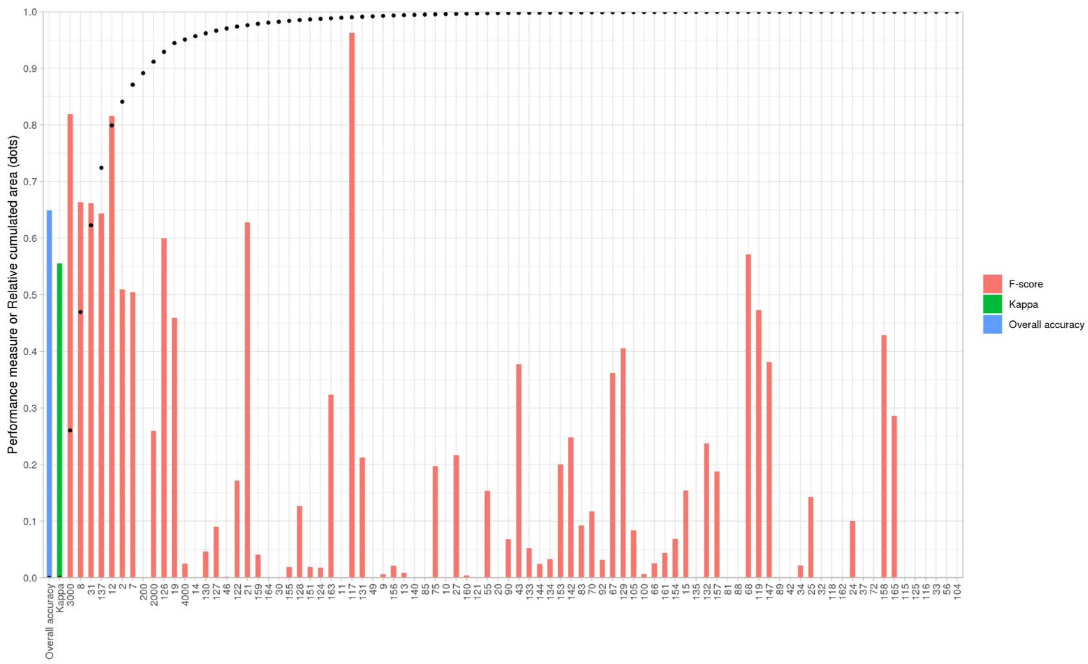


Figure 5-19. OA, Kappa and F-Score values for end-of-season crop type map in ROU 2018

5.2.6.2 Producer’s accuracy

Producer’s accuracy matrix is provided in Table 5-22 for the 15 main crop types included in the end-of-season classification. For each crop type, the table identifies the three crop types with which they are most confused, and gives the corresponding percentage of confused parcels.

Table 5-22. Producer's accuracy matrix for end-of-season crop type map in ROU 2018

CTnumL4A	CTL4A	Declared parcels	Well classified	Producer accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	Grassland	866950	825128	0.952	Corn	2.0	Autumn Common whe	1.8	Alfalfa	0.6	0.4
31	Corn	477753	363245	0.760	Autumn Common whe	9.1	Grassland	6.0	Sunflower	5.2	3.7
8	Autumn Common whe	302494	248317	0.821	Corn	7.9	Grassland	3.5	Sunflower	3.3	3.2
2	Alfalfa	186979	79346	0.424	Grassland	22.8	Corn	20.6	Autumn Common whe	9.1	5.1
2000	Permanent crop	171637	25970	0.151	Grassland	60.5	Corn	15.6	Autumn Common whe	6.4	2.4
137	Sunflower	140949	102313	0.726	Corn	14.5	Autumn Common whe	8.7	Grassland	1.6	2.6
200	Forage plants	140461	37	0.000	Grassland	58.9	Corn	17.0	Alfalfa	10.4	13.7
12	Autumn rape	47485	38190	0.804	Autumn Common whe	11.3	Corn	3.5	Sunflower	2.0	2.8
7	Autumn Barley	42626	16657	0.391	Autumn Common whe	41.0	Corn	9.1	Grassland	4.4	6.4
46	Fresh vegetables	36638	32	0.001	Corn	57.2	Grassland	13.2	Sunflower	10.9	18.6
130	Spring oat	35373	850	0.024	Corn	44.8	Autumn Common whe	26.1	Grassland	14.3	12.4
164	Potatoes_late	27434	12	0.000	Corn	51.0	Grassland	26.7	Sunflower	11.3	11.0
4000	Fallow land	24686	316	0.013	Grassland	47.1	Autumn Common whe	27.2	Corn	17.0	7.4
19	Bean peas	21138	8944	0.423	Corn	21.6	Autumn Common whe	17.4	Sunflower	12.3	6.4
127	Spring barley	21127	1044	0.049	Corn	42.4	Autumn Common whe	27.5	Grassland	9.8	15.4

The crop types with a producer’s accuracy below 0.8 are listed below with the crop types with which they are most confused:

- Corn (producer accuracy = 0,760):
  - Diffuse confusion (no clear scheme);
- Alfalfa (producer accuracy = 0,424):

    - Low confusion with “Grassland” and “Corn”;
    - It **could** be added to the grassland group;
- “Permanent crop” and “Fallow land” (producer accuracy = 0,151; 0,013):
    - Strong confusion with “Grassland”;
    - Such confusion was expected due to the fact that fallow lands are made of grass species, to the possibly high part of grassland areas in the permanent fruit plantations as well as to the “permanent” presence of vegetation throughout the season;
- Sunflower (producer accuracy = 0,726):
    - Low confusion with “Corn”;
- Forage plants (producer accuracy = 0):
    - Strong confusion with “Grassland”;
    - It **could** be added to the grassland group
- Autumn barley (producer accuracy = 0,391):
    - Moderate confusion with “Autumn common wheat”;
    - These 2 crop types **could** be grouped together because they have a similar phenology;
- “Fresh vegetables”, “Spring oat” and “Potatoes late” (producer accuracy = 0n001; 0,024; 0):
    - Strong confusion with “Corn”;
    - Moderate confusion with “Autumn common wheat” (Spring oat) and “Grassland” (Potatoes late);
- Bean peas (producer accuracy = 0,423):
    - Low confusion with “Corn”, “Autumn common wheat” and “Sunflower”;
- Spring barley (producer accuracy = 0,049):
    - Moderate confusion with “Corn” and “Autumn common wheat”.

5.2.6.3 User’s accuracy

User’s accuracy matrix is provided in Table 5-23 for the 15 main crop types included in the end-of-season classification. For each crop type, the table identifies the three crop types with which they are most confused, and gives the corresponding percentage of confused parcels.

Table 5-23. User’s accuracy matrix for end-of-season crop type map in ROU 2018

CTnumL4A	CTL4A	Classified parcels	Well classified	User accuracy	Confusion class 1	%	Confusion class 2	%	Confusion class 3	%	Rest %
3000	Grassland	1147594	825128	0.719	Permanent crop	9.0	Forage plants	7.2	Alfalfa	3.7	8.2
31	Corn	619944	363245	0.586	Alfalfa	6.2	Permanent crop	4.3	Forage plants	3.8	27.1
8	Autumn Common whe	446212	248317	0.557	Corn	9.7	Autumn Barley	3.9	Alfalfa	3.8	26.9
2	Alfalfa	124452	79346	0.638	Forage plants	11.7	Corn	8.6	Grassland	4.3	11.6
2000	Permanent crop	28501	25970	0.911	Grassland	2.9	Corn	1.7	Fresh vegetables	0.9	3.4
137	Sunflower	177053	102313	0.578	Corn	14.0	Autumn Common whe	5.6	Alfalfa	3.8	18.8
200	Forage plants	70	37	0.529	Grassland	10.0	Grassland	10.0	Alfalfa	8.6	18.5
12	Autumn rape	46124	38190	0.828	Autumn Common whe	5.5	Corn	3.3	Sunflower	1.6	6.8
7	Autumn Barley	23436	16657	0.711	Autumn Common whe	12.4	Corn	4.2	Alfalfa	2.4	9.9
46	Fresh vegetables	45	32	0.711	Potatoes_early	8.9	Corn	6.7	Water melons and mel	4.4	8.9
130	Spring oat	1345	850	0.632	Corn	8.3	Autumn Oat	6.2	Spring barley	5.7	16.6
164	Potatoes_late	14	12	0.857	Potatoes_early	7.1	Potatoes_early	7.1	Phacelia	0.0	0.1
4000	Fallow land	783	316	0.404	Grassland	10.5	Autumn RYE	7.5	Autumn RYE	7.5	34.1
19	Bean peas	17848	8944	0.501	Corn	7.3	Spring barley	5.3	Autumn Common whe	4.9	32.4
127	Spring barley	2076	1044	0.503	Spring oat	20.7	Spring Common wheat	6.6	Corn	6.1	16.3

The crop types with a user’s accuracy below 0.8 are listed below with the crop types with which they are most confused:

- “Grassland”, “Alfalfa” and “Forage plants” (user accuracy = 0,719; 0,638; 0,529):
    - Moderate or low confusion between each other;
    - These 3 crop types **could** be grouped together because they have a similar phenology;
- Corn (user accuracy = 0,586):
    - Low confusion with Alfalfa;
- Autumn common wheat (user accuracy = 0,557):
    - Low confusion with Corn;
- Sunflower (user accuracy = 0,578):
    - Moderate or low confusion with “Corn” and “Autumn common wheat”;
- Autumn barley (user accuracy = 0,711):
    - Confusion with “Autumn common wheat”;
    - These 2 crop types **could** be grouped together because they have a similar phenology;
- Fresh vegetables (user accuracy = 0,711):
    - Low confusion with “Potatoes early” and “Corn”;
- Spring oat (user accuracy = 0,632):
    - Low confusion with “Corn”, “Autumn oat” and “Spring barley”;
- Fallow land (user accuracy = 0,404):
    - Moderate or low confusion with “Grassland” and “Autumn rye”;
- Bean peas (user accuracy = 0,501):
    - Low confusion with “Corn” and “Spring barley”;
- Spring barley (user accuracy = 0,503):
    - Moderate or low confusion with “Spring oat” and “Spring common wheat”;
    - These 3 crop types **could** be grouped together because they have a similar phenology.

5.2.6.4 Recommendations for future

Crop types that are confused with each other and that could be grouped together because of their similar phenology and crop calendar, and because they belong to the same high-level crop group (PA to confirm that such grouping makes sense in the CAP context):

- AUTUMN/WINTER CEREALS: Autumn common wheat and Autumn barley;
- SPRING/SUMMER CEREALS: Spring oat, Spring barley and Spring common wheat;
- GRASSLAND AND LEGUMES: Grassland, Alfalfa and Forage plants.

Crop types that require specific attention to increase their accuracy: Corn, Permanent crops, Fallow land, Sunflower, Fresh vegetables, Potatoes late and Bean peas.

5.2.6.5 Crop diversification use case

The results of the conformity assessment at the parcel-level and the crop diversification assessment at the holding-level, based on the end-of-season crop type map, are given in Figure 5-20 and Figure 5-21.

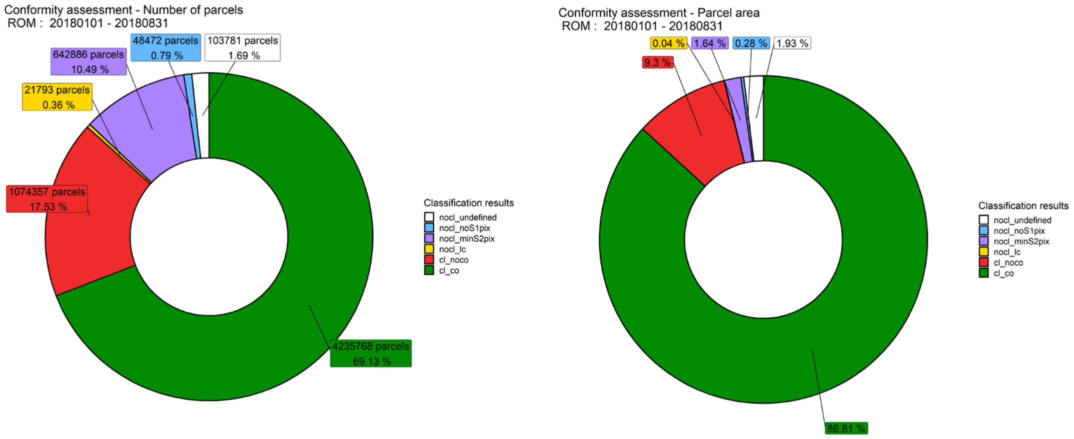


Figure 5-20. Conformity assessment at the parcel level in ROU 2018

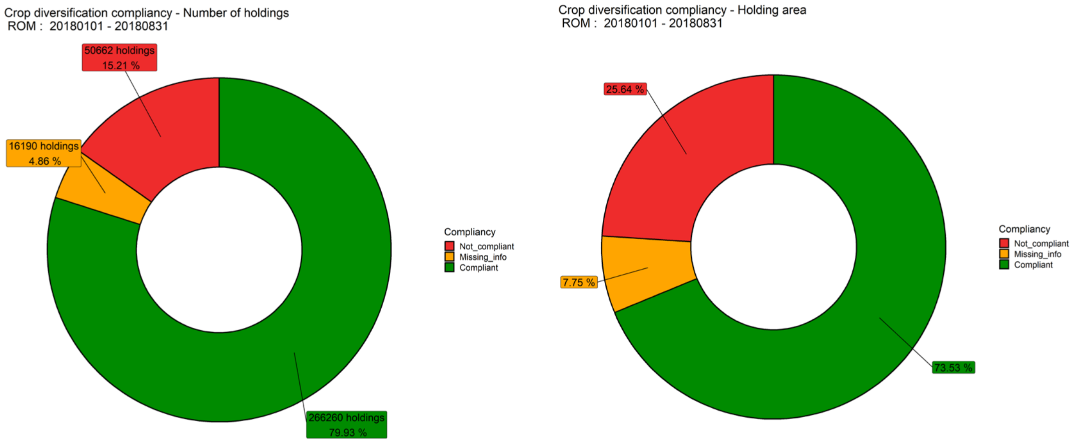


Figure 5-21. Crop diversification assessment at the holding level in ROU 2018

5.3 Grassland Mowing detection product

The 2018 products were validated using the two types of validation datasets (Planet data interpretation and farmer interviews) as explained in Section 3.3. The methodology followed for this validation is explained below. The results are then presented country by country.

1) Validation datasets preparation

✓ ***Planet Dataset***

For each country, a sample of parcels has been randomly selected in order to be statistically representative of national grassland parcels characteristics. To this end, a preliminary analysis has been performed to characterize the grassland parcels distribution in terms of (i) crop type and (ii) parcel size. Examples for Netherlands are provided in Figure 5-22 and Figure 5-23.

Figure 5-22. Grassland parcel type distribution in the Netherlands (2018)

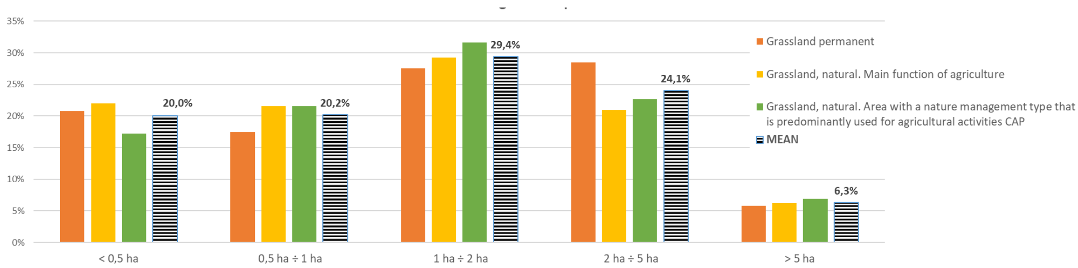


Figure 5-23. Grassland parcel size distribution in the Netherlands (2018)

The parcels to be visually interpreted on the Planet dataset have been chosen according to the following criteria:

- Selection of **200 parcels** for small countries (NLD, CZE and LTU) and **of 400 parcels** for large countries (ITA, ESP and ROU);
- Parcels selection **following the crop type national distribution**, with a **minimum of five parcels per crop type**. In the Dutch case, using Figure 5-22, the 200 parcels would be distributed as 180 parcels of “Grassland permanent”, 5 parcels of “Grassland, natural. Main function of agriculture” and 10 parcels of “Grassland, natural. Area with a nature management type that is predominantly used for agricultural activities CAP”;
- Parcels selection **uniformly distributed within the 5 classes of size** (< 0.5 ha, 0.5 ha - 1 ha, 1 ha - 2 ha, 2 ha - 5 ha, > 5 ha), in order to evaluate the impact of parcel area on the detection accuracy;
- Parcel’s sampling in order to have a **uniform spatial density over the entire countries** that, especially for larger ones, can be characterized by different mowing practices or frequency, and different grassland phenological behavior (drought, etc.) during the growing season. Example for Netherlands is shown in Figure 5-24;
- Parcels selection **excluding** the parcels already available in the validation dataset provided by the PAs (**farmer interview**), in order to enlarge the global validation dataset.

Figure 5-24. Distribution of parcels selected for Planet interpretation in the Netherlands (2018)

The Planet validation dataset is obtained by the visual interpretation of the Planet temporal series (mean resolution: 3.5 m), in order to identify the:

- mowing start date, corresponding to the last available cloud-free Planet image where the grassland seems to be not mowed;
- mowing end date, corresponding to the first available cloud-free Planet image where the grassland seems to be mowed;
- percentage of parcel mowed.

✓ ***Farmer interview dataset***

The validation dataset collected through the farmer interviews has been analyzed and filtered in order to select a sub-set of parcels, providing the following minimum set of information:

- mowing start date;
- mowing end date;
- practice type: grazing or mowing;
- percentage of parcel mowed.

It has to be highlighted that this dataset is collected interviewing a number of farmers\holding selected based on the willingness of the farmers to answer. Therefore, its composition is expected to be not so representative in terms of geographic distribution or of parcel size (see Figure 5-25 for the example in the Netherlands).

Figure 5-25. Distribution of parcels derived from farmer interviews in the Netherlands (2018)

2) Validation datasets reliability

The reliability of the validation dataset is crucial for the correct assessment of a product accuracy. The two truth datasets available for the grassland mowing detection accuracy do not guarantee for their nature, as explained below, a 100% level of correctness.

✓ ***Planet Dataset***

Planet data offer the big advantage to provide near to daily information, but some aspects can affect their correct interpretation:

- **Cloud coverage**: especially in the Northern countries, the temporal series can be characterized by long data gaps due to cloud coverage persistency (more than 1 month). Logically, such a situation would prevent the detection of any mowing during this gap (the grassland re-growth being very fast especially in Northern countries);
- **Non-availability of false color data** (in the Web Mapping Service (WMS) available for the Sen4CAP project): this aspect has a relevant impact on the correct interpretation of the practices. Especially in the Southern countries, it can be difficult to distinguish between mowing and ploughing and, also, between mowing and grassland drought;
- **Image quality**: Planet data are collected by a constellation of small satellites that guarantee a near to daily acquisition. Depending on satellites that acquire the data, even if collected in a short time range (few days), the images can look

strongly different in terms of resolution and color (lighter or darker), risking to cause the identification of "false" mowing practice.

For the aforementioned reasons, in order to consolidate the reliability of the validation dataset, the sample of parcels initially selected has been reduced in some countries during the Planet data interpretation (e.g. parcel too small or image quality too low to identify the mowing with a high level of confidence). Yet, we consider that the Planet data represent a high-quality truth dataset, especially if they can be visually double-checked with NDVI temporal trends derived from S2 (when temporal series are sufficiently dense) to clarify doubt cases on mowing\drought.

✓ ***Farmer interview dataset***

The experience acquired using this type of data in the prototype phase of 2017 has been confirmed in 2018: the information retrieved by farmer's interviews cannot be so accurate, especially for what concerns the dates of mowing. It has been confirmed, also by the PAs that, because the farmers usually manage several grassland parcels, mowed in different days, they may provide a unique date (reference period) for all the parcels, affecting the quality of the information and, consequently, the accuracy assessment.

Figure 5-26 provides an example of not precise mowing period provided by the farmer, as confirmed by the visual interpretation of Planet data. Adopting "as it is" the farmer information as truth, the mowing date correctly detected by the algorithm should result in False Negative and False Positive detections, while they can be in fact visually confirmed on the Planet data.

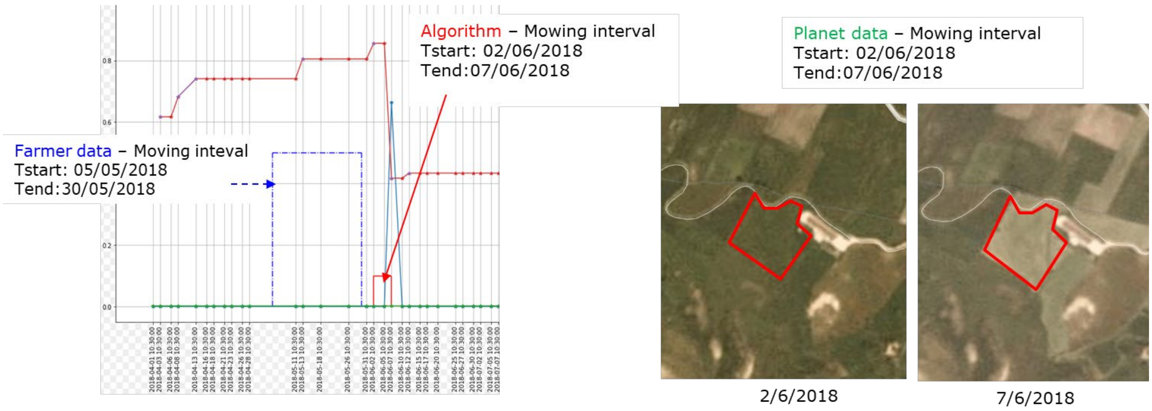


Figure 5-26. Example of not precise mowing date provided by the farmer

To conclude, it can be assumed that the reliability of the Planet data is usually higher than the one provided by the farmers. In order to highlight the impact of not fully reliable validation dataset on the accuracy assessment, the product validation has been assessed in 2 modes, using (i) Planet dataset only and (ii) Planet dataset + Farmer interviews.

3) Validation approach

The objective of validation is to estimate two accuracy indices:

a) **Recall**: fraction of relevant instances that have been retrieved over the total amount of relevant instances

$$Recall\ (\%) = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}$$

b) Precision: fraction of relevant instances among the retrieved instances

$$Precision\ (\%) = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}}$$

where: TP = True Positive, FN = False Negative, FP = False Positive

The accuracy parameters (TP, FP and FN) are estimated as follows:

- Each mowing detection is expressed as a temporal interval (Tstart - Tend), in which the mowing probably occurred;
- The truth mowing dates are temporal interval too, with a minimum of 1 day. A *buffer* of -7 days / + 7 days has been applied to the truth interval (Figure 5-27), considering that:
    - It could be a level of uncertainty of +/- n days, especially for what concerns the farmer information;
    - If the mowing is performed in the afternoon, it will be visible on the satellite acquisition of the day after;
    - The grass can remain on the field for some days after the mowing, impacting on the NDVI value that remains high for a longer time;

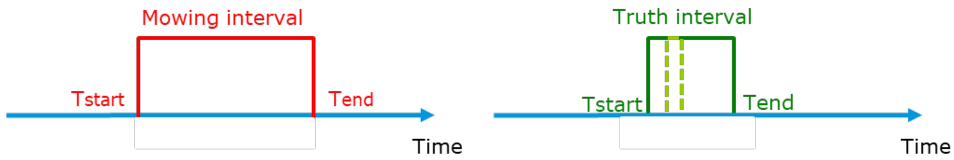


Figure 5-27. Detection mowing and truth (bufferized) mowing intervals

- Considering (i) that the algorithm focuses on the detection of mowing events and (ii) that the grazing is a phenomenon usually too slow and not enough uniform to be identified with the same approach: when a mowing (in the detection) intersects a grazing (in the truth dataset), the detected mowing is not considered neither as a True Positive, nor as a False Positive.

Figure 5-28 summarizes the TP, FP and TN estimation methodology.

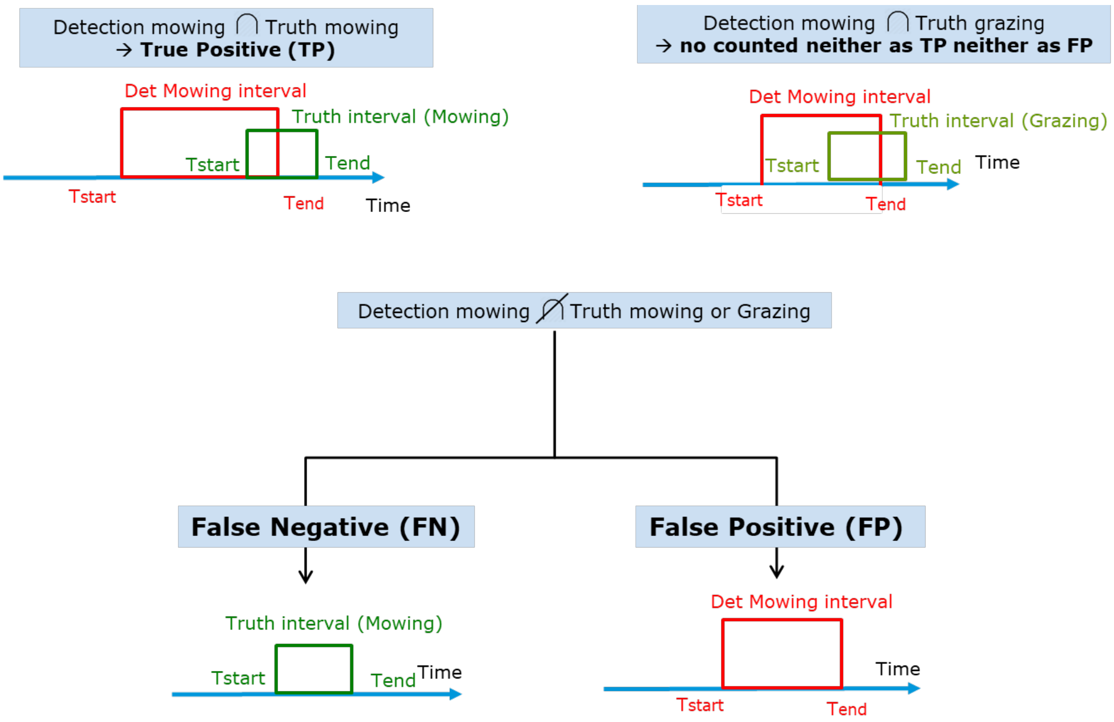


Figure 5-28. True Positive, False Positive and False Negative estimation methodology

4) Validation results

The validation results (recall and precision) are extracted according to the following four condition tests (Table 5-24):

Table 5-24. Validation scenarios for grassland mowing detection

Validation type	Truth dataset	Percentage of parcel mowed
Validation 1	Planet	Partial mowing (< 100%)
Validation 2	Planet	Complete mowing (100%)
Validation 3	Planet + Farmer interview	Partial mowing (< 100%)
Validation 4	Planet + Farmer interview	Complete mowing (100%)

In addition to highlight the impact of the validation dataset quality, the scope of this analysis is to understand the impact of a partial mowing on the detection capability.

The sections below detail all the aspects aforementioned for each countries.

5.3.1 Spain - Castilla y Leon

5.3.1.1 Grassland parcels characteristics

Table 5-25, Table 5-26, Figure 5-29 and Figure 5-30 describe the distribution of the grassland parcels in terms of crop type and size in CyL in 2018. They show that:

- the largest part of grassland parcels belongs to 3 main crop types: (i) pasture of 5 or more years, (ii) arbustive pasture of 5 or more years and (iii) wooden pasture of 5 or more years;
- more than 50% of grassland parcels are smaller than 0.5 ha.

Table 5-25. Crop type distribution of the grassland parcels in CyL in 2018

Crop name	Crop code	Parcel number	Frequency
Alfa-alfa	60	53750	**4,2%**
Pasture less than 5 years (arable land no)	63	52605	**4,1%**
Pasture of 5 or more years	64	451334	**35,0%**
Arbustive pasture of 5 or more years	65	562105	**43,6%**
Wooden pasture of 5 or more years	66	124070	**9,6%**
Sanfoin	67	9184	**0,7%**
Fescue (aralble land no)	68	63	**0,0%**
Ryegrass (arable land no)	69	12448	**1,0%**
Bluegrass	74	36	**0,00%**
Clover	77	245	**0,02%**
Vetch and oat mixture	241	12023	**0,9%**
Vetch and tritical mixture	242	293	**0,02%**
Vetch and wheat mixture	243	2397	**0,2%**
Vetch and barley mixture	244	380	**0,0%**
Mixed crops of meadow species	247	7616	**0,6%**
Sorghum	328	18	**0,001%**
Total parcels (number)		1288567	

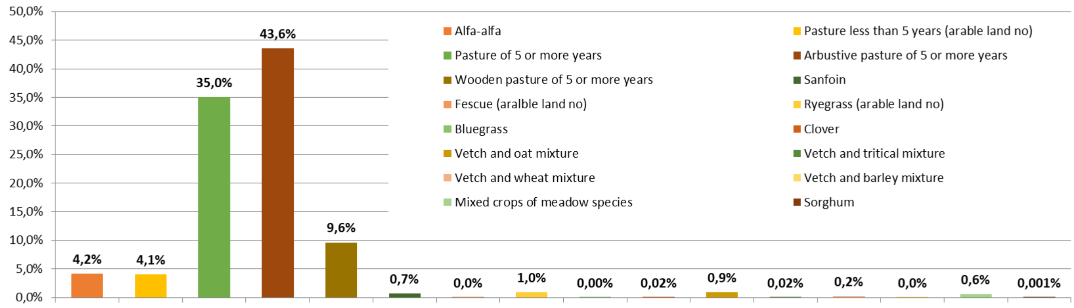


Figure 5-29. 2018 CyL grassland parcel type distribution, expressed as an histogram

Table 5-26. Size distribution of the grassland parcels in CyL in 2018

Crop name	Crop code	< 0,5 ha	0,5 ha ÷ 1 ha	1 ha ÷ 2 ha	2 ha ÷ 5 ha	> 5 ha
Alfa-alfa	60	38%	18%	17%	18%	9%
Pasture less than 5 years (arable land no)	63	69%	13%	8%	5%	5%
Pasture of 5 or more years	64	77%	11%	6%	4%	2%
Arbustive pasture of 5 or more years	65	73%	9%	6%	5%	7%
Wooden pasture of 5 or more years	66	54%	13%	10%	9%	15%
Sanfoin	67	60%	16%	12%	10%	3%
Fescue (aralble land no)	68	44%	13%	10%	25%	8%
Ryegrass (arable land no)	69	44%	19%	17%	15%	5%
Bluegrass	74	39%	19%	8%	12%	23%
Clover	77	37%	14%	19%	24%	6%
Vetch and oat mixture	241	50%	21%	15%	11%	3%
Vetch and tritical mixture	242	39%	19%	22%	13%	7%
Vetch and wheat mixture	243	43%	19%	19%	15%	5%
Vetch and barley mixture	244	46%	17%	16%	17%	5%
Mixed crops of meadow species	247	100%	0%	0%	0%	0%
Sorghum	328	69%	16%	9%	4%	2%
Mean parcel size distribution (%)		**55,0%**	**14,8%**	**12,1%**	**11,6%**	**6,5%**

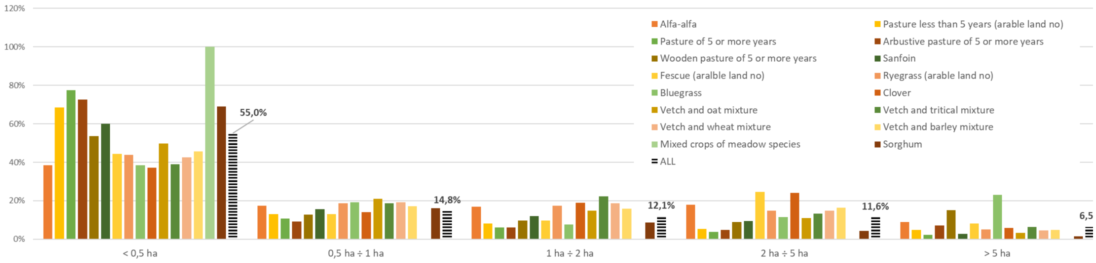


Figure 5-30. 2018 CyL grassland parcel size distribution, expressed as an histogram

5.3.1.2 Validation datasets characteristics

The validation datasets derived from the Planet interpretation and the farmer interviews are described in Table 5-27 and Figure 5-31. The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

Table 5-27. Planet and farmers validation datasets characterization in terms of crop type

Crop name	Crop code	Validation datasets	
		Planet parcel number	Farmer parcel number
Alfa-alfa	60	10	57
Pasture less than 5 years (arable land no)	63	15	19
Pasture of 5 or more years	64	145	439
Arbustive pasture of 5 or more years	65	174	80
Wooden pasture of 5 or more years	66	41	7
Sanfoin	67	5	0
Fescue (aralble land no)	68	5	0
Ryegrass (arable land no)	69	5	30
Bluegrass	74	5	0
Clover	77	5	0
Vetch and oat mixture	241	5	0
Vetch and tritical mixture	242	5	0
Vetch and wheat mixture	243	5	0
Vetch and barley mixture	244	5	0
Mixed crops of meadow species	247	5	13
Sorghum	328	5	0
Total parcels (number)		**440**	**454**

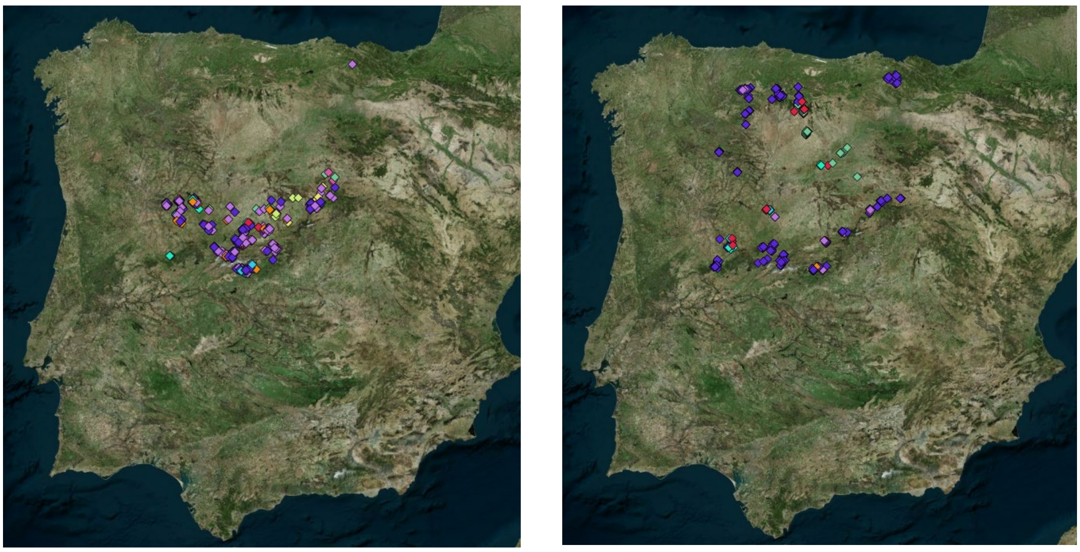


Figure 5-31. Spatial distribution of the 2018 CyL parcels selected for Planet interpretation (left) and derived from farmer interview (right)

5.3.1.3 Validation results

The results obtained with the different scenarios presented in Table 5-24 are presented below.

Table 5-28. Validation results for grassland mowing detection in CyL 2018, based on the Planet data only and considering the partial mowing (top) or only the complete mowing (bottom)

Validation 1 - Truth dataset: Planet		Percentage of parcel mowed: Partial mowing (< 100%)				
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**263**	**64**	**478**	**19**	**77%**	**12%**
0 ha - 0.5 ha	217	53	395	15	78%	12%
0.5 ha - 1 ha	168	47	299	13	78%	14%
1 ha - 2 ha	109	31	205	6	84%	13%
2 ha - 5 ha	59	12	113	2	86%	10%

Validation 2 - Truth dataset: Planet		Percentage of parcel mowed: Complete mowing (100%)				
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**234**	**41**	**458**	**13**	**76%**	**8%**
0 ha - 0.5 ha	189	31	374	9	78%	8%
0.5 ha - 1 ha	143	27	280	8	77%	9%
1 ha - 2 ha	94	17	196	5	77%	8%
2 ha - 5 ha	54	7	109	2	78%	6%

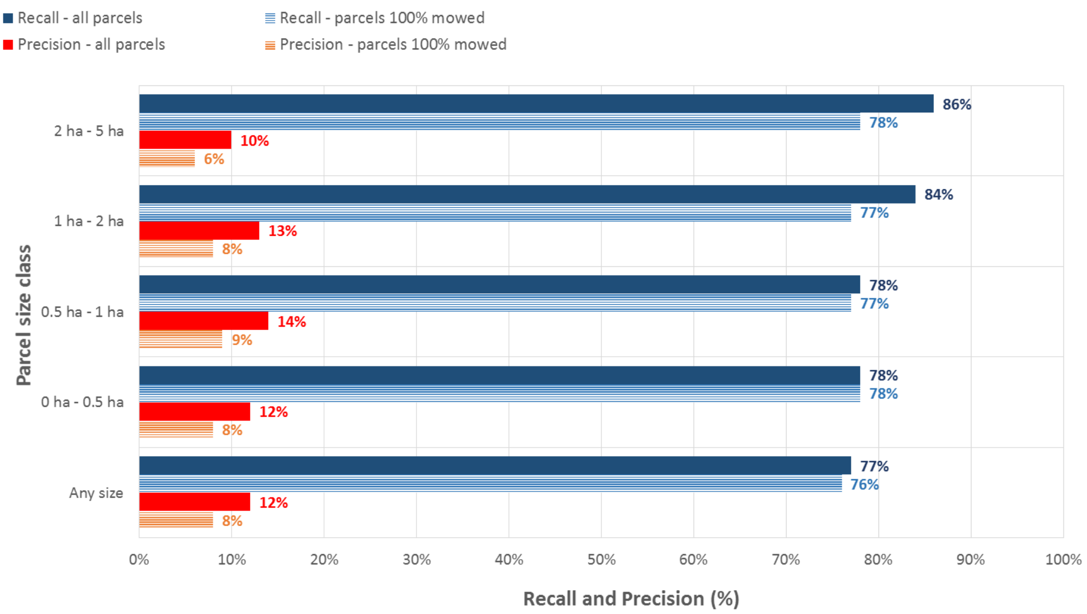


Figure 5-32. 2018 CyL validation results (scenarios 1 and 2 – Planet dataset)

Table 5-29. Validation results for grassland mowing detection in CyL 2018, based on the Planet data and on the farmers' interviews and considering the partial mowing (top) or only the complete mowing (bottom)

Validation 3 - Truth dataset: Planet + Farmer interview			Percentage of parcel mowed: Partial mowing (< 100%)			
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**975**	**484**	**1592**	**311**	**61%**	**23%**
0 ha - 0.5 ha	614	291	954	167	64%	23%
0.5 ha - 1 ha	440	214	648	111	66%	25%
1 ha - 2 ha	253	115	392	59	66%	23%
2 ha - 5 ha	110	40	178	18	69%	18%

Validation 4 - Truth dataset: Planet + Farmer interview			Percentage of parcel mowed: Complete mowing (100%)			
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**934**	**456**	**1553**	**298**	**60%**	**23%**
0 ha - 0.5 ha	575	265	919	154	63%	22%
0.5 ha - 1 ha	406	190	620	101	65%	23%
1 ha - 2 ha	229	97	374	53	65%	21%
2 ha - 5 ha	100	33	172	15	69%	16%

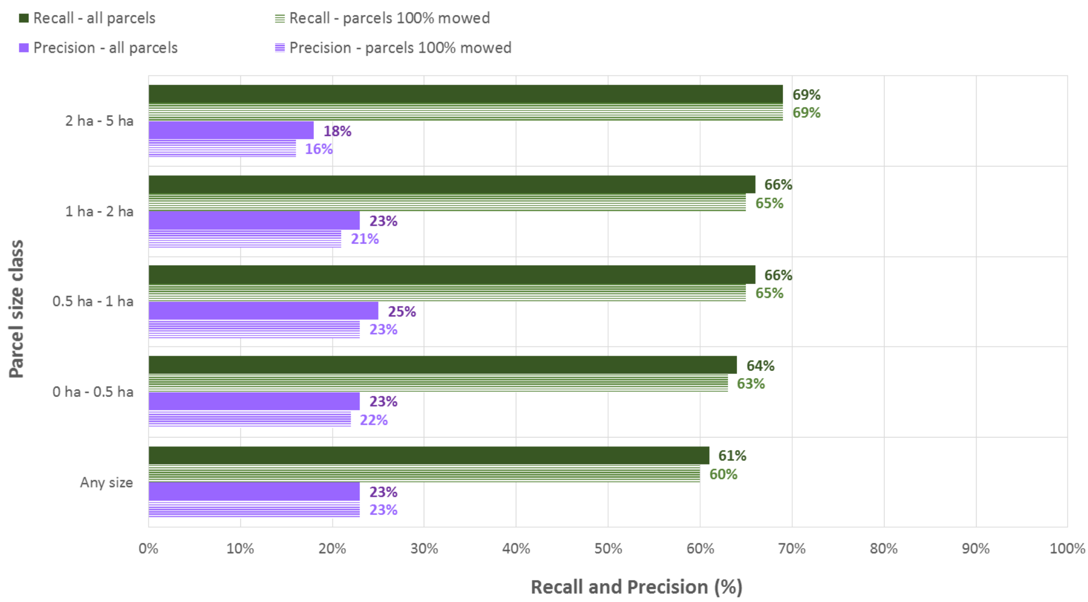


Figure 5-33. 2018 CyL Validation results (scenarios 3 and 4 – Planet + Farmer interviews dataset)

5.3.2 Czech Republic

5.3.2.1 Grassland parcels characteristics

Table 5-30, Table 5-31, Figure 5-34 and Figure 5-35 describe the distribution of 2018 Czech grassland parcels in terms of crop type and size. They show that:

- the largest part of grassland parcels belongs to a single crop type, which is "Grassland on arable land";
- the parcels size is quite uniformly distributed.

Table 5-30. Crop type distribution of the grassland parcels in CZE 2018

Crop name	Crop code	Parcel number	Frequency
Grassland	G	14994	5%
Grassland on arable land	T	308232	95%
Total parcels (number)		323226	

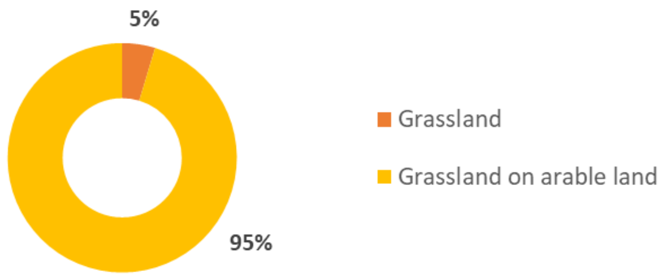


Figure 5-34. 2018 CZE grassland parcel type distribution, expressed as a chart

Table 5-31. Size distribution of the grassland parcels in CZE 2018

Crop name	Crop code	< 0,5 ha	0,5 ha ÷ 1 ha	1 ha ÷ 2 ha	2 ha ÷ 5 ha	> 5 ha
Grassland	265	35%	21%	19%	17%	8%
Grassland on arable land	331	25%	19%	20%	20%	16%
Mean parcel size distribution (%)		30,1%	19,9%	19,5%	18,7%	12,0%

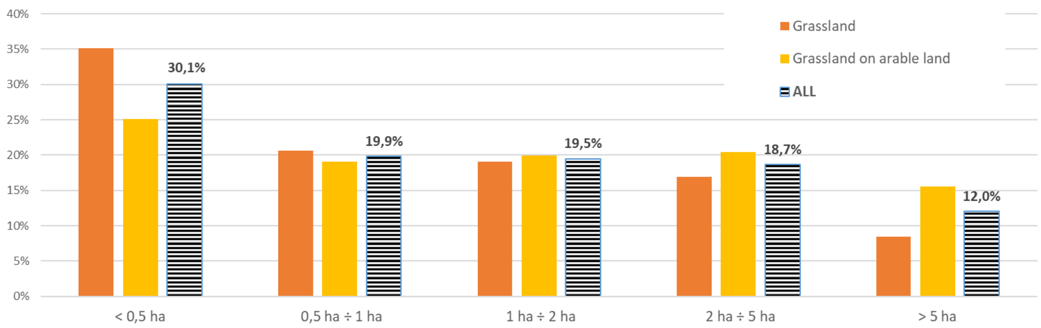


Figure 5-35. 2018 CZE grassland parcel size distribution, expressed as an histogram

5.3.2.2 Validation datasets characteristics

The validation datasets derived from the Planet interpretation and the farmer interviews are described in Table 5-32 and Figure 5-36. The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

Table 5-32. Planet and farmers validation datasets characterization in terms of crop type

Crop name	Crop code	Validation datasets	
		Planet parcel number	Farmer parcel number
Grassland	G	10	0
Grassland on arable land	T	190	454
Total parcels (number)		200	454

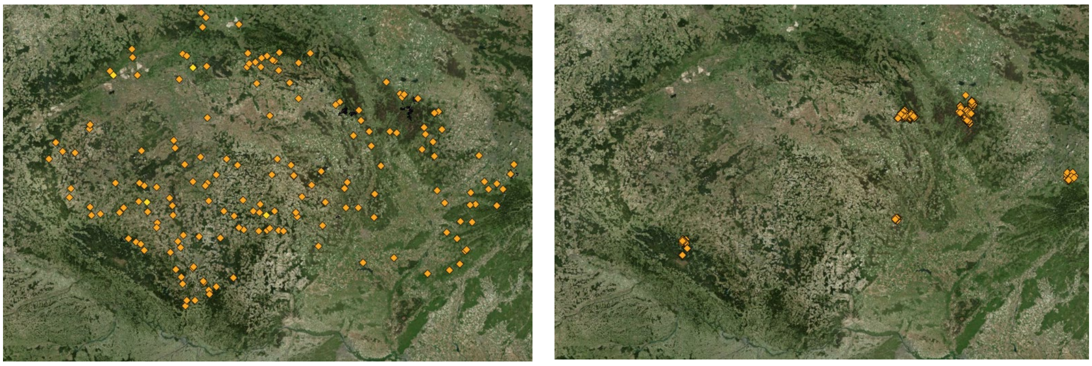


Figure 5-36. Distribution of 2018 CZE parcels selected for Planet interpretation (left) and derived from farmer interview (right)

5.3.2.3 Validation results

The results obtained with the different scenarios presented in Table 5-24 are presented below.

Table 5-33. Validation results for grassland mowing detection in CZE 2018, based on the Planet data only and considering the partial mowing (top) or only the complete mowing (bottom)

Validation 2 - Truth dataset: Planet		Percentage of parcel mowed: Complete mowing (100%)				
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**197**	**158**	**192**	**31**	**84%**	**45%**
0 ha - 0.5 ha	153	128	151	20	86%	46%
0.5 ha - 1 ha	111	96	115	12	89%	45%
1 ha - 2 ha	69	64	77	4	94%	45%
2 ha - 5 ha	30	28	34	1	97%	45%

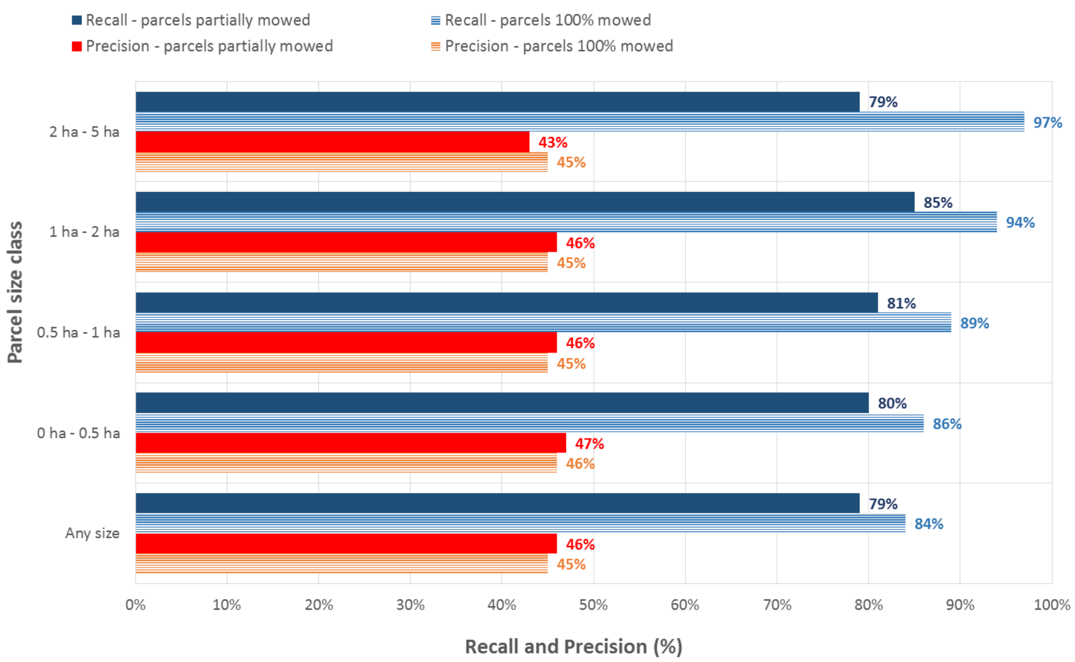


Figure 5-37. 2018 CZE Validation results (scenarios 1 and 2 – Planet dataset)

Table 5-34. Validation results for grassland mowing detection in CZE 2018, based on the Planet data and on the farmers' interviews and considering the partial mowing (top) or only the complete mowing (bottom)

Validation 3 - Truth dataset: Planet + Farmer interview			Percentage of parcel mowed: Partial mowing (< 100%)			
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**1250**	**600**	**275**	**275**	**69%**	**50%**
0 ha - 0.5 ha	1171	555	262	262	69%	51%
0.5 ha - 1 ha	970	452	214	214	69%	51%
1 ha - 2 ha	705	311	160	160	69%	54%
2 ha - 5 ha	452	185	117	117	67%	56%

Validation 4 - Truth dataset: Planet + Farmer interview			Percentage of parcel mowed: Complete mowing (100%)			
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**828**	**573**	**593**	**247**	**70%**	**49%**
0 ha - 0.5 ha	781	542	548	234	70%	50%
0.5 ha - 1 ha	642	452	445	187	71%	50%
1 ha - 2 ha	477	338	308	138	71%	52%
2 ha - 5 ha	315	218	180	96	69%	55%

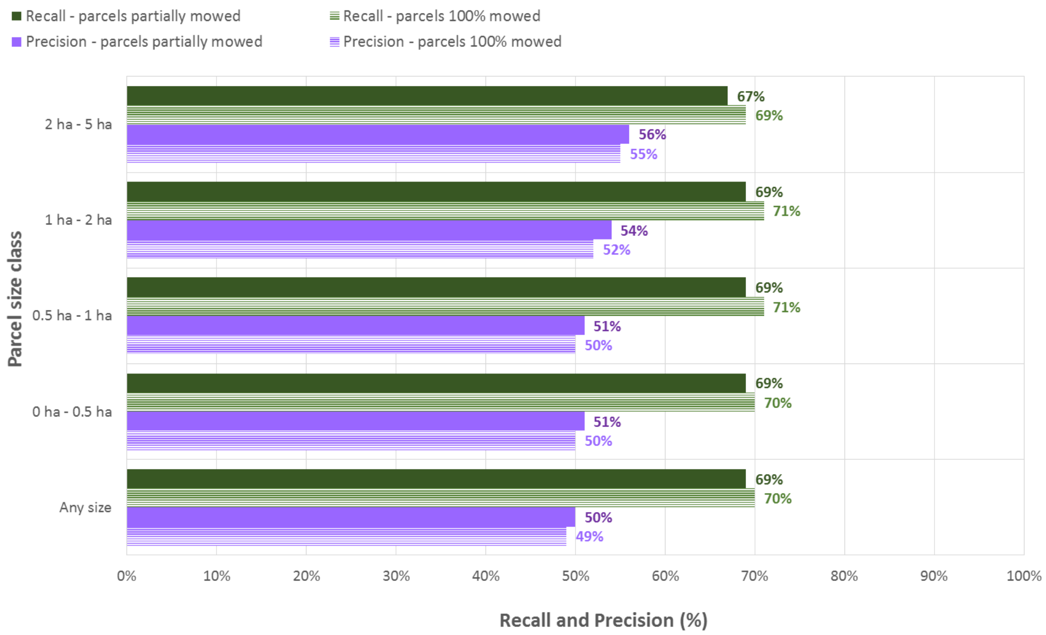


Figure 5-38. 2018 CZE validation results (scenarios 3 and 4 – Planet + Farmer interviews dataset)

5.3.3 Italy

5.3.3.1 Grassland parcels characteristics

Table 5-35, Table 5-36, Figure 5-39 and Figure 5-40 describe the distribution of 2018 Italian grassland parcels in terms of crop type and size. They show that:

- the largest part of grassland parcels belongs to 3 main crop types, which are (i) "Grassland", "Meadow" and "Alpha-alpha";
- more than 70% of grassland parcels cover an area smaller than 0.5 ha.

Table 5-35. Crop type distribution of the grassland parcels in ITA in 2018

Crop name	Crop code	Parcel number	Frequency
Grassland	65	155773	32%
Meadow	336	133133	27%
Alpha-Alpha	357	3015	1%
Permanent grassland with envinromental constraints	391	186	0,04%
Alpha-Alpha	562	146461	30%
Permanent grassland	899	48769	10%
Total parcels (number)		487337	

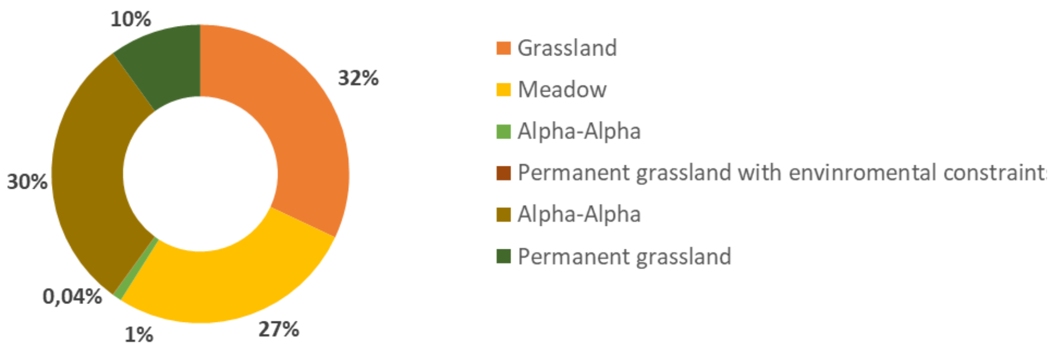


Figure 5-39. 2018 ITA grassland parcel type distribution, expressed as a chart

Table 5-36. Size distribution of the grassland parcels in ITA 2018

Crop name	Crop code	< 0,5 ha	0,5 ha ÷ 1 ha	1 ha ÷ 2 ha	2 ha ÷ 5 ha	> 5 ha
Grassland	65	80%	8%	5%	4%	3%
Meadow	336	86%	7%	4%	2%	1%
Alpha-Alpha	357	52%	15%	14%	14%	5%
Permanent grassland with envinromental constraints	391	75%	12%	6%	3%	4%
Alpha-Alpha	562	64%	15%	11%	8%	3%
Permanent grassland	899	82%	8%	5%	3%	2%
Mean parcel size distribution (%)		73,0%	11,0%	7,0%	6,0%	3,0%

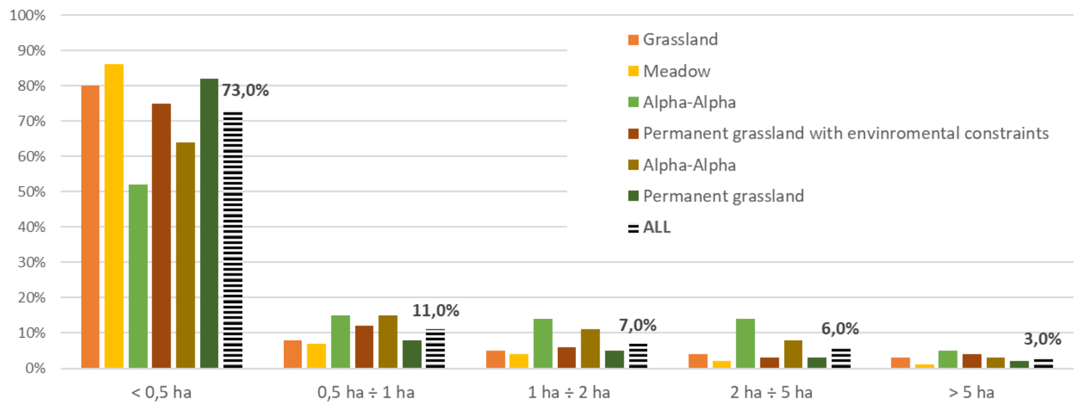


Figure 5-40. 2018 ITA grassland parcel size distribution, expressed as an histogram

5.3.3.2 Validation datasets characteristics

The validation datasets derived from the Planet interpretation and the farmer interviews are described in Table 5-37 and Figure 5-41. The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

Table 5-37. Planet and farmers validation datasets characterization in terms of crop type

Crop name	Crop code	Validation datasets	
		Planet parcel number	Farmer parcel number
Grassland	65	**125**	165
Meadow	336	**105**	172
Alpha-Alpha	357	**5**	33
Permanent grassland with envinromental constraints	391	**5**	0
Alpha-Alpha	562	**120**	19
Permanent grassland	899	**40**	216
Total parcels (number)		**400**	**454**

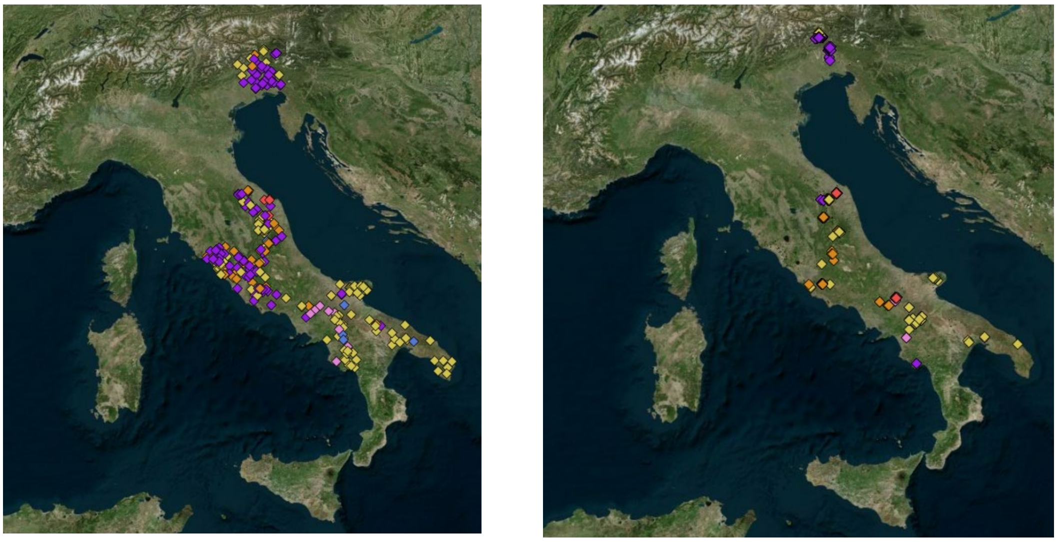


Figure 5-41. Distribution of 2018 ITA parcels selected for Planet interpretation (left) and derived from farmer interview (right)

5.3.3.3 Validation results

The results obtained with the different scenarios presented in Table 5-24 are presented below.

Table 5-38. Validation results for grassland mowing detection in ITA 2018, based on the Planet data only and considering the partial mowing (top) or only the complete mowing (bottom)

Validation 1 - Truth dataset: Planet	Percentage of parcel mowed: Partial mowing (< 100%)					
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	328	139	513	53	72%	21%
0 ha - 0.5 ha	285	124	463	43	74%	21%
0.5 ha - 1 ha	212	87	365	36	71%	19%
1 ha - 2 ha	152	62	254	29	68%	20%
2 ha - 5 ha	71	28	138	8	78%	17%

Validation 2 - Truth dataset: Planet	Percentage of parcel mowed: Complete mowing (100%)					
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	251	89	460	26	77%	16%
0 ha - 0.5 ha	210	75	411	17	82%	15%
0.5 ha - 1 ha	149	49	324	11	82%	13%
1 ha - 2 ha	105	36	229	8	82%	14%
2 ha - 5 ha	56	17	127	4	81%	12%

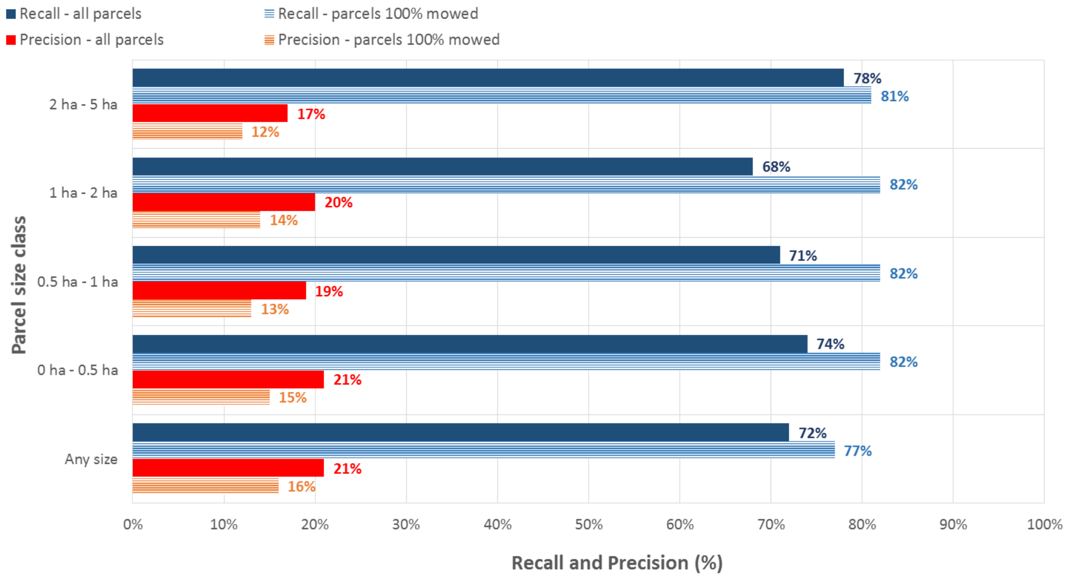


Figure 5-42. 2018 ITA validation results (scenarios 1 and 2 – Planet dataset)

Table 5-39. Validation results for grassland mowing detection in ITA 2018, based on the Planet data and on the farmers' interviews and considering the partial mowing (top) or only the complete mowing (bottom)

Validation 3 - Truth dataset: Planet + Farmer interview			Percentage of parcel mowed: Partial mowing (< 100%)			
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**871**	**458**	**1345**	**277**	**62%**	**25%**
0 ha - 0.5 ha	470	263	821	89	75%	24%
0.5 ha - 1 ha	333	182	602	62	75%	23%
1 ha - 2 ha	229	128	397	40	76%	24%
2 ha - 5 ha	103	57	199	11	84%	22%

Validation 4 - Truth dataset: Planet + Farmer interview			Percentage of parcel mowed: Complete mowing (100%)			
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**794**	**408**	**1292**	**250**	**62%**	**24%**
0 ha - 0.5 ha	395	214	769	63	77%	22%
0.5 ha - 1 ha	270	144	561	37	80%	20%
1 ha - 2 ha	182	102	372	19	84%	22%
2 ha - 5 ha	88	46	188	7	87%	20%

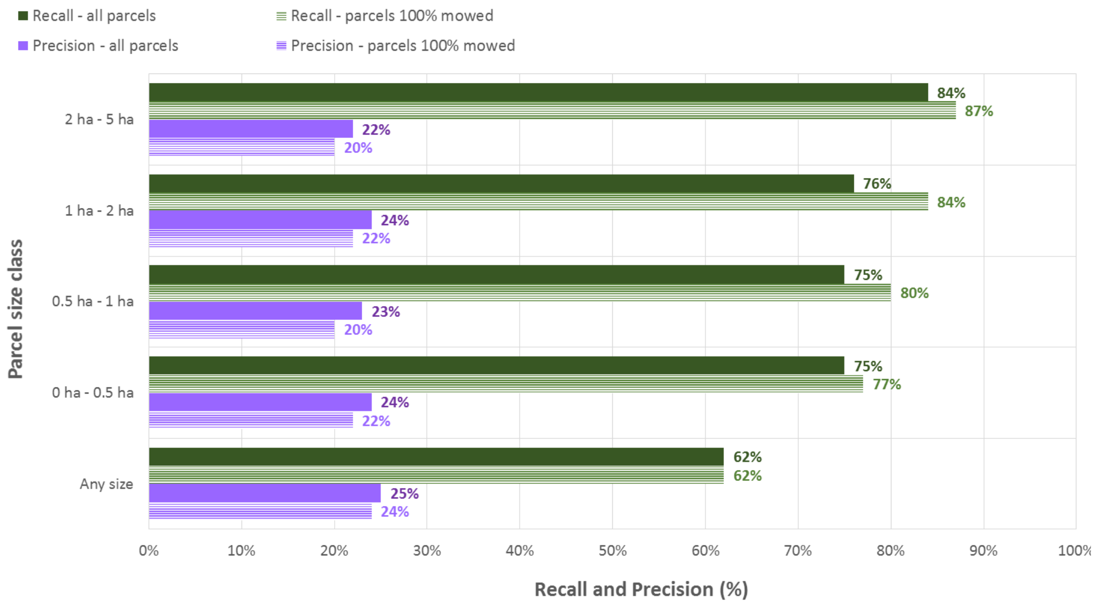


Figure 5-43. 2018 ITA validation results (scenarios 3 and 4 – Planet + Farmer interviews dataset)

5.3.4 Lithuania

5.3.4.1 Grassland parcels characteristics

Table 5-40, Table 5-41, Figure 5-44 and Figure 5-45 describe the distribution of 2018 Lithuanian grassland parcels in terms of crop type and size. They show that:

- the largest part of grassland parcels belongs to 2 main crop types, which are (i) “Perennial pasture or meadow 5 years or more” and (ii) “Pasture or meadow, perennial grass up to 5 years or more”;
- the parcels size is quite uniformly distributed.

Table 5-40. Crop type distribution of the grassland parcels in LTU in 2018

Crop name	Crop code	Parcel number	Frequency
Extensive management of wetlands	5PT-2	1296	**0,3%**
Perennial pastures or meadows 5 years and more	DGP	392745	**79,7%**
Extensive meadows grazing with livestock	EPT	4961	**1,0%**
Pasture or meadow, perennial grass up to 5 years, renewed in the current year	GPA	1666	**0,3%**
Pasture or meadow, perennial grass up to 5 years	GPZ	90694	**18,4%**
Natural and semi-natural meadows	NPT	260	**0,1%**
Specific meadows	SPT	868	**0,2%**
Total parcels (number)		492490	

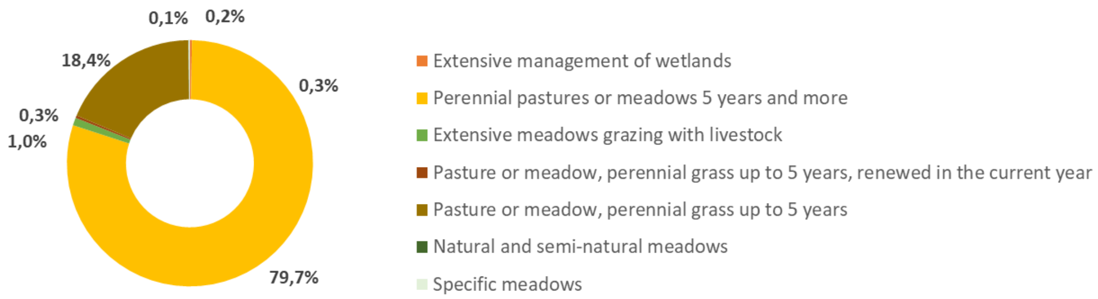


Figure 5-44. 2018 LTU grassland parcel type distribution, expressed as a chart

Table 5-41. Size distribution of the grassland parcels in LTU 2018

Crop name	Crop code	< 0,5 ha	0,5 ha ÷ 1 ha	1 ha ÷ 2 ha	2 ha ÷ 5 ha	> 5 ha
Extensive management of wetlands	5PT-2	23%	17%	25%	21%	14%
Perennial pastures or meadows 5 years and more	DGP	27%	23%	24%	19%	7%
Extensive meadows grazing with livestock	EPT	16%	16%	24%	27%	18%
Pasture or meadow, perennial grass up to 5 years, rene	GPA	36%	20%	18%	18%	9%
Pasture or meadow, perennial grass up to 5 years	GPZ	39%	20%	20%	15%	6%
Natural and semi-natural meadows	NPT	19%	22%	20%	26%	14%
Specific meadows	SPT	18%	18%	29%	24%	12%
Mean parcel size distribution (%)		**25,3%**	**19,2%**	**22,7%**	**21,5%**	**11,4%**

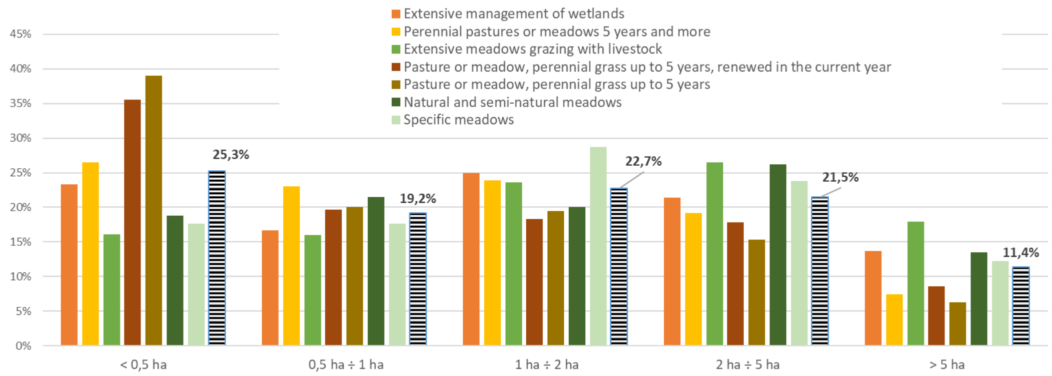


Figure 5-45. 2018 LTU grassland parcel size distribution, expressed as an histogram

5.3.4.2 Validation datasets characteristics

The validation datasets derived from the Planet interpretation and the data provided by the PA (inspectors on site control) are described in Table 5-42 and Figure 5-46.

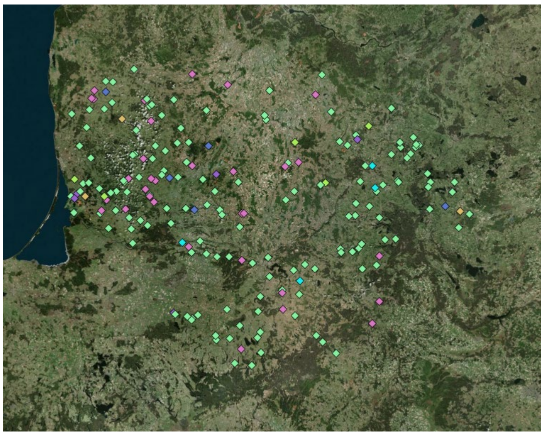
The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

The validation dataset provided by the PA is not comparable with Planet ones because it just lists the parcels:

- mowed (completely, without grass not laying in the fields), without providing the mowing date
- not mowed (all or partly, and if the mowing grass is still laying in the field)

Table 5-42. Planet and farmers validation datasets characterization in terms of crop type

Crop name	Crop code	Validation datasets		
		Planet parcel number	PA parcel number (mowed)	PA parcel number (mowed)
Extensive management of wetlands	5PT-2	5	2	0
Perennial pastures or meadows 5 years and more	DGP	155	24536	585
Extensive meadows grazing with livestock	EPT	5	9	0
Pasture or meadow, perennial grass up to 5 years, renewed in the current year	GPA	5	96	5
Pasture or meadow, perennial grass up to 5 years	GPZ	35	4725	119
Natural and semi-natural meadows	NPT	5	0	0
Specific meadows	SPT	5	1	0
Total parcels (number)		**215**	**30078**	



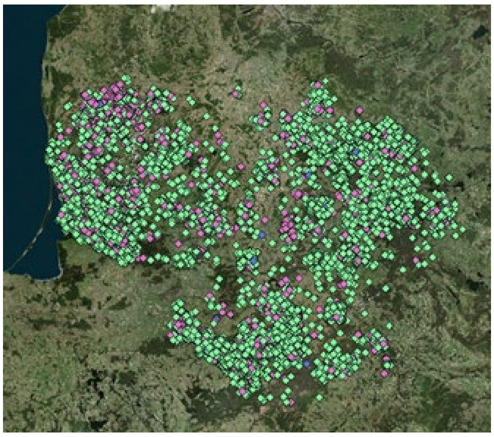


Figure 5-46. Distribution of 2018 LTU parcels selected for Planet interpretation (left) and derived from farmer interview (right)

The not availability of mowing event dates and the dis-proportion between mowed and not mowed cases do not allow to extract reliable accuracy parameters (recall and precision). For these reasons the validation has been based just on Planet data.

5.3.4.3 Validation results

The results obtained with the different scenarios presented in Table 5-24 are presented below.

Table 5-43. Validation results for grassland mowing detection in LTU 2018, based on the Planet data only and considering the partial mowing (top) or only the complete mowing (bottom)

Validation 1 - Truth dataset: Planet		Percentage of parcel mowed: Partial mowing (< 100%)				
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**298**	**230**	**390**	**68**	**77%**	**37%**
0 ha - 0.5 ha	235	189	317	46	80%	37%
0.5 ha - 1 ha	178	142	251	36	80%	36%
1 ha - 2 ha	122	97	162	25	80%	37%
2 ha - 5 ha	63	54	82	9	86%	40%

Validation 2 - Truth dataset: Planet		Percentage of parcel mowed: Complete mowing (100%)				
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**225**	**189**	**354**	**36**	**84%**	**35%**
0 ha - 0.5 ha	180	158	292	22	88%	35%
0.5 ha - 1 ha	132	116	229	16	88%	34%
1 ha - 2 ha	86	77	154	9	90%	33%
2 ha - 5 ha	46	44	79	2	96%	36%

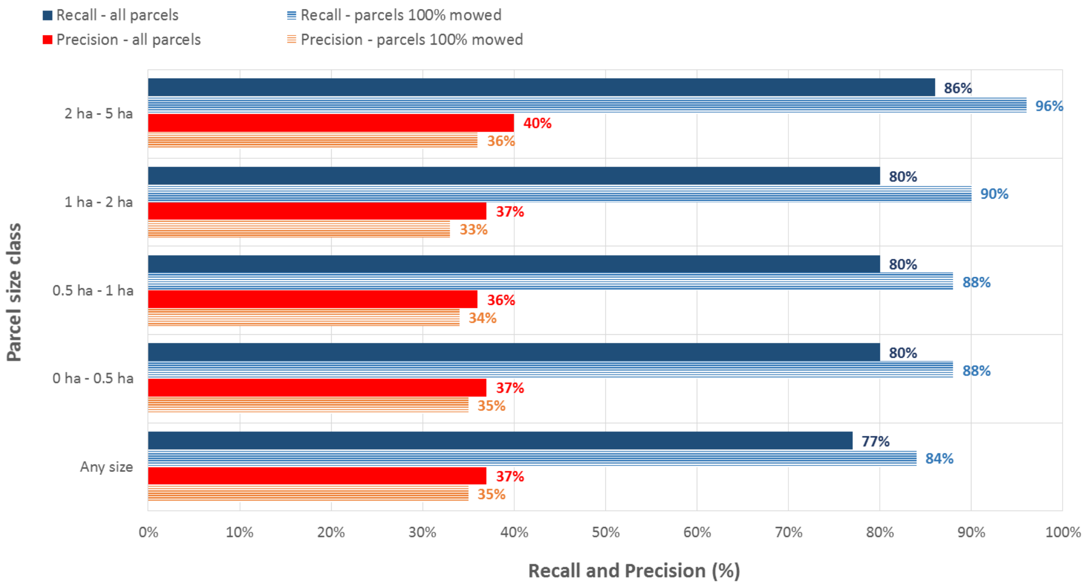


Figure 5-47. 2018 LTU validation results (scenarios 1 and 2 – Planet dataset)

5.3.5 Netherlands

5.3.5.1 Grassland parcels characteristics

Table 5-44, Table 5-45, Figure 5-48 and Figure 5-49 describe the distribution of 2018 Netherlands grassland parcels in terms of crop type and size. They show that:

- the largest part of grassland parcels belongs to a single crop type, which is “Grassland permanent”;
- the parcels size is quite uniformly distributed.

Table 5-44. Crop type distribution of the grassland parcels in NLD in 2018

Crop name	Crop code	Parcel number	Frequency
Grassland permanent	265	366141	**90%**
Grassland, natural. Main function of agriculture	331	13367	**3%**
Grassland, natural. Area with a nature management type that is predominantly used for agricultural activities CAP	336	25467	**6%**
Total parcels (number)		404975	

Figure 5-48. 2018 NLD grassland parcel type distribution, expressed as a chart

Table 5-45. Size distribution of the grassland parcels in NLD 2018

Crop name	Crop code	< 0,5 ha	0,5 ha ÷ 1 ha	1 ha ÷ 2 ha	2 ha ÷ 5 ha	> 5 ha
Grassland permanent	265	21%	18%	28%	29%	6%
Grassland, natural. Main function of agriculture	331	22%	22%	29%	21%	6%
Grassland, natural. Area with a nature management type that is predominantly used for agricultural activities CAP	336	17%	22%	32%	23%	7%
Mean parcel size distribution (%)		20,0%	20,2%	29,4%	24,1%	6,3%

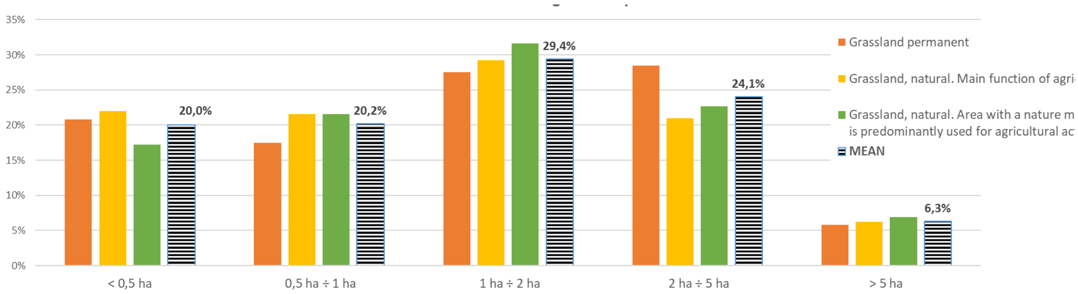


Figure 5-49. 2018 NLD grassland parcel size distribution, expressed as an histogram

5.3.5.2 Validation datasets characteristics

The validation datasets derived from the Planet interpretation and the farmer interviews are described in Table 5-46 and Figure 5-50. The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

Table 5-46. Planet and farmers validation datasets characterization in terms of crop type

Crop name	Crop code	Validation datasets	
		Planet parcel number	Farmer parcel number
Grassland permanent	265	180	177
Grassland, natural. Main function of agriculture	331	5	7
Grassland, natural. Area with a nature management type that is predominantly used for agricultural activities CAP	336	10	0
Total parcels (number)		195	184

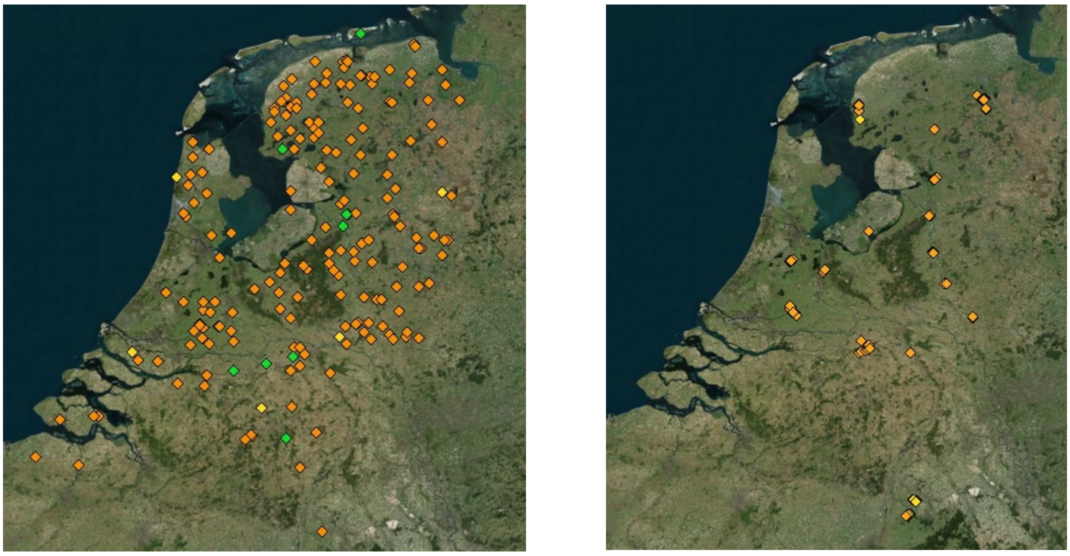


Figure 5-50. Distribution of 2018 NLD parcels selected for Planet interpretation (left) and derived from farmer interview (right)

5.3.5.3 Validation results

The results obtained with the different scenarios presented in Table 5-24 are presented below.

Table 5-47. Validation results for grassland mowing detection in NLD 2018, based on the Planet data only and considering the partial mowing (top) or only the complete mowing (bottom)

Validation 1 - Truth dataset: Planet		Percentage of parcel mowed: Partial mowing (< 100%)				
Parcel size class	**Total Truth**	**TP**	**FP**	**FN**	**Recall**	**Precision**
Any size	**364**	**296**	**268**	**68**	**81%**	**52%**
0 ha - 0.5 ha	307	257	233	50	84%	52%
0.5 ha - 1 ha	247	202	180	45	82%	53%
1 ha - 2 ha	180	143	122	37	79%	54%
2 ha - 5 ha	92	76	60	16	83%	56%

Validation 2 - Truth dataset: Planet		Percentage of parcel mowed: Complete mowing (100%)				
Parcel size class	**Total Truth**	**TP**	**FP**	**FN**	**Recall**	**Precision**
Any size	**331**	**278**	**263**	**53**	**84%**	**51%**
0 ha - 0.5 ha	275	240	227	35	87%	51%
0.5 ha - 1 ha	215	185	174	30	86%	52%
1 ha - 2 ha	153	129	113	24	84%	53%
2 ha - 5 ha	74	66	53	8	89%	55%

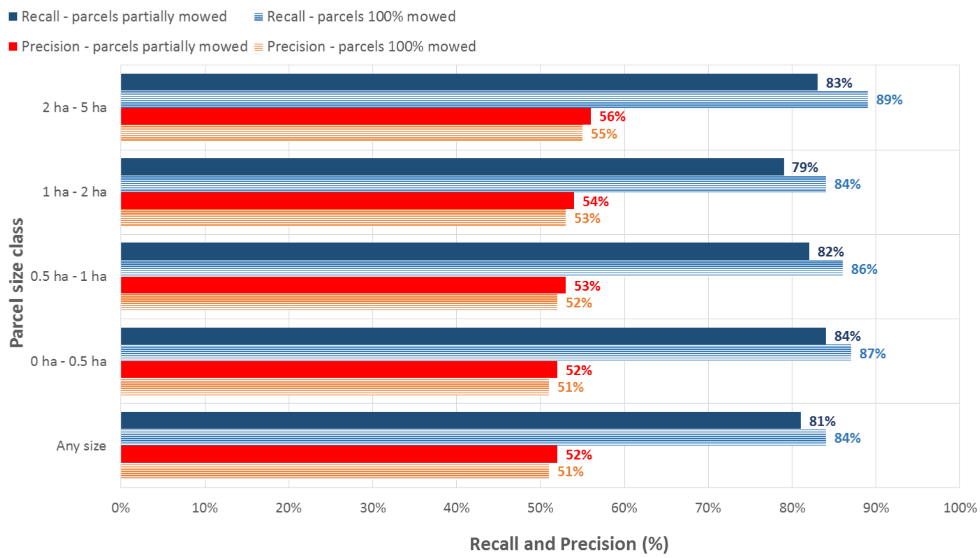


Figure 5-51. 2018 NLD Validation results (scenarios 1 and 2 – Planet dataset)

Table 5-48. Validation results for grassland mowing detection in NLD 2018, based on the Planet data and on the farmers' interviews and considering the partial mowing (top) or only the complete mowing (bottom)

Validation 3 - Truth dataset: Planet + Farmer interview			Percentage of parcel mowed: Partial mowing (< 100%)			
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**783**	**601**	**469**	**182**	**77%**	**56%**
0 ha - 0.5 ha	679	529	410	150	78%	56%
0.5 ha - 1 ha	567	440	319	127	78%	58%
1 ha - 2 ha	329	258	195	71	78%	57%
2 ha - 5 ha	101	83	68	18	82%	55%
Validation 4 - Truth dataset: Planet + Farmer interview			**Percentage of parcel mowed: Complete mowing (100%)**			
Parcel size class	**Total Truth**	**TP**	**FP**	**FN**	**Recall**	**Precision**
Any size	**750**	**583**	**464**	**167**	**78%**	**56%**
0 ha - 0.5 ha	647	512	404	135	79%	56%
0.5 ha - 1 ha	535	423	313	112	79%	57%
1 ha - 2 ha	302	244	186	58	81%	57%
2 ha - 5 ha	83	73	61	10	88%	54%

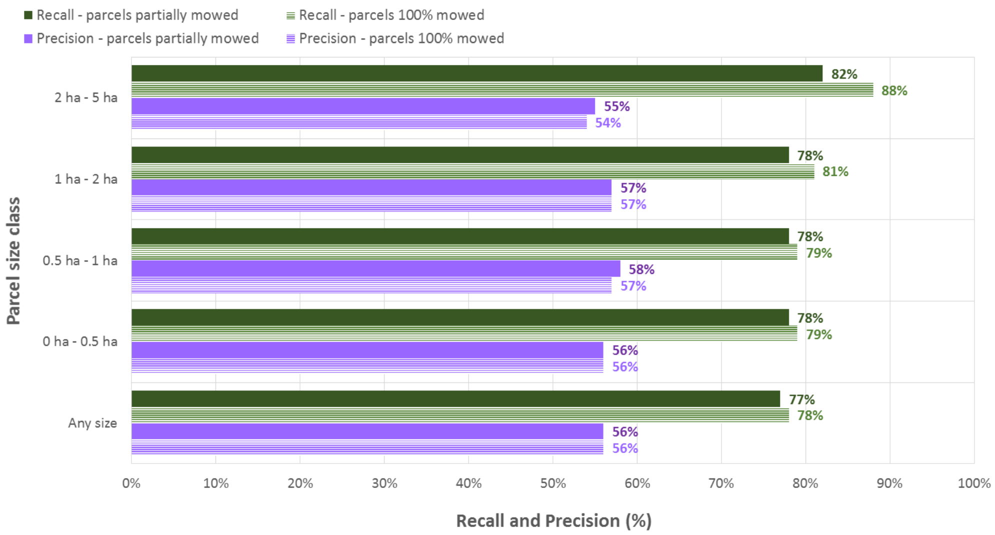


Figure 5-52. 2018 NLD validation results (scenarios 3 and 4 – Planet + Farmer interviews dataset)

5.3.6 Romania

5.3.6.1 <u>Grassland parcels characteristics</u>

Table 5-49, Table 5-50, Figure 5-53 and Figure 5-54 describe the distribution of 2018 Netherlands grassland parcels in terms of crop type and size. They show that:

- - the largest part of grassland parcels belongs mainly to 4 crop types: (i) "Temporary grassland (artificial, sowed on AL < 5 years)", (ii) "Permanent grassland used individually", (iii) "Individually used meadows" and (iv) "Alfalfa";
- more than 50% of grassland parcels are smaller than 1 ha.

Table 5-49. Crop type distribution of the grassland parcels in ROU in 2018

Crop name	Crop code	Parcel number	Crop type distribution
Temporary grassland (artificial, sowed on AL < 5 years)	450	96494	9,2%
Public permanent grasslands used in common	603	30110	2,9%
Permanent grasslands used in common	604	14745	1,4%
Public permanent grasslands used individually	605	36012	3,4%
Permanent grasslands used individually	606	281963	26,9%
Individually used meadows	607	418504	39,9%
Public meadows used individually	608	548	0,1%
Energy natural meadows	662	9	0,001%
Alfalfa	974	159826	15,2%
Energy grass	9547	18	0,002%
Energy Sudan grass	9558	17	0,002%
Alfalfa	9748	10329	1,0%
Total parcels (number)		1048575	

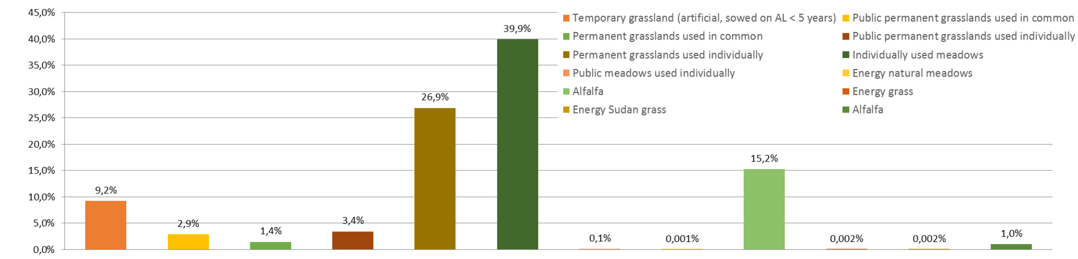


Figure 5-53. 2018 ROU grassland parcel type distribution, expressed as a bar chart

Table 5-50. Size distribution of the grassland parcels in ROU 2018

Crop name	Crop code	< 0,5 ha	0,5 ha ÷ 1 ha	1 ha ÷ 2 ha	2 ha ÷ 5 ha	> 5 ha
Temporary grassland (artificial, sowed on AL < 5 years)	450	62%	26%	9%	3%	1%
Public permanent grasslands used in common	603	5%	13%	19%	27%	36%
Permanent grasslands used in common	604	31%	30%	16%	11%	12%
Public permanent grasslands used individually	605	7%	11%	16%	26%	40%
Permanent grasslands used individually	606	42%	31%	16%	7%	4%
Individually used meadows	607	53%	31%	12%	3%	1%
Public meadows used individually	608	42%	26%	15%	10%	8%
Energy natural meadows	662	44%	44%	11%	0%	0%
Alfalfa	974	54%	32%	11%	3%	0%
Energy grass	9547	28%	17%	33%	17%	6%
Energy Sudan grass	9558	59%	29%	6%	0%	6%
Alfalfa	9748	31%	37%	21%	8%	2%
Mean parcel size distribution (%)		38%	27%	15%	10%	10%

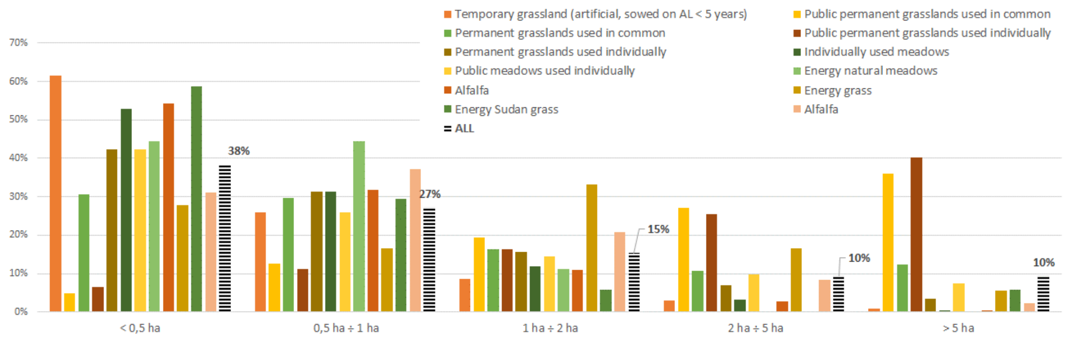


Figure 5-54. 2018 ROU grassland parcel size distribution, expressed as an histogram

5.3.6.2 Validation datasets characteristics

The validation dataset, derived only from Planet interpretation because farmer interviews were not available for Romania, is described in Table 5-51 and Figure 5-55. The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

Table 5-51. Planet and farmers validation datasets characterization in terms of crop type

Crop name	Crop code	Validation datasets Planet parcel number
Temporary grassland (artificial, sowed on AL < 5 years)	450	35
Public permanent grasslands used in common	603	10
Permanent grasslands used in common	604	5
Public permanent grasslands used individually	605	10
Permanent grasslands used individually	606	105
Individually used meadows	607	155
Public meadows used individually	608	5
Energy natural meadows	662	5
Alfalfa	974	60
Energy grass	9547	5
Energy Sudan grass	9558	5
Alfalfa	9748	5
Total parcels (number)		405

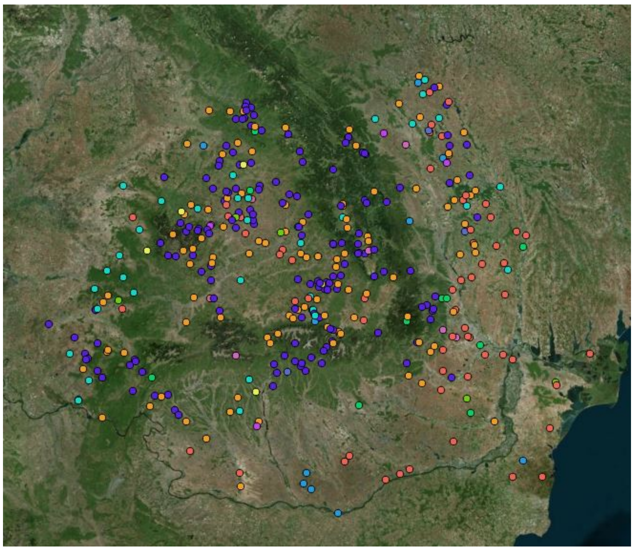


Figure 5-55. Distribution of 2018 ROU parcels selected for Planet interpretation (left) and derived from farmer interview (right)

5.3.6.3 Validation results

The results obtained with the different scenarios presented in Table 5-24 are presented below.

Table 5-52. Validation results for grassland mowing detection in ROU 2018, based on the Planet data only and considering the partial mowing (top) or only the complete mowing (bottom)

Validation 1 - Truth dataset: Planet	Percentage of parcel mowed: Partial mowing (< 100%)					
Parcel size class	Total Truth	TP	FP	FN	Recall	Precision
Any size	**588**	**223**	**289**	**171**	**57%**	**44%**
0 ha - 0.5 ha	471	179	233	140	56%	43%
0.5 ha - 1 ha	355	131	177	103	56%	43%
1 ha - 2 ha	230	86	124	62	58%	41%
2 ha - 5 ha	109	38	62	32	54%	38%

Validation 2 - Truth dataset: Planet		Percentage of parcel mowed: Complete mowing (100%)				
Parcel size class	**Total Truth**	**TP**	**FP**	**FN**	**Recall**	**Precision**
Any size	**399**	**137**	**259**	**68**	**67%**	**35%**
0 ha - 0.5 ha	310	108	204	50	68%	35%
0.5 ha - 1 ha	235	79	149	35	69%	35%
1 ha - 2 ha	152	54	102	16	77%	35%
2 ha - 5 ha	67	20	53	8	71%	27%

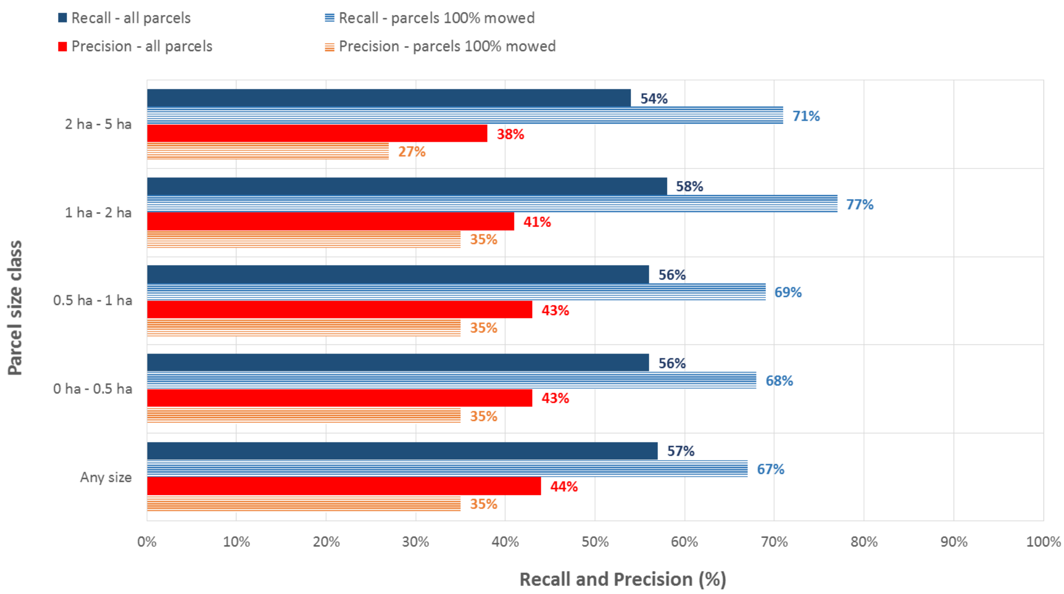


Figure 5-56. 2018 ROU Validation results (scenarios 1 and 2 – Planet dataset)

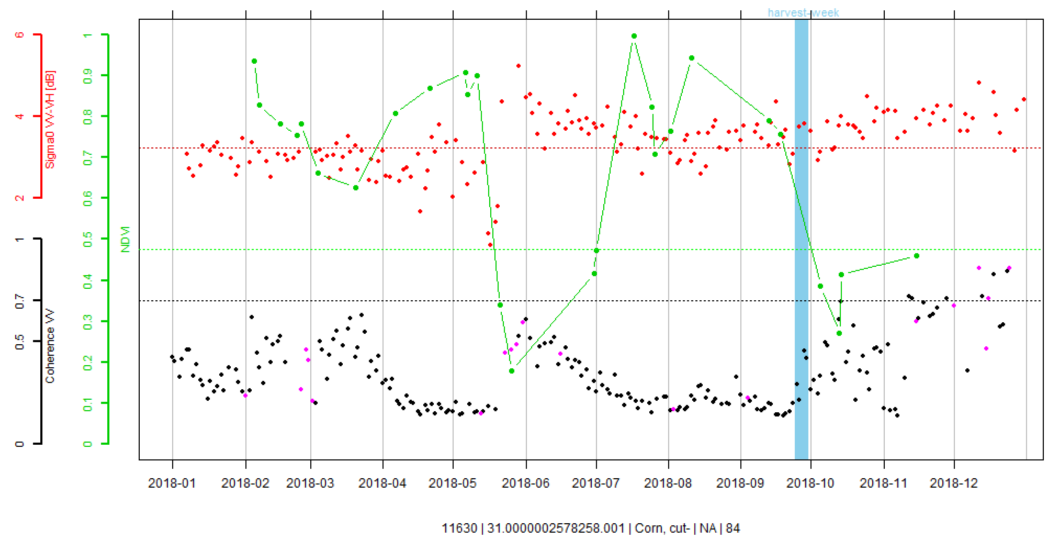
5.4 Agricultural Practices monitoring product

Two sources of reference data have been used for validation – information obtained from farmers (provided by the PAs) and information obtained from Planet imagery (interpreted by the consortium). Separate validation is performed for both datasets.

1) Validation of the harvest detection for the main crop

The harvest/clearance week of the Sen4CAP product is defined as the first week when the harvest markers confirm the presence of the vegetation of the parcel (M1) and the process of the vegetation loss on the parcel in all 3 input time-series (M2:M5).

The harvest of the main crop from the Planet imagery is interpreted as the period between the date of the last image with the vegetation still present on the parcel and the date of the first image of the parcel with the vegetation lost (Figure 5-57).



Declared crop	Planet from	Planet to	Sen4CAP week start	Sen4CAP week start	Week difference
Corn	20.9.2018	25.9.2018	2018-09-24	2018-09-30	0

Figure 5-57. Example of the harvest/clearance week validation where the week period is illustrated in blue

2) Validation of agricultural practices crop monitoring

The validation is done through individual markers used for the evaluation of the respective EFA practice. These markers are compared with the reference datasets.

The markers used for the EFA monitoring:

- M6: Marker 6 - Presence of vegetation based on NDVI within the agricultural practice period;
- M7: Marker 7 - Growth of vegetation based on NDVI within the agricultural practice period;
- M8: Marker 8 - No loss of vegetation based on NDVI within the agricultural practice period;
- M9: Marker 9 - No loss of vegetation based on SAR backscatter within the agricultural practice period;
- M10: Marker 10 - Presence of vegetation (dynamic conditions) based on SAR coherence within the agricultural practice period;
- Harvest of the main crop shall be detected before the start of the EFA period (only for catch crop after main crop);
- Harvest/clearance shall / shall not be detected during the EFA period (only for nitrogen fixing crops (NFC) and fallow land).

3) S1 data availability

Dense time series of S1 data is very important for the agricultural practices monitoring. The image acquisition is performed in a 6-day time period for one S1 orbit. Each parcel is usually covered by 2 to 4 orbits. In average, there are 3 acquisitions each week in the S1 time series. In case of data gaps, the assessment reliability is affected and the harvest/clearance week or the degree of compliancy with the EFA practice can be evaluated incorrectly. The information on data gaps is provided as an attribute in the resulting table/shapefile for each parcel in order to monitor the number of weeks for which the S1 data are completely missing.

5.4.1 Spain - Castilla y Leon

Three products were produced and delivered in 2018:

- harvest/clearance week: evaluated for all arable land parcels (except of the parcels with the declared EFA practice for which separated product is provided);
- growing of the NFC: evaluated for the parcels with the declared EFA NFC practice;
- fallow land: evaluated for the parcels with the declared EFA fallow land practice.

The number of parcels in the harvest/clearance week product and EFA products is provided in Table 5-53. Only parcels with at least one S1 inner pixel were processed and evaluated.

Table 5-53. Number of parcels in the L4C products for 2018 in CyL

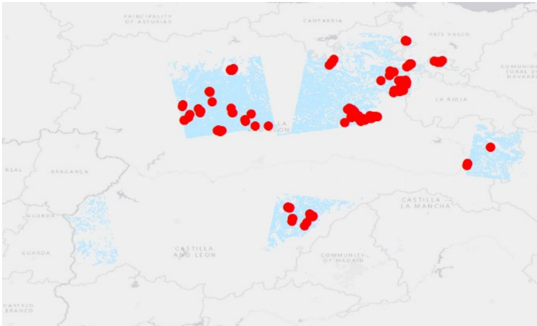
Practice	Number of declared parcels	Number of processed parcels	Proportion of processed parcels [%]
HARVEST	1 602 518	1 208 102	75.4
EFA	651 250	464 443	71.3

The S1 data availability in 2018 over CyL is illustrated in Figure 5-58.

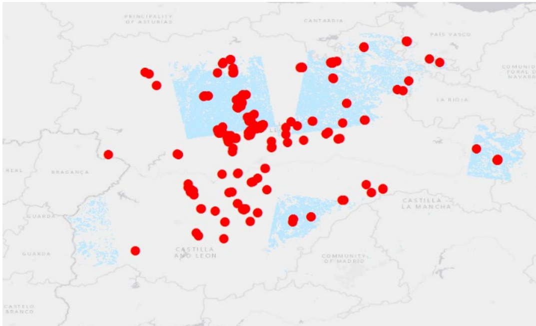
Figure 5-58. S1 data availability in CyL 2018 – The number of weeks for which the S1 data are completely missing is represented with a colour code: 8 – dark green, 9 – light green, 10 – pink, 11 – red, 12 – dark red, more than 12 weeks – gray

The distribution of the reference parcels is shown in Figure 5-59. Only the parcels with less than 10 missing week of S1 data were used for validation. The parcels were randomly selected.

Harvest detection



Nitrogen fixing crops



Fallow lands

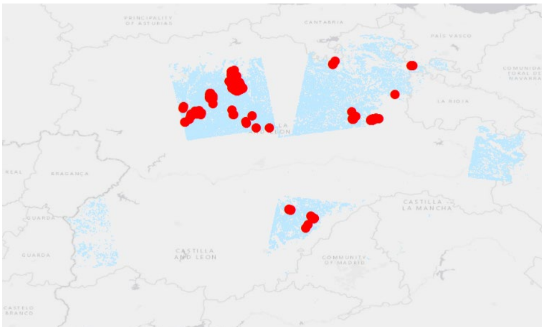


Figure 5-59. Distribution of the reference parcels for the harvest detection (top left), nitrogen fixing crops (top right) and fallow lands (below) in CyL 2018

5.4.1.1 Validation of harvest detection for the main crop

Due to the high number of parcels for which data from farmers were available, the main data source was these famers interviews. Results are shown in Table 5-54.

Table 5-54. Accuracy of main crop harvest detection based on farmers interviews – CyL 2018

Difference [weeks]	**Reference data Provided by farmers**	**% Category /**	**Cummulative**	**Reference data Planet imagery**	**% Category /**	**Cummulative**	**Reference data Total**	**% Category /**	**Cummulative**
0-1	243	53%	53%				243	53%	53%
2	73	16%	69%				73	16%	69%
3	57	12%	81%				57	12%	81%
> 3	62	14%	95%				62	14%	95%
Not detect.	24	5%	100%				24	5%	100%
Total	**459**	**100%**		**0**			**459**	**100%**	

Based on the results of analysis of parcels with difference of 3 and more weeks, it was found that cereals are grown on all these parcels. It is often the case that the detected harvest week is shifted for about 2 weeks as the plant senescence phase is wrongly interpreted as harvest due to the abrupt decrease of NDVI. Another vegetation index with higher sensitivity to the dry ripe cereals' vegetation could be useful.

Based on the request from the PA, the accuracy of data obtained from farmers has been evaluated for 21 randomly selected parcels using Planet imagery (Table 5-55).

Table 5-55. Accuracy of main crop harvest detection based on Planet data – CyL 2018

Difference [weeks]	Reference data Farmer's interview	% Category /	Cummulative
0-1	16	76%	76%
2	2	10%	86%
3	1	5%	90%
> 3	2	10%	100%
Not detect.	0	0%	100%
Total	**21**	**100%**	

The data reported by farmers have been confirmed for around 75% of parcels.

5.4.1.2 Validation of nitrogen fixing crop monitoring

The individual markers used for the evaluation of the EFA practice are compared with the reference data based on the farmer interviews (250 parcels).

Crops must reach at least blooming state. Sowing density and the rest of tilling tasks have to be suitable and according to local agricultural habits.

The markers used for the nitrogen fixing crop practice monitoring:

- Presence of vegetation in the practice period (Table 5-56);
- Harvest/clearance in the practice period (Table 5-57).

Table 5-56. Presence of vegetation within the NFC practice period in CyL 2018

	Presence of vegetation in the practice period (01.03.-31.08.)				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference	**TRUE**	**98.8**	1.2	0	100
	FALSE	0	**0**	0	0
	NR	0	0	**0**	0
	Total	98.8	1.2	0	**100**

Table 5-57. Harvest/clearance within the NFC practice period in CyL 2018

	Harvest/clearance in the practice period (02.04.-15.08.)				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference	**TRUE**	**80.4**	19.6	0	100
	FALSE	0	**0**	0	0
	NR	0	0	**0**	0
	Total	80.4	19.6	0	**100**

5.4.1.3 Validation of fallow land monitoring

The individual markers used for the evaluation of the EFA practice are compared with the reference data based on visual interpretation of the Planet imagery (250 parcels).

Fallow land must stay without grazing or harvesting during 6 months, till the end June. In this period, any kind of agricultural production is forbidden on the parcel, crops must not be harvested, grazed or removed, tilling tasks are allowed (mandatory once a year), applying cattle manure or mulch is allowed, crops to be buried as green manure are also allowed.

The markers used for the fallow land practice monitoring:

- Presence of vegetation in the practice period (Table 5-58);
- Harvest/clearance in the practice period (Table 5-59).

Table 5-58. Presence of vegetation within the fallow land practice period in CyL 2018

	Presence of vegetation in the practice period (01.02.-30.06.)				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference	**TRUE**	**30.0**	40.0	0	70.0
	FALSE	0	**30.0**	0	30.0
	NR	0	0	**0**	0
	Total	30.0	70.0	0	**100**

Table 5-59. Harvest/clearance within the stable fallow land practice period in CyL 2018

	Harvest/clearance in the practice period (02.04.-30.06.)				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference	**TRUE**	**4.4**	51.6	0	56.0
	FALSE	0.8	**43.2**	0	44.0
	NR	0	0	**0**	0
	Total	5.2	94.8	0	**100**

5.4.2 Czech Republic

Four products were produced and delivered in 2018:

- harvest/clearance week: evaluated for all arable land parcels (except of the parcels with the declared EFA practice for which separated product is provided);
- growing of the catch crop: evaluated for the parcels with the declared EFA catch-crop practice;
- growing of the NFC: evaluated for the parcels with the declared EFA nitrogen fixing crop practice;
- fallow land: evaluated for the parcels with the declared EFA fallow land practice.

The number of parcels in the harvest/clearance week product and EFA products is provided in Table 5-60. Only parcels with at least one S1 inner pixel were processed and evaluated.

Table 5-60. Number of parcels in the L4C products for 2018 in CZE

Practice	Number of declared parcels	Number of processed parcels	Proportion of processed parcels [%]
HARVEST	153 262	148 342	96.8
EFA	27 458	26 282	95.7

The S1 data availability in 2018 over CyL is illustrated in Figure 5-60.

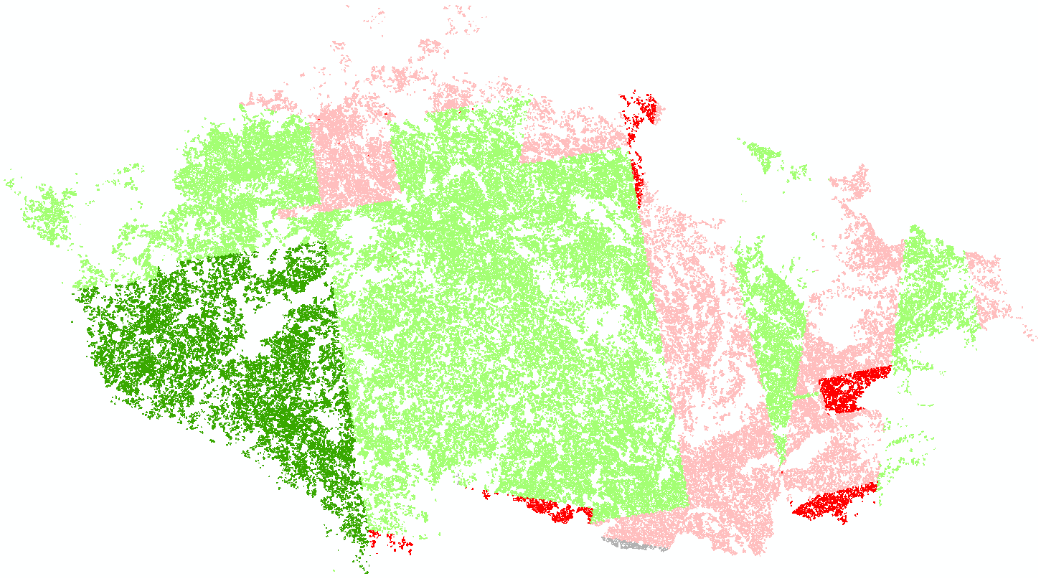


Figure 5-60. S1 data availability in CZE 2018 – The number of weeks for which the S1 data are completely missing is represented with a colour code: 2 – dark green, 3 – light green, 4 – pink, 5 – red, more than 5 weeks – grey

The distribution of the reference parcels is shown in Figure 5-61. Only the parcels with 2 or 3 missing weeks of S1 data were selected for validation. The parcels for validation were randomly selected. The number of parcels of different catch crop types (summer catch crop, winter catch crop) were selected according to the proportional representation of each catch crop type.

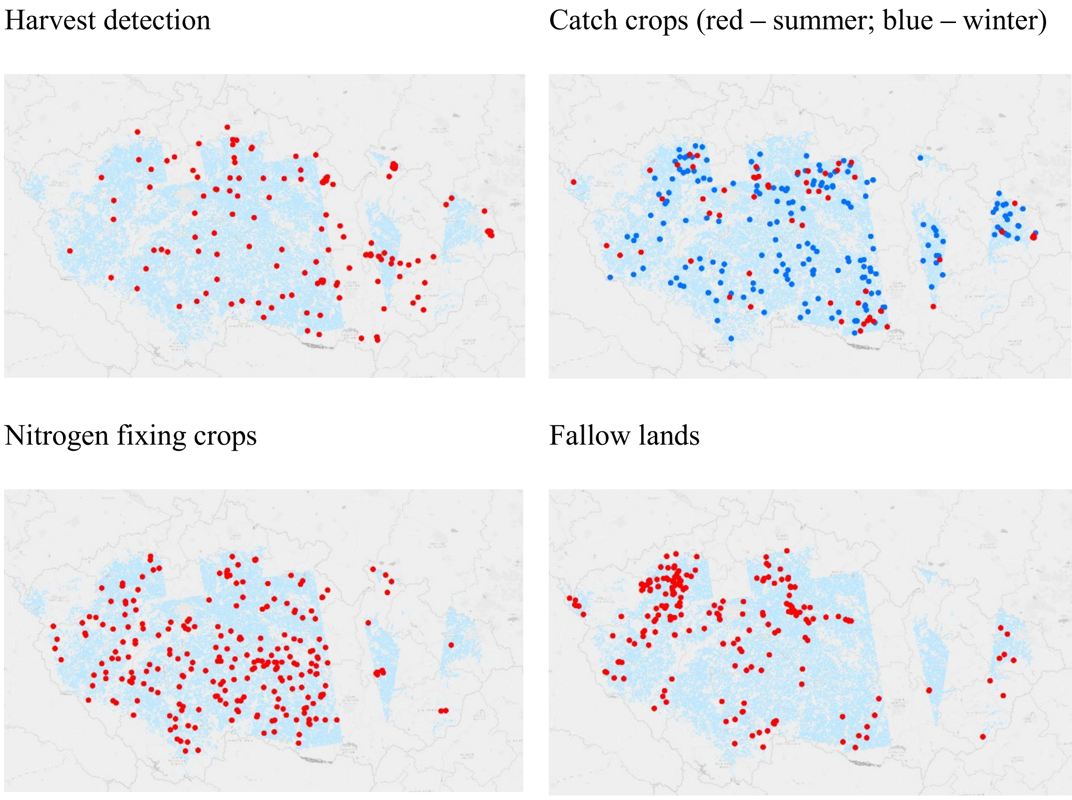


Figure 5-61. Distribution of the reference parcels for the harvest detection (top left), catch crops (top right), nitrogen fixing crops (below left) and fallow lands (below right) in CZE 2018

5.4.2.1 Validation of harvest detection for the main crop

Both farmers interviews and Planet data were used for the validation of the main crop harvest detection in CZE. Results are shown in Table 5-61.

Table 5-61. Accuracy of main crop harvest detection based on farmers interviews and Planet data – CZE 2018

Difference [weeks]	Reference data Provided by farmers	% Category /	Cummulative	Reference data Planet imagery	% Category /	Cummulative	Reference data Total	% Category /	Cummulative
0-1	54	77%	77%	244	72%	72%	298	73%	73%
2	6	9%	86%	49	14%	87%	55	13%	87%
3	4	6%	91%	21	6%	93%	25	6%	93%
> 3	6	9%	100%	20	6%	99%	26	6%	99%
Not detect.	0	0%	100%	4	1%	100%	4	1%	100%
Total	**70**	**100%**		**338**	**100%**		**408**	**100%**	

5.4.2.2 Validation of catch crop monitoring

The validation has been done for 250 catch crop parcels, considering the five markers individually.

The markers used for the nitrogen fixing crop practice monitoring:

- Marker 6 which evaluates the presence of vegetation within the practice period based on the NDVI (Table 5-62);
- Marker 7 which evaluates the growth of vegetation within the practice period, based on the NDVI (Table 5-63);
- Marker 8 which evaluates, based on the NDVI, a no loss of vegetation within the practice period (Table 5-64);
- Marker 9 which evaluates, based on the SAR backscatter, a no loss of vegetation within the practice period (Table 5-65);
- Marker 10 which evaluates, based on the SAR coherence, the presence of vegetation within the practice period (Table 5-66).

The marker related to the pre-requisite that the main crop must be harvested before the catch crop monitoring was also validated (Table 5-67).

Table 5-62. Marker 6 validation for catch crop monitoring in CZE 2018

M6	**Presence of vegetation based on NDVI**				
Reference dataset	**%**	**TRUE**	**FALSE**	**NR**	**Total**
	TRUE	**82.8**	5.2	2	90
	FALSE	1.2	**8.4**	0.4	10
	NR	0	0	**0**	0
	Total	84.0	13.6	2.4	**100**

Table 5-63. Marker 7 validation for catch crop monitoring in CZE 2018

M7	**Growth of vegetation based on NDVI**				
Reference dataset	**%**	**TRUE**	**FALSE**	**NR**	**Total**
	TRUE	**66.5**	21.4	2.0	89.9
	FALSE	0	**9.7**	0.4	10.1
	NR	0	0	**0**	0
	Total	66.5	31.1	2.4	**100**

Table 5-64. Marker 8 validation for catch crop monitoring in CZE 2018

M8	**No loss of vegetation based on NDVI**				
Reference dataset	**%**	**TRUE**	**FALSE**	**NR**	**Total**
	TRUE	**62.6**	17.9	1.6	82.1
	FALSE	2.4	**14.6**	0.8	17.9
	NR	0	0	**0**	0
	Total	65.0	32.5	2.4	**100**

Table 5-65. Marker 9 validation for catch crop monitoring in CZE 2018

M9	**No loss of vegetation based on SAR backscatter**				
Reference	**%**	**TRUE**	**FALSE**	**NR**	**Total**
	TRUE	**75.6**	5.2	1.6	82.4

FALSE	15.2	**1.6**	0.8	17.6
NR	0	0	**0**	0
Total	90.8	6.8	2.4	**100**

A number of false positives cases was detected. An increase SAR backscatter values indicates the loss of vegetation on a parcel. In some cases, especially in the autumn period, the increase in the SAR backscatter values is not detected even when the vegetation is lost on the parcel.

Table 5-66. Marker 10 validation for catch crop monitoring in CZE 2018

M10	**Presence of vegetation based on SAR coherence**				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**59.2**	28.8	2.0	90.0
	FALSE	1.2	**8.4**	0.4	10.0
	NR	0	0	**0**	0
	Total	60.4	37.2	2.4	**100**

A number of false negatives cases was detected. High value of a SAR coherence or an increase of this value indicates a low or no vegetation on a parcel. In some cases, especially in the autumn period, high coherence values and breaks are observed in the coherence time-series even when the vegetation is present on the parcel.

Table 5-67. Validation of the marker "Harvest of the main crop before the catch crop period" in CZE 2018

	Harvest/clearance of the main crop between 01.05. and P_START (31.07./06.09.)				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**96.4**	1.2	0	97.6
	FALSE	0.8	**1.6**	0	2.4
	NR	0	0	**0**	0
	Total	97.2	2.8	0	**100**

5.4.2.3 Validation of nitrogen fixing crop monitoring

The individual markers used for the evaluation of the EFA practice are compared with the reference data based on the farmer interviews (250 parcels).

The parcel shall be covered by the crops or by herbal residuals at least between 1 June and 15 July of the given calendar year.

The markers used for the nitrogen fixing crop practice monitoring:

- Presence of vegetation in the practice period (Table 5-68);
- Harvest/clearance in the practice period (Table 5-69).

Table 5-68. Presence of vegetation within the NFC practice period in CZE 2018

Reference dataset	Presence of vegetation in the practice period (01.06.-15.07.)				
	%	TRUE	FALSE	NR	Total
	TRUE	**100**	0	0	100
	FALSE	0	**0**	0	0
	NR	0	0	**0**	0
	Total	100	0	0	**100**

Table 5-69. Harvest/clearance within the NFC practice period in CZE 2018

Reference dataset	Harvest/clearance in the practice period (01.06.-15.07.)				
	%	TRUE	FALSE	NR	Total
	TRUE	**9.2**	58.0	0	67.2
	FALSE	0.8	**32.0**	0	32.8
	NR	0	0	**0**	0
	Total	10	90	0	**100**

5.4.2.4 Validation of fallow land monitoring

The individual markers used for the evaluation of the EFA practice are compared with the reference data based on visual interpretation of the Planet imagery (250 parcels).

Green fallow shall be present from 1 June of the first year of declaration to 15 July of the final year of declaration. During the declared period, any kind of agricultural production is forbidden on the parcel (the crops must not be harvested & removed or grazed). The farmer is obliged to cut or mulch the crop between 1 June and 31 August.

The markers used for the fallow land practice monitoring:

- Presence of vegetation in the practice period (Table 5-70);
- Harvest/clearance in the practice period (Table 5-71);
- Loss of vegetation (mulching) between 1st June and 31st August (Table 5-72).

Table 5-70. Presence of vegetation within the fallow land practice period in CZE 2018

Reference dataset	Presence of vegetation in the practice period (01.03.-15.07.)				
	%	TRUE	FALSE	NR	Total
	TRUE	**99.5**	0.5	0	100,0
	FALSE	0	**0**	0	0,0
	NR	0	0	**0**	0,0
	Total	99.5	0.5	0	**100**

Table 5-71. Harvest/clearance within the stable fallow land practice period in CZE 2018

Reference dataset	Harvest/clearance in the practice period (01.03.-15.07.)				
	%	TRUE	FALSE	NR	Total
	TRUE	**14.6**	34.0	0	48.5
	FALSE	0	**51.5**	0	51.5
	NR	0	0	**0**	0
	Total	14.6	85.4	0	**100**

Table 5-72. Loss of vegetation (mulching) between 1st June and 31st August for fallow land monitoring in CZE 2018

	Loss of vegetation (mulching) between 01.06.-31.08				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**0.5**	50.0	9.2	59.7
	FALSE	1.9	**32.5**	5.8	40.3
	NR	0	0	**0**	0
	Total	2.4	82.5	15.0	**100**

5.4.3 Italy

Three products were produced and delivered in 2018:

- harvest/clearance week: evaluated for all arable land parcels (except of the parcels with the declared EFA practice for which separated product is provided);
- growing of the nitrogen fixing crop: evaluated for the parcels with the declared EFA nitrogen fixing crop practice;
- fallow land: evaluated for the parcels with the declared EFA fallow land practice.

The number of parcels in the harvest/clearance week product and EFA products is provided in Table 5-73. Only parcels with at least one S1 inner pixel were processed and evaluated.

Table 5-73. Number of parcels in the L4C products for 2018 in CZE

Practice	Number of declared parcels	Number of processed parcels	Proportion of processed parcels [%]
HARVEST	742 552	458 062	61.7
EFA	646 547	284 795	44.0

The S1 data availability in 2018 over ITA is illustrated in Figure 5-62.

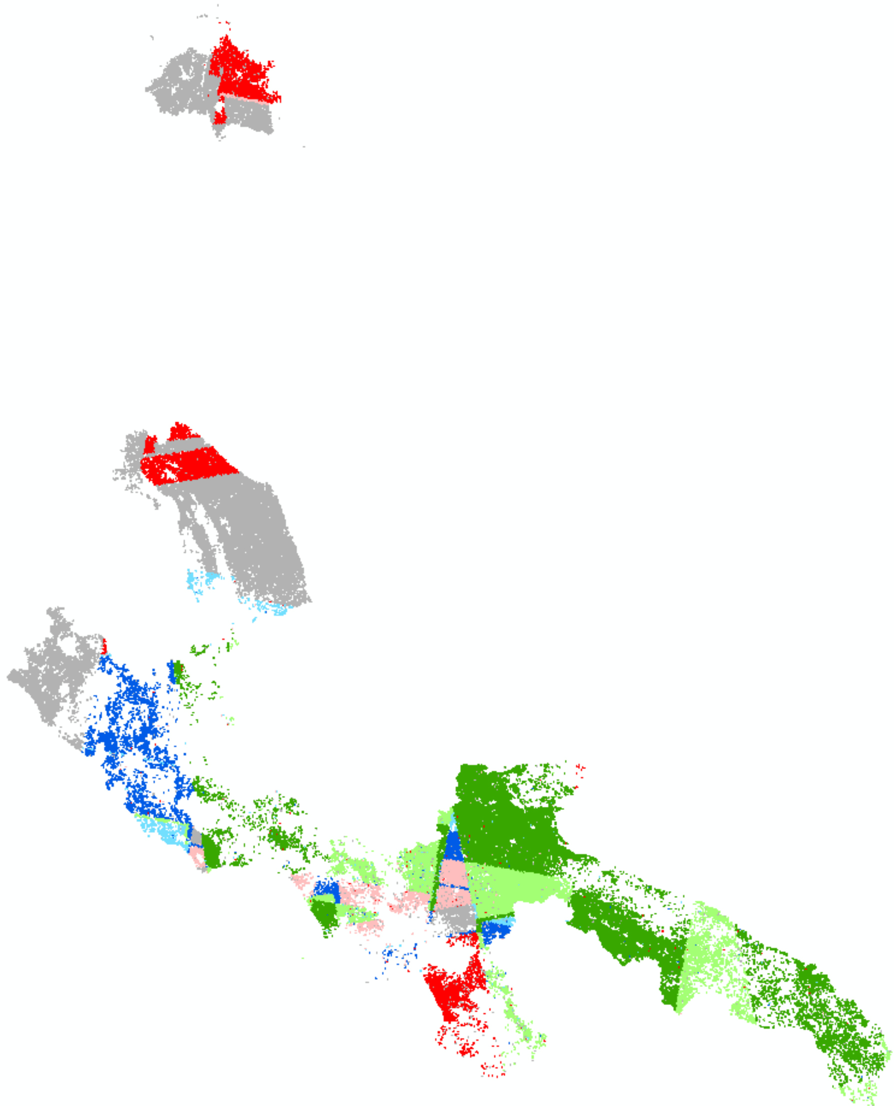
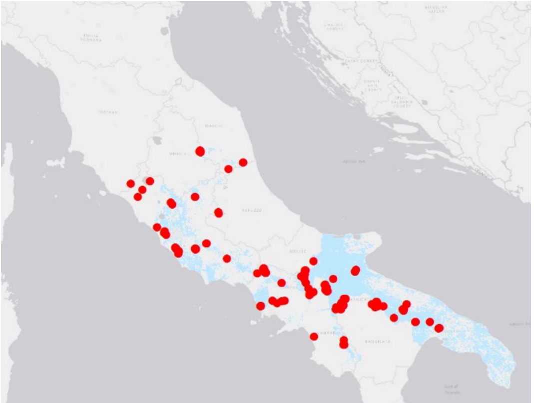


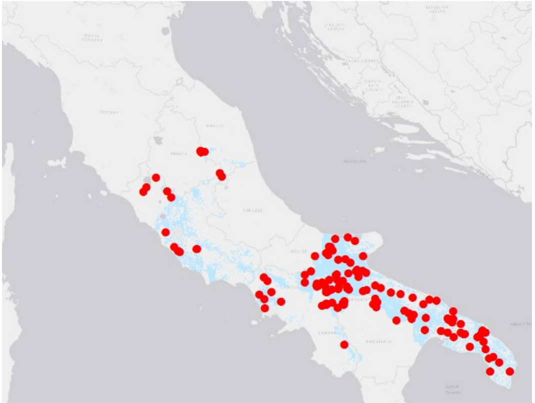
Figure 5-62. S1 data availability in ITA 2018 – The number of weeks for which the S1 data are completely missing is represented with a colour code: 0 – dark green, 1 – light green, 2 – light blue, 3 – dark blue, 4 – pink, 5 – red, more than 5 weeks – grey

The distribution of the reference parcels is shown in Figure 5-63. Only the parcels with 0-3 missing week of S1 data were selected for validation. The parcels were randomly selected.

Harvest detection



Nitrogen fixing crops



Fallow lands

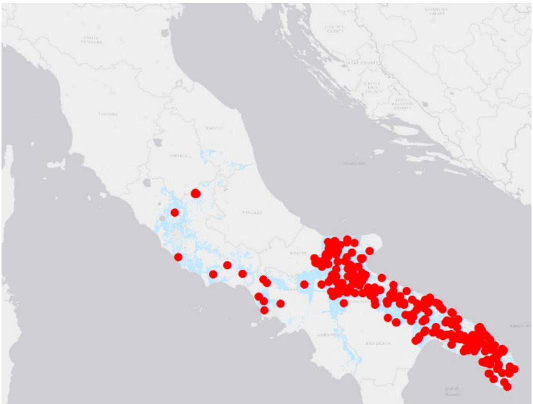


Figure 5-63. Distribution of the reference parcels for the harvest detection (top left), nitrogen fixing crops (top right) and fallow lands (below) in ITA 2018

5.4.3.1 Validation of harvest detection for the main crop

Both farmers interviews and Planet data were used for the validation of the main crop harvest detection in ITA. Results are shown in Table 5-74.

Table 5-74. Accuracy of main crop harvest detection based on farmers interviews and Planet data – ITA 2018

Difference [weeks]	Reference data Provided by farmers	% Category / Cummulative		Reference data Planet imagery	% Category / Cummulative		Reference data Total	% Category / Cummulative	
0-1	99	41%	41%	25	76%	76%	124	45%	45%
2	37	15%	57%	4	12%	88%	41	15%	60%
3	27	11%	68%	2	6%	94%	29	11%	71%
> 3	68	28%	96%	2	6%	100%	70	26%	97%
Not detect.	9	4%	100%	0	0%	100%	9	3%	100%
Total	**240**	**100%**		**33**	**100%**		**273**	**100%**	

Due to the low validation accuracy obtained for data reported by farmers, the accuracy of reported data has been evaluated for 21 randomly selected parcels using Planet imagery.

It has been found out that two harvests occurred on 8 of 21 parcels. Mostly, Sen4CAP analysis detected correctly the first harvest while the second harvest was reported by the farmer. This explains high percentage (almost 30%) of parcels with more than 3 weeks difference between Sen4CAP results and farmers reports. The results for the remaining 13 parcels are presented in Table 5-75. The data reported by farmers have been confirmed for around 70% of parcels.

Table 5-75. Comparison between farmers' reports and interpretation of Planet imagery for remaining 13 parcels

Difference	**Reference data**	**%**	
[weeks]	**Farmer's interview**	**Category / Cummulative**	
0-1	9	69%	69%
2	0	0%	69%
3	1	8%	77%
> 3	3	23%	100%
Not detect.	0	0%	100%
Total	**13**	**100%**	

5.4.3.2 Validation of nitrogen fixing crop monitoring

The individual markers used for the evaluation of the EFA practice are compared with the reference data based on visual interpretation of the Planet imagery or the farmer interviews (250 parcels).

The parcel shall be covered by the crops adequate to the respective phenology, along the year.

The markers used for the nitrogen fixing crop practice monitoring:

- Presence of vegetation in the practice period (Table 5-76);
- Harvest/clearance in the practice period (Table 5-77).

Table 5-76. Presence of vegetation within the NFC practice period in ITA 2018

	Presence of vegetation in the practice period (01.03.-31.08.)				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**100**	0	0	100
	FALSE	0	**0**	0	0
	NR	0	0	**0**	0
	Total	100	0	0	**100**

Table 5-77. Harvest/clearance within the NFC practice period in ITA 2018

	Harvest/clearance in the practice period (02.04.-31.08.)				
Reference dataset	**%**	**TRUE**	**FALSE**	**NR**	**Total**
	TRUE	**70.4**	14.8	0	85.2
	FALSE	5.6	**9.2**	0	14.8
	NR	0	0	**0**	0
	Total	76.0	24.0	0	**100**

5.4.3.3 Validation of fallow land monitoring

The individual markers used for the evaluation of the EFA practice are compared with the reference data based on visual interpretation of the Planet imagery.

Fallow land must be for 6 months from 1 January to 30 June. After 31 March cutting/mulching is expected to prevent fire.

The markers used for the fallow land practice monitoring:

- Presence of vegetation in the practice period (Table 5-78);
- Harvest/clearance in the stable practice period (Table 5-79).

Table 5-78. Presence of vegetation within the fallow land practice period in ITA 2018

	Presence of vegetation in the practice period (01.01.-30.06.)				
Reference dataset	**%**	**TRUE**	**FALSE**	**NR**	**Total**
	TRUE	**92.4**	0	0	92.4
	FALSE	1.6	**6.0**	0	7.6
	NR	0	0	**0**	0
	Total	94.0	6.0	0	**100**

Table 5-79. Harvest/clearance within the stable fallow land practice period in ITA 2018

	Harvest/clearance in the stable practice period (01.01.-31.03.)				
Reference dataset	**%**	**TRUE**	**FALSE**	**NR**	**Total**
	TRUE	**5.2**	5.2	0	10.4
	FALSE	1.2	**88.4**	0	89.6
	NR	0	0	**0**	0
	Total	6.4	93.6	0	**100**

5.4.4 Lithuania

Four products were produced and delivered in 2018:

- harvest/clearance week: evaluated for all arable land parcels (except of the parcels with the declared EFA practice for which separated product is provided);
- growing of the catch crop: evaluated for the parcels with the declared EFA catch-crop practice;
- growing of the nitrogen fixing crop: evaluated for the parcels with the declared EFA nitrogen fixing crop practice;

- fallow land: evaluated for the parcels with the declared EFA fallow land practice.

The number of parcels in the harvest/clearance week product and EFA products is provided in Table 5-80. Only parcels with at least one S1 inner pixel were processed and evaluated.

Table 5-80. Number of parcels in the L4C products for 2018 in LTU

Practice	Number of declared parcels	Number of processed parcels	Proportion of processed parcels [%]
HARVEST	549 050	437 039	79.6
EFA	48 845	44 734	91.6

The S1 data availability in 2018 over LTU is illustrated in Figure 5-64.

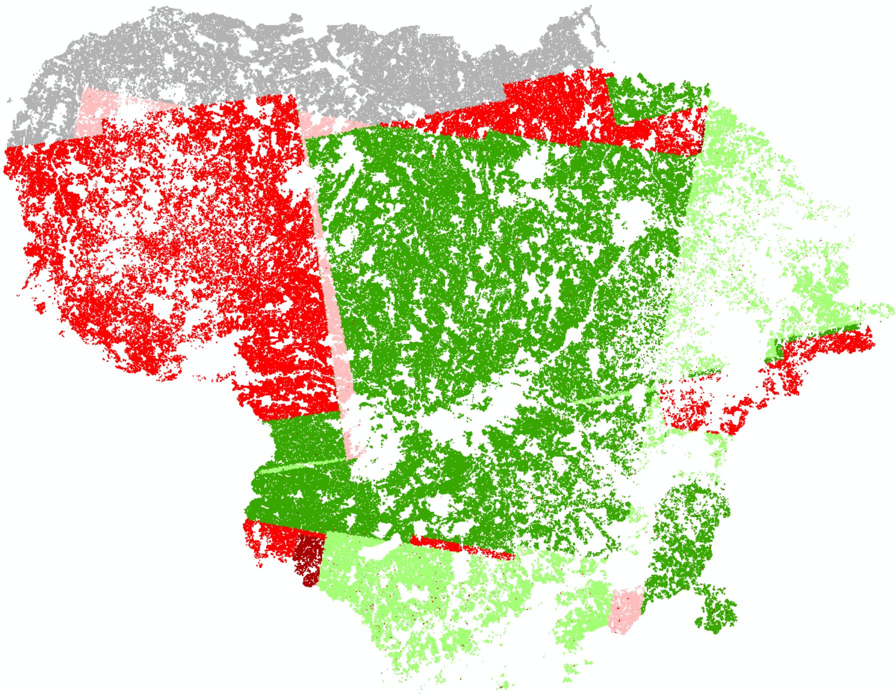


Figure 5-64. S1 data availability in LTU 2018 – The number of weeks for which the S1 data are completely missing is represented with a colour code: 2 – dark green, 3 – light green, 4 – pink, 5 – red, more than 5 weeks – grey

The distribution of the reference parcels is shown in Figure 5-65. Only the parcels with 0 or 1 missing week of S1 data were selected for validation. The parcels for validation were randomly selected. The number of parcels of different catch crop types (fast-growing crop - IS, catch crop - PO) and fallow land types (green fallow - PDŽ, black fallow - PDJ) were selected according to the proportional representation of each catch crop type.

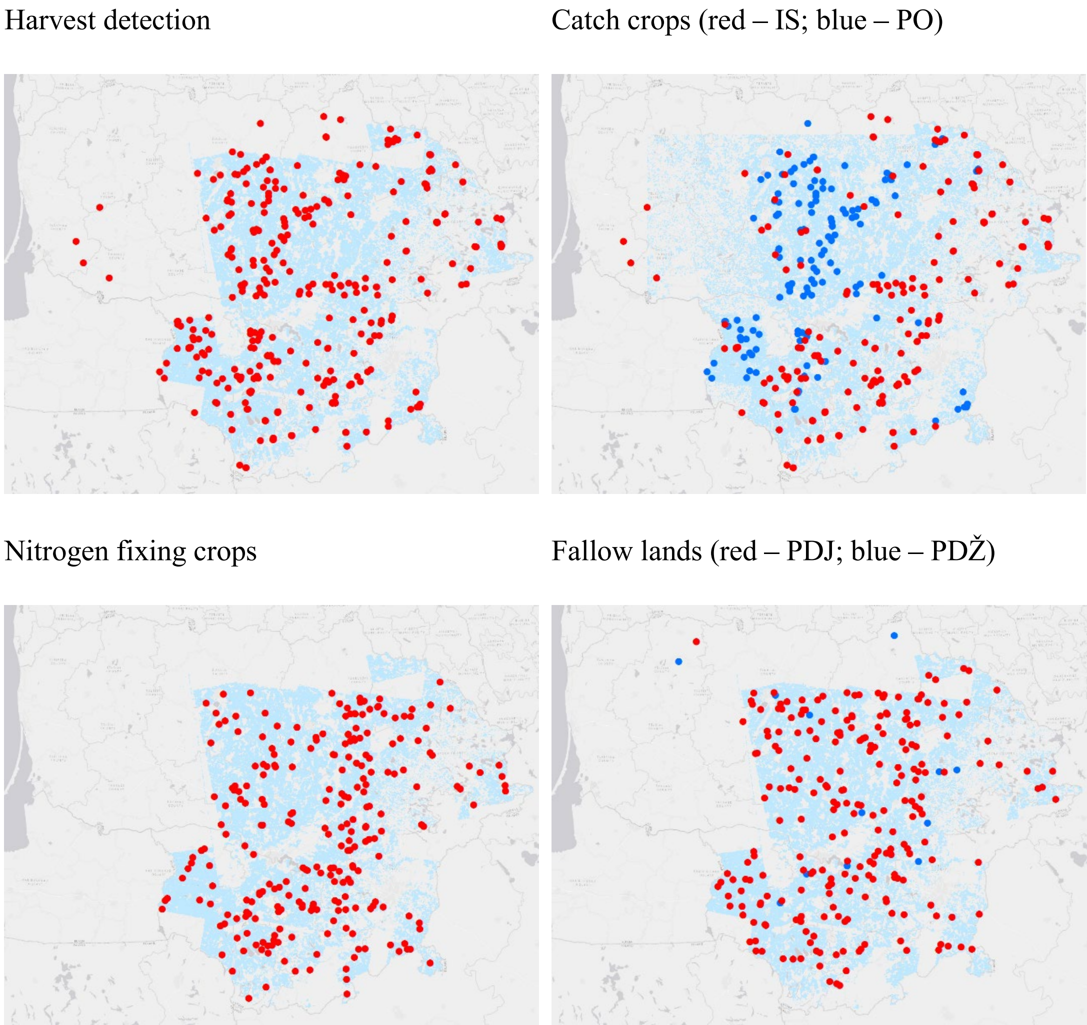


Figure 5-65. Distribution of the reference parcels for the harvest detection (top left), catch crops (top right), nitrogen fixing crops (below left) and fallow lands (below right) in LTU 2018

5.4.4.1 Validation of harvest detection for the main crop

Both farmers interviews and Planet data were used for the validation of the main crop harvest detection in LTU. Results are shown in Table 5-81.

Table 5-81. Accuracy of main crop harvest detection based on farmers interviews and Planet data – LTU 2018

Difference [weeks]	Reference data Provided by farmers	% Category /	Cummulative	Reference data Planet imagery	% Category /	Cummulative	Reference data Total	% Category /	Cummulative
0-1				186	74%	74%	186	74%	74%
2				37	15%	89%	37	15%	89%
3				9	4%	93%	9	4%	93%
> 3				10	4%	97%	10	4%	97%
Not detect.				8	3%	100%	8	3%	100%
Total	**0**			**250**	**100%**		**250**	**100%**	

5.4.4.2 Validation of catch crop monitoring

The validation has been done for 250 catch crop parcels.

The markers used for the nitrogen fixing crop practice monitoring:

- Marker 6 which evaluates the presence of vegetation within the practice period based on the NDVI (Table 5-82);
- Marker 7 which evaluates the growth of vegetation within the practice period, based on the NDVI (Table 5-83);
- Marker 8 which evaluates, based on the NDVI, a no loss of vegetation within the practice period (Table 5-84);
- Marker 9 which evaluates, based on the SAR backscatter, a no loss of vegetation within the practice period (Table 5-85);
- Marker 10 which evaluates, based on the SAR coherence, the presence of vegetation within the practice period (Table 5-86).

The marker related to the pre-requisite that the main crop must be harvested before the catch crop monitoring was also validated (Table 5-87).

Table 5-82. Marker 6 validation for catch crop monitoring in LTU 2018

M6	**Presence of vegetation based on NDVI**				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**96.2**	2.5	0	98.7
	FALSE	0.6	**0.6**	0	1.3
	NR	0	0	**0**	0
	Total	96.9	3.1	0	**100**

Table 5-83. Marker 7 validation for catch crop monitoring in LTU 2018

M7	**Growth of vegetation based on NDVI**				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**71.7**	27.0	0	98.7
	FALSE	0	**1.3**	0	1.3
	NR	0	0	**0**	0
	Total	71.7	28.3	0	**100**

Table 5-84. Marker 8 validation for catch crop monitoring in LTU 2018

M8	No loss of vegetation based on NDVI				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**63.5**	3.1	0	66.7
	FALSE	6.3	**27.0**	0	33.3
	NR	0	0	**0**	0
	Total	69.8	30.2	0	**100**

Table 5-85. Marker 9 validation for catch crop monitoring in LTU 2018

M9	No loss of vegetation based on SAR backscatter				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**59.7**	6.9	0	66.7
	FALSE	14.5	**18.9**	0	33.3
	NR	0	0	**0**	0
	Total	74.2	25.8	0	**100**

Table 5-86. Marker 10 validation for catch crop monitoring in LTU 2018

M10	Presence of vegetation based on SAR coherence (4 weeks limit)				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**30.8**	67.9	0	98.7
	FALSE	0	**1.3**	0	1.3
	NR	0	0	**0**	0
	Total	30.8	69.2	0	**100**

Table 5-87. Validation of the marker "Harvest of the main crop before the catch crop period" in LTU 2018

	Harvest/clearance of the main crop between 01.06. and P_START (01.09.)				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**98.3**	**0.9**	**0**	99.1
	FALSE	**0.9**	**0**	**0**	0.9
	NR	**0**	**0**	**0**	0
	Total	99.1	0.9	0	**100**

5.4.4.3 Validation of nitrogen fixing crop monitoring

The individual markers used for the evaluation of the EFA practice are compared with the reference data based visual interpretation of the Planet imagery (250 parcels).

Nitrogen-fixing crops are grown in the main vegetation season.

The markers used for the nitrogen fixing crop practice monitoring:

- Presence of vegetation in the practice period (Table 5-88);
- Harvest/clearance in the practice period (Table 5-89).

Table 5-88. Presence of vegetation within the NFC practice period in LTU 2018

	Presence of vegetation in the practice period (02.04.-31.10.)				
	%	TRUE	FALSE	NR	Total
Reference dataset	TRUE	**100**	0	0	100
	FALSE	0	**0**	0	0
	NR	0	0	**0**	0
	Total	100	0	0	**100**

Table 5-89. Harvest/clearance within the NFC practice period in LTU 2018

	Harvest/clearance in the practice period (01.06.-31.10.)				
	%	TRUE	FALSE	NR	Total
Reference dataset	TRUE	**94.4**	3.6	0	98.0
	FALSE	0.4	**1.6**	0	2
	NR	0	0	**0**	0
	Total	94.8	5.2	0	**100**

5.4.4.4 Validation of fallow land monitoring

The individual markers used for the evaluation of the EFA practice are compared with the reference data based on visual interpretation of the Planet imagery (250 parcels).

Green Fallow (PDŽ) shall not be grazed or mowed (no agricultural activity at all). The green fallow shall be inserted into the soil until 15th of September.

Black Fallow (PDJ) needs to be cultivated at least 9 months (January-September), it is periodically ploughed, at least once every 2 months (no weeds or other plants). After that, until 1 November the parcel shall be sown.

Table 5-90. Presence of vegetation within the fallow land practice period in LTU 2018

	Presence of vegetation in the practice period (green fallow)				
	%	TRUE	FALSE	NR	Total
Reference dataset	TRUE	**100**	0	0	100
	FALSE	0	**0**	0	0
	NR	0	0	**0**	0
	Total	100	0	0	**100**

Table 5-91. Harvest/clearance within the stable fallow land practice period in LTU 2018

	Vegetation is present at least 8 weeks within the practice period (black fallow)				
	%	TRUE	FALSE	NR	Total
Reference dataset	TRUE	**27.4**	4.7	0	32.1
	FALSE	6.5	**61.4**	0	67.9
	NR	0	0	**0**	0
	Total	34.0	66.0	0	**100**

5.4.5 Netherlands

Two products were produced and delivered in 2018:

- harvest/clearance week: evaluated for all arable land parcels (except of the parcels with the declared EFA practice for which separated product is provided);
- growing of the catch crop: evaluated for the parcels with the declared EFA catch-crop practice.

The number of parcels in the harvest/clearance week product and EFA products is provided in Table 5-92. Only parcels with at least one S1 inner pixel were processed and evaluated.

Table 5-92. Number of parcels in the L4C products for 2018 in CZE

Practice	Number of declared parcels	Number of processed parcels	Proportion of processed parcels [%]
HARVEST	153 262	148 342	96.8
EFA	27 458	26 282	95.7

The S1 data availability in 2018 over NLD is illustrated in Figure 5-66.

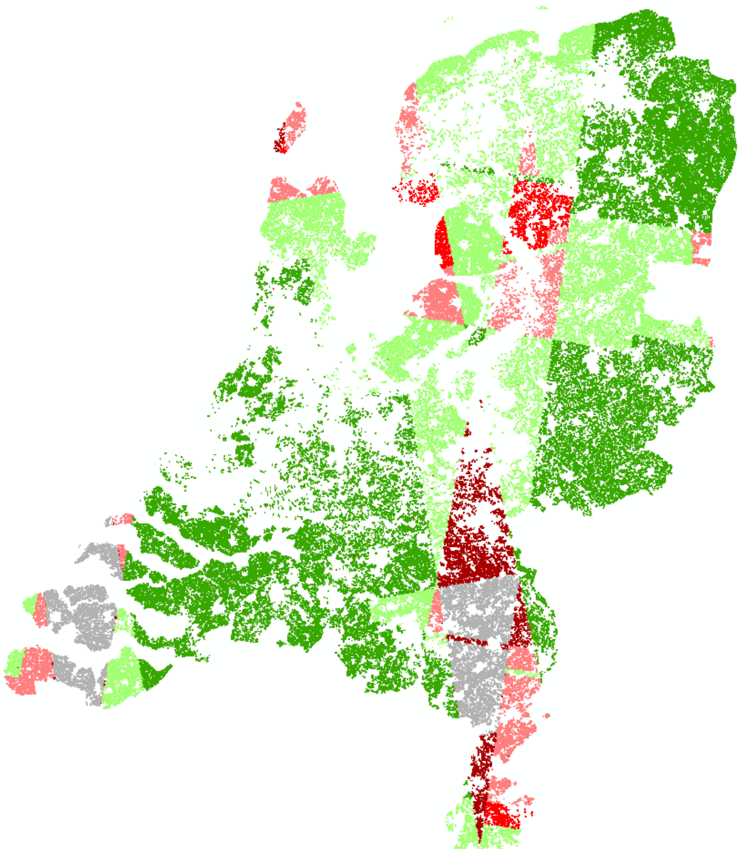


Figure 5-66. S1 data availability in NLD 2018 – The number of weeks for which the S1 data are completely missing is represented with a colour code: 2 – dark green, 3 – light green, 4 – pink, 5 – red, more than 5 weeks – grey

The distribution of the reference parcels is shown in Figure 5-67. Only the parcels with 0 or 1 missing week of S1 data were selected for validation. The parcels for validation were randomly selected. The number of parcels of different catch crop types (catch crop as the main crop, catch crop after main crop – category 1,2,3) were selected according to the proportional representation of each catch crop type.

Harvest detection

Catch crops (red – catch crop 1, blue – catch crop 2, green – catch crop 3, violet – catch crop is main crop)

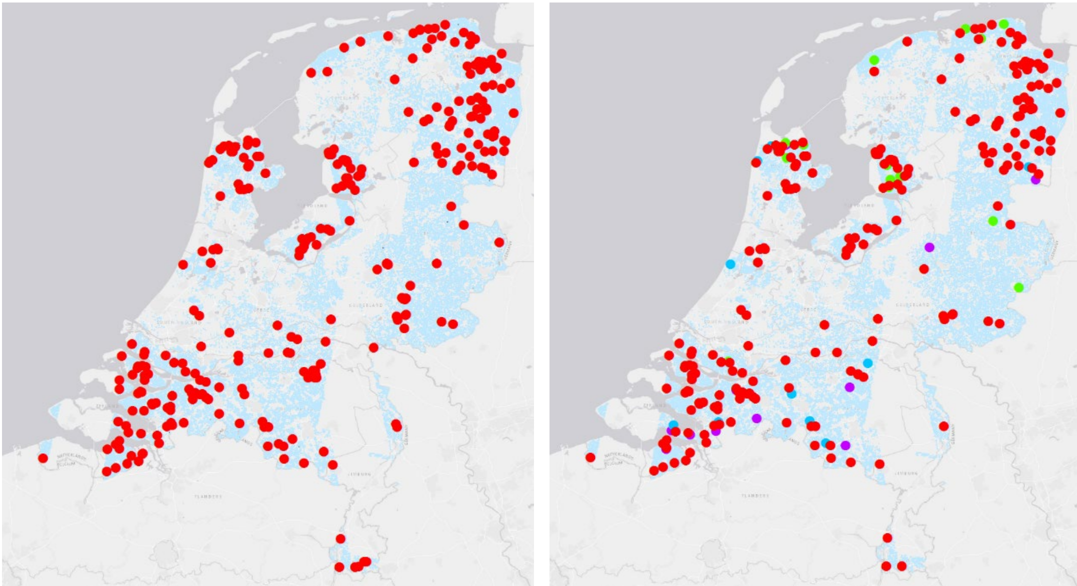


Figure 5-67. Distribution of the reference parcels for the harvest detection (top left) and catch crops (top right) in NLD 2018

5.4.5.1 Validation of harvest detection for the main crop

Both farmers interviews and Planet data were used for the validation of the main crop harvest detection in NLD. Results are shown in Table 5-93.

Table 5-93. Accuracy of main crop harvest detection based on farmers interviews and Planet data – NLD 2018

Difference [weeks]	**Reference data Provided by farmers**	**% Category / Cummulative**		**Reference data Planet imagery**	**% Category / Cummulative**		**Reference data Total**	**% Category / Cummulative**	
0-1	30	57%	57%	207	83%	83%	237	78%	78%
2	15	28%	85%	19	8%	91%	34	11%	90%
3	4	8%	92%	7	3%	94%	11	4%	93%
> 3	3	6%	98%	2	1%	94%	5	2%	95%
Not detect.	1	2%	100%	14	6%	100%	15	5%	100%
Total	**53**	**100%**		**249**	**100%**		**302**	**100%**	

5.4.5.2 Validation of catch crop monitoring

The validation has been done for 250 catch crop parcels.

The markers used for the catch crop practice monitoring:

- Marker 6 which evaluates the presence of vegetation within the practice period based on the NDVI (Table 5-94);
- Marker 7 which evaluates the growth of vegetation within the practice period, based on the NDVI (Table 5-95);
- Marker 8 which evaluates, based on the NDVI, a no loss of vegetation within the practice period (Table 5-96);
- Marker 9 which evaluates, based on the SAR backscatter, a no loss of vegetation within the practice period (Table 5-97);
- Marker 10 which evaluates, based on the SAR coherence, the presence of vegetation within the practice period (Table 5-98).

The marker related to the pre-requisite that the main crop must be harvested before the catch crop monitoring was also validated (Table 5-99).

Table 5-94. Marker 6 validation for catch crop monitoring in NLD 2018

M6	Presence of vegetation based on NDVI				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**78.7**	2.1	2.5	83.3
	FALSE	4.2	**12.1**	0.4	16.7
	NR	0	0	**0**	0
	Total	82.8	14.2	2.9	**100**

Table 5-95. Marker 7 validation for catch crop monitoring in NLD 2018

M7	Growth of vegetation based on NDVI				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**72.0**	10.2	2.5	84.7
	FALSE	2.1	**12.7**	0.4	15.3
	NR	0	0	**0**	0
	Total	74.2	22.9	3.0	**100**

Table 5-96. Marker 8 validation for catch crop monitoring in NLD 2018

M8	No loss of vegetation based on NDVI				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference dataset	**TRUE**	**56.4**	9.7	0.8	66.9
	FALSE	10.2	**20.8**	1.7	32.6
	NR	0	0	**0**	0
	Total	66.5	30.5	2.5	**100**

Table 5-97. Marker 9 validation for catch crop monitoring in NLD 2018

M9	No loss of vegetation based on SAR backscatter				
	%	TRUE	FALSE	NR	Total
Reference dataset	TRUE	**71.0**	**9.3**	**1.2**	81.5
	FALSE	**10.5**	**6.9**	**1.2**	18.5
	NR	**0**	**0**	**0**	0
	Total	81.5	16.1	2.4	**100**

Table 5-98. Marker 10 validation for catch crop monitoring in NLD 2018

M10	Presence of vegetation based on SAR coherence				
	%	TRUE	FALSE	NR	Total
Reference dataset	TRUE	**37.2**	26.8	2.4	66.4
	FALSE	2.8	**30.4**	0.4	33.6
	NR	0	0	**0**	0
	Total	40	57.2	2.8	**100**

Table 5-99. Validation of the marker "Harvest of the main crop before the catch crop period" in NLD 2018

	Harvest/clearance of the main crop between 15.5. and P_START (Cat1/2)				
	%	TRUE	FALSE	NR	Total
Reference dataset	TRUE	**91.5**	4.5	0	96.0
	FALSE	2.2	**1.8**	0	4.0
	NR	0	0	**0**	0
	Total	93.7	6.3	0	**100**

5.4.6 Romania

Three products were produced and delivered in 2018:

- harvest/clearance week: evaluated for all arable land parcels (except of the parcels with the declared EFA practice for which separated product is provided);
- growing of the catch crop: evaluated for the parcels with the declared EFA catch-crop practice;
- growing of the nitrogen fixing crop: evaluated for the parcels with the declared EFA nitrogen fixing crop practice.

The number of parcels in the harvest/clearance week product and EFA products is provided in Table 5-100. Only parcels with at least 1 Sentinel-1 inner pixel were processed and evaluated.

Table 5-100. Number of parcels in the L4C products for 2018 in ROU

Practice	Number of declared parcels	Number of processed parcels	Proportion of processed parcels [%]
HARVEST	3 570 752	1 015 422	28.4
EFA	163 120	127 163	78

The S1 data availability in 2018 over ROU is illustrated in Figure 5-68.

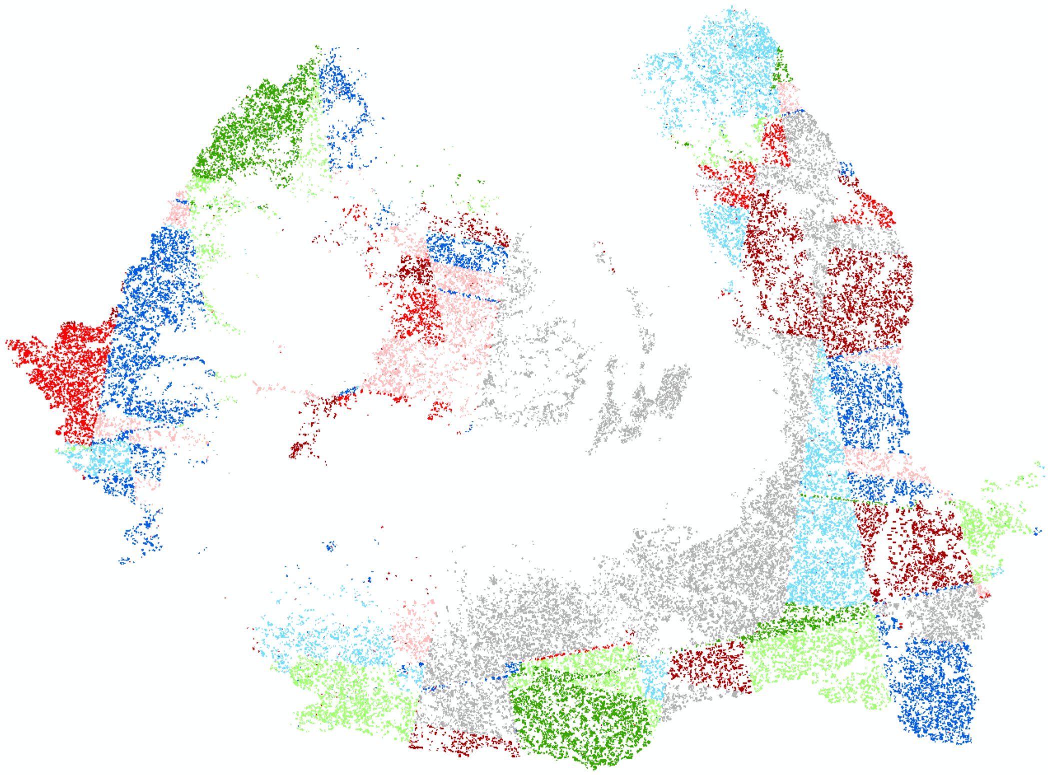
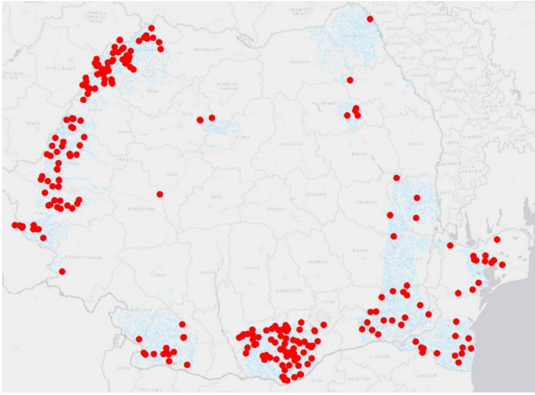


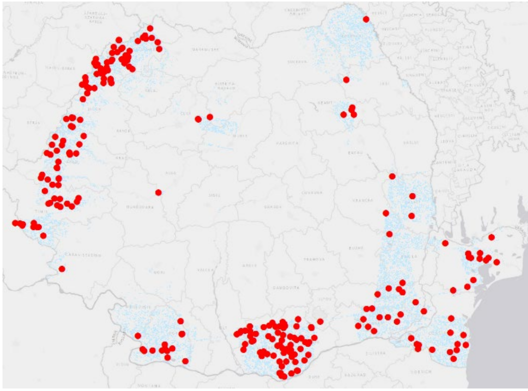
Figure 5-68. S1 data availability in ROU 2018 – The number of weeks for which the S1 data are completely missing is represented with a colour code: 2 – dark green, 3 – light green, 4 – pink, 5 – red, more than 5 weeks – grey

The distribution of the reference parcels is shown in Figure 5-69. Only the parcels with 0-3 missing week of S1 data were selected for validation. The parcels were randomly selected.

Harvest detection



Catch crops (red – summer; blue – winter)



Nitrogen fixing crops

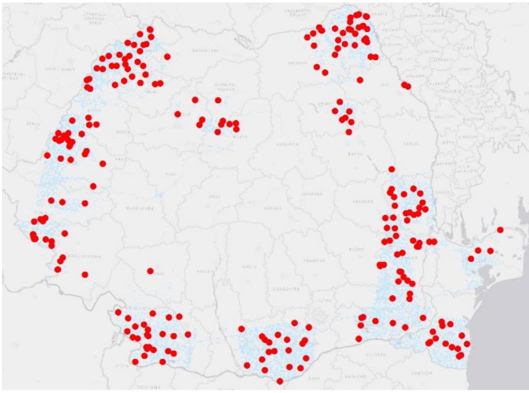


Figure 5-69. Distribution of the reference parcels for the harvest detection (top left), catch crops (top right) and nitrogen fixing crops (below) in ROU 2018

5.4.6.1 Validation of harvest detection for the main crop

Both farmers interviews and Planet data were used for the validation of the main crop harvest detection in ROU. Results are shown in Table 5-101.

Table 5-101. Accuracy of main crop harvest detection based on farmers interviews and Planet data – ROU 2018

Difference [weeks]	**Reference data Provided by farmers**	**% Category / Cummulative**		**Reference data Planet imagery**	**% Category / Cummulative**		**Reference data Total**	**% Category / Cummulative**	
0-1				174	70%	70%	174	70%	70%
2				35	14%	84%	35	14%	84%
3				15	6%	90%	15	6%	90%
> 3				24	10%	99%	24	10%	99%
Not detect.				2	1%	100%	2	1%	100%
Total	**0**			**250**	**100%**		**250**	**100%**	

5.4.6.2 Validation of catch crop monitoring

The validation has been done for 250 catch crop parcels.

The markers used for the catch crop practice monitoring:

- Marker 6 which evaluates the presence of vegetation within the practice period based on the NDVI (Table 5-102);
- Marker 7 which evaluates the growth of vegetation within the practice period, based on the NDVI (Table 5-103);
- Marker 8 which evaluates, based on the NDVI, a no loss of vegetation within the practice period (Table 5-104);
- Marker 9 which evaluates, based on the SAR backscatter, a no loss of vegetation within the practice period (Table 5-105);
- Marker 10 which evaluates, based on the SAR coherence, the presence of vegetation within the practice period (Table 5-106).

The marker related to the pre-requisite that the main crop must be harvested before the catch crop monitoring was also validated (Table 5-107).

Table 5-102. Marker 6 validation for catch crop monitoring in ROU 2018

M6	Presence of vegetation based on NDVI				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference	**TRUE**	**49.7**	4.1	0.5	54.3
	FALSE	5.6	**40.1**	0	45.7
	NR	0	0	**0**	0
	Total	55.3	44.2	0.5	**100**

Table 5-103. Marker 7 validation for catch crop monitoring in ROU 2018

M7	Growth of vegetation based on NDVI				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference	**TRUE**	**29.0**	22.8	0.5	52.3
	FALSE	1.0	**46.6**	0	47.7
	NR	0	0	**0**	0
	Total	30.1	69.4	0.5	**100**

Table 5-104. Marker 8 validation for catch crop monitoring in ROU 2018

M8	No loss of vegetation based on NDVI				
	%	**TRUE**	**FALSE**	**NR**	**Total**
Reference	**TRUE**	**20.2**	7.8	0.5	28.5
	FALSE	7.3	**64.2**	0	71.5
	NR	0	0	**0**	0
	Total	27.5	72.0	0.5	**100**

Table 5-105. Marker 9 validation for catch crop monitoring in ROU 2018

M9	No loss of vegetation based on SAR backscatter				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**21.7**	0.8	0.4	23.0
	FALSE	55.7	**21.3**	0	77.0
	NR	0	0	**0**	0
	Total	77.5	22.1	0.4	**100**

Table 5-106. Marker 10 validation for catch crop monitoring in ROU 2018

M10	Presence of vegetation based on SAR coherence				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**12.6**	32.8	0.4	45.7
	FALSE	0	**54.3**	0	54.3
	NR	0	0	**0**	0
	Total	12.6	87.0	0.4	**100**

Table 5-107. Validation of the marker "Harvest of the main crop before the catch crop period" in ROU 2018

	Harvest/clearance of the main crop between 15.06. and P_START				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**89.1**	0.8	0	89.9
	FALSE	9.7	**0.4**	0	10.1
	NR	0	0	**0**	0
	Total	98.8	1.2	0	**100**

5.4.6.3 Validation of nitrogen fixing crop monitoring

The individual markers used for the evaluation of the EFA practice are compared with the reference data based on the farmer interviews (250 parcels).

The nitrogen fixing crop is needed to be in the field at least in the growing period of vegetation.

The markers used for the nitrogen fixing crop practice monitoring:

- Presence of vegetation in the practice period (Table 5-108);
- Harvest/clearance in the practice period (Table 5-109).

Table 5-108. Presence of vegetation within the NFC practice period in ROU 2018

	Presence of vegetation in the practice period				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**92.4**	0.4	0	92.8
	FALSE	2.8	**4.4**	0	7.2
	NR	0	0	**0**	0
	Total	95.2	4.8	0	**100**

Table 5-109. Harvest/clearance within the NFC practice period in ROU 2018

Reference dataset	Harvest/clearance in the practice period				
	%	TRUE	FALSE	NR	Total
	TRUE	**6.4**	12.8	0	19.2
	FALSE	1.6	**79.2**	0	80.8
	NR	0	0	**0**	0
	Total	8.0	92.0	0	**100**

5.4.7 Summary

The summary of validation results for all countries is presented in this chapter.

The harvest detection accuracy assessed using Planet imagery is rather consistent among individual countries (mostly the differences in all categories are below 5%). It confirms the method is robust and works well in different conditions (including impact of data gaps in S1 time series).

The differences in validation accuracy assessed using data reported by farmers are affected by the fact that each PA has chosen different approach to collect the data and the error rate in these datasets differs country by country. Also, in contrast to random selection of parcels assessed using Planet imagery, the datasets provided by the PA may be biased (due to the various approaches how the farmers were selected).

Table 5-110. Summary results of validation of harvest detection for the main crop (Planet imagery)

Harvest detection accuracy 2018 [%]						
Difference [weeks]	**CZE**	**ITA**	**LTU**	**NLD**	**ROU**	**ESP**
<=1	72	76	74	83	70	53
2	15	12	15	8	14	16
3	6	6	4	3	6	12
> 3	6	6	4	1	10	14
Not detected	1	0	3	6	1	5
Total	100	100	100	100	100	100

The summary validation results for markers used within the catch crop monitoring show higher accuracy figures for NDVI derived markers (above 80%) and lower figures for SAR derived markers (60 – 70%), as shown in Table 5-111. This is compensated by the fact that SAR derived markers provide timely and guaranteed information.

In the same Table 5-111, the summary validation results for markers used within the nitrogen fixing crop and fallow land monitoring show high accuracy figures (> 80%) for two markers that are common for monitoring of both practices in all relevant countries.

The compliance accuracy for all practices has been derived from the compliancy index (which is the result of joint analysis of all relevant markers). The values of “STRONG” and “MODERATE” were categorized as compliant while the values of “POOR” and

"WEAK" as non-compliant. The reference compliancy assessment has been part of Planet imagery interpretation.

Table 5-111. Summary validation results of catch crop, nitrogen fixing crop and fallow land monitoring

Catch crop [%]				
Markers	**CZE**	**LTU**	**NLD**	**ROU**
Presence of vegetation (NDVI)	91.2	96.8	90.8	89.8
Growth of vegetation (NDVI)	76.2	73	84.7	75.6
No loss of vegetation (NDVI)	77.2	90.5	77.2	84.4
No loss of vegetation (backscatter ratio)	77.2	78.6	77.9	43
Presence of vegetation - dynamic conditions (VV coherence)	67.6	32.1	67.6	66.9
Harvest of the main crop before the practice period	98.0	98.3	93.3	89.5
COMPLIANCE YES – C_INDEX „STRONG" / „MOD" NO – C_INDEX „POOR" / „WEEK"	**79,6**	**86,8**	**80,4**	**88,3**

Nitrogen fixing crop [%]					
Markers	**CZE**	**ITA**	**LTU**	**ROU**	**ESP**
Presence of vegetation (NDVI)	100	100	100	96.8	98.8
Harvest in the practice period	41.2	79.6	96	85.6	80.4
COMPLIANCE YES – C_INDEX „STRONG" / „MOD" NO – C_INDEX „POOR" / „WEEK"	**41,2**	**100**	**100**	**82,8**	**98,8**

Fallow land [%]				
Markers	**CZE**	**ITA**	**LTU**	**ESP**
Presence of vegetation (NDVI)	99.5	98.4	100	60
Harvest in the practice period	66.1	93.6	88.8	47.6
COMPLIANCE YES – C_INDEX „STRONG" / „MOD" NO – C_INDEX „POOR" / „WEEK"	**66,6**	**93,6**	**88,8**	**47,6**

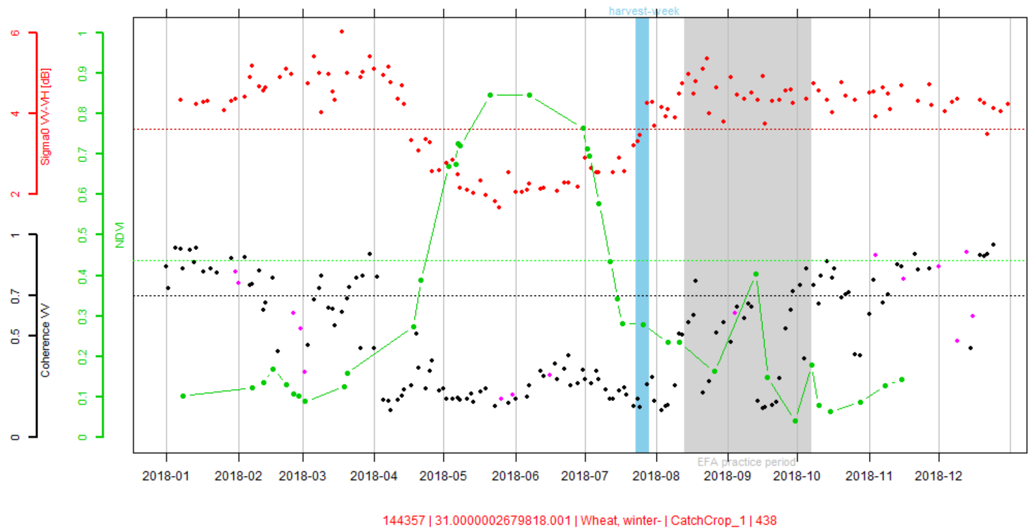
5.4.8 Reliability of reference data

When analyzing the validation results number of additional external factors have to be considered:

- Data gaps in S1 time series
- Possible errors in data reported by farmers

- Possible bias in selection of farmers for interviews
- Non-availability of NIR spectral band for Planet data interpretation
- Sensitivity of NDVI to plant senescence

To document some typical disagreements between the SenCAP automated analysis and visual interpretation of the Planet imagery (on the marker level), number of examples are presented below.



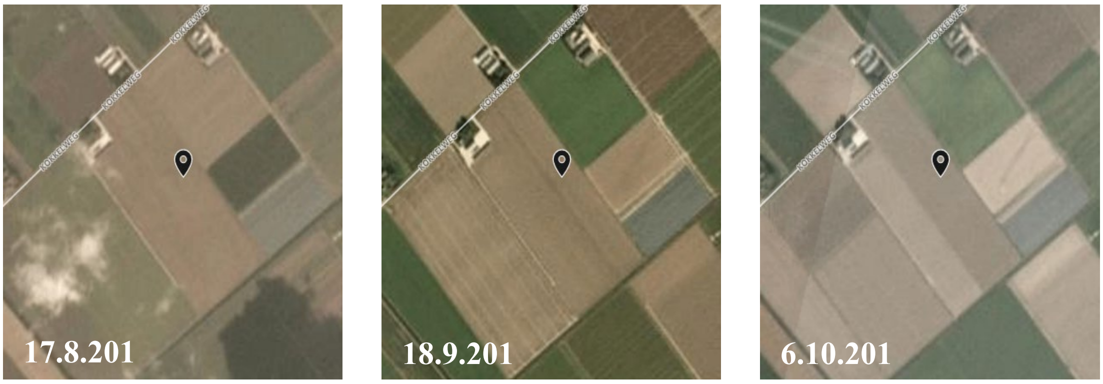


Figure 5-70. Example of the M6 false positive case. Due to the single high NDVI value within the practice period (marked in gray) the algorithm evaluated the vegetation as present while the interpretation of the Planet data indicates the vegetation was not present.

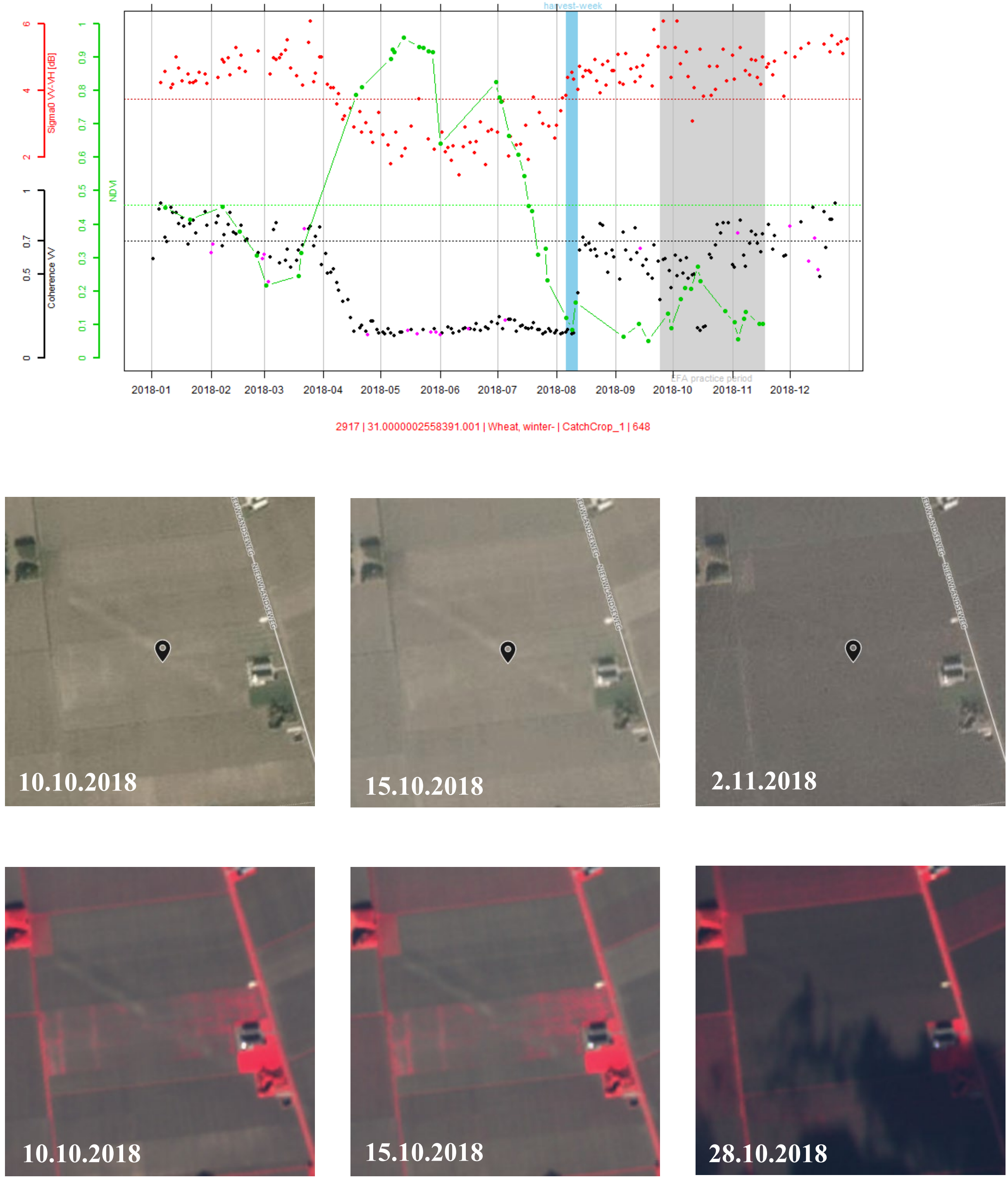


Figure 5-71. Example of the M6 false negative case. Due to low NDVI values within the practice period (marked in gray) the algorithm evaluated the vegetation as not present while the interpretation of the Planet data indicates the vegetation was present

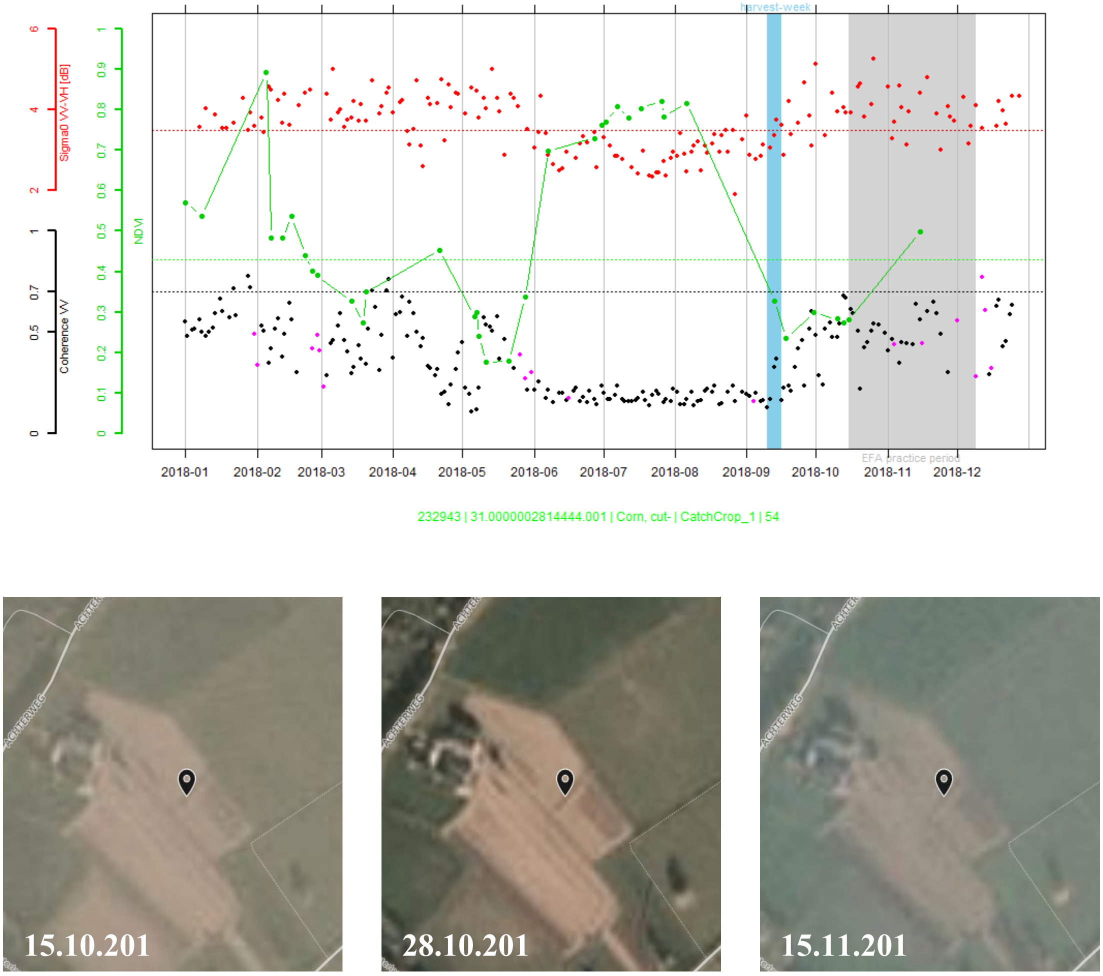


Figure 5-72. Example of the M7 false positive parcel. Due to the increase of the NDVI value detected within the practice period (marked in gray) the algorithm evaluates the vegetation as growing while the interpretation of the Planet data indicates the vegetation was not growing on the parcel.

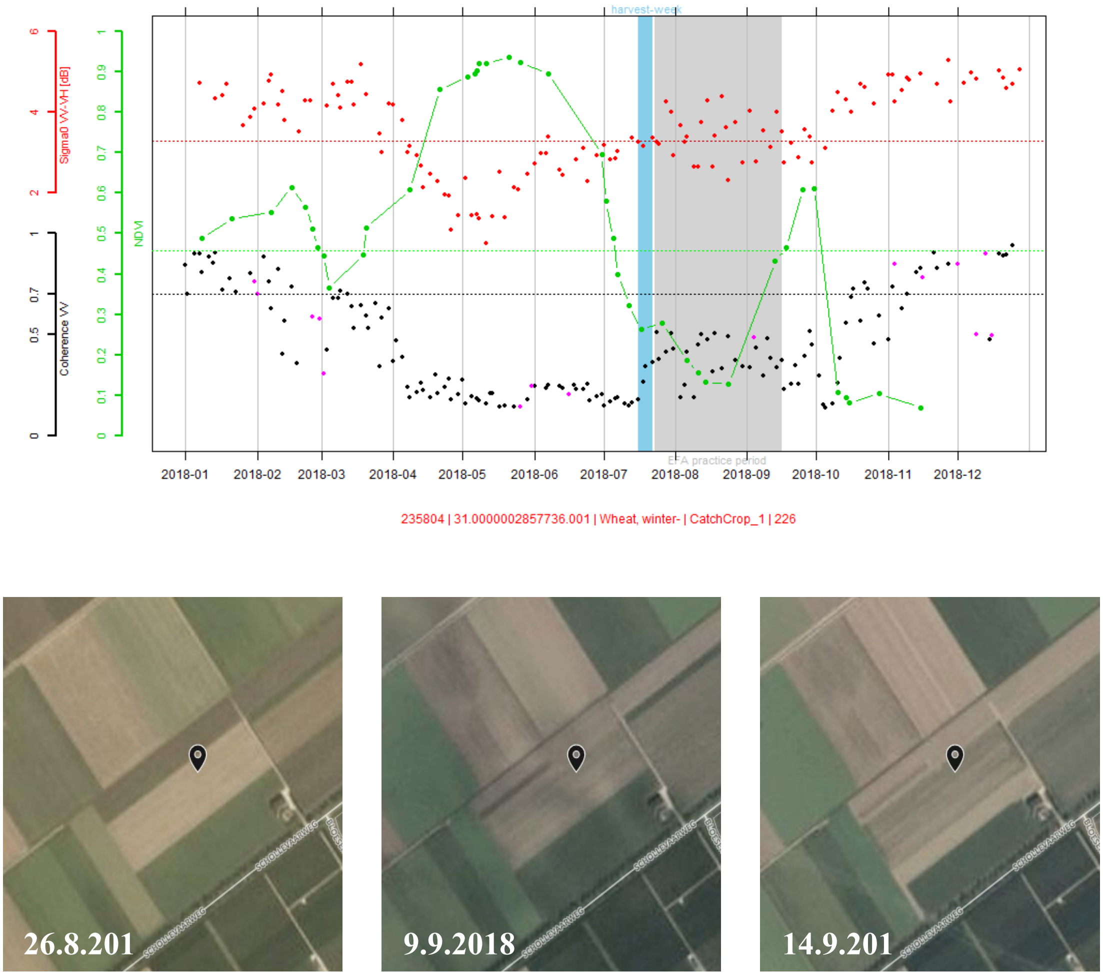


Figure 5-73. Example of the M7 false negative parcel. Due to the low NDVI values during most of the practice period (the practice period is marked in gray) the algorithm evaluates the vegetation as not growing while the interpretation of the Planet data indicates the vegetation was growing

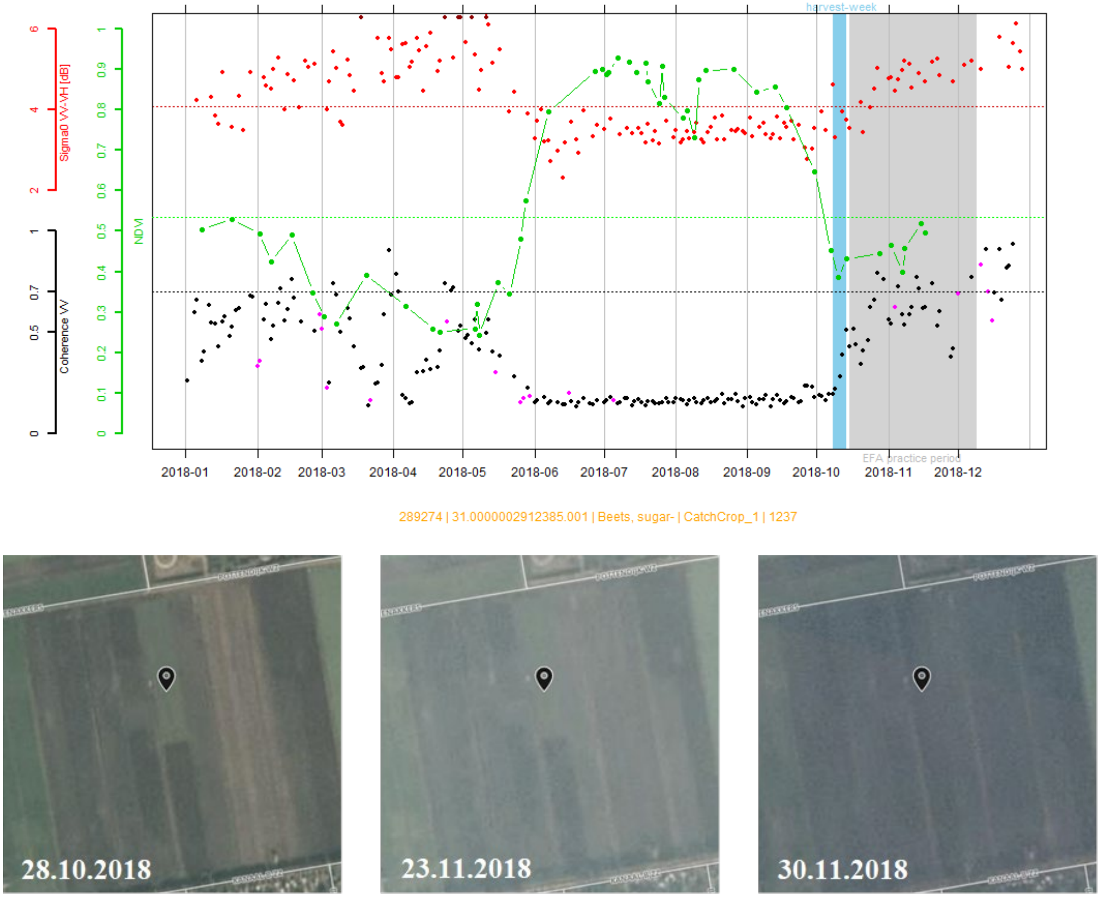


Figure 5-74. Example of the M8 false positive parcel. Due to the low NDVI values within the practice period (the practice period is marked in gray) the algorithm evaluates no loss of vegetation while the interpretation of the Planet data indicates the vegetation was lost within the practice period. The NDVI values are missing at the end of the practice period

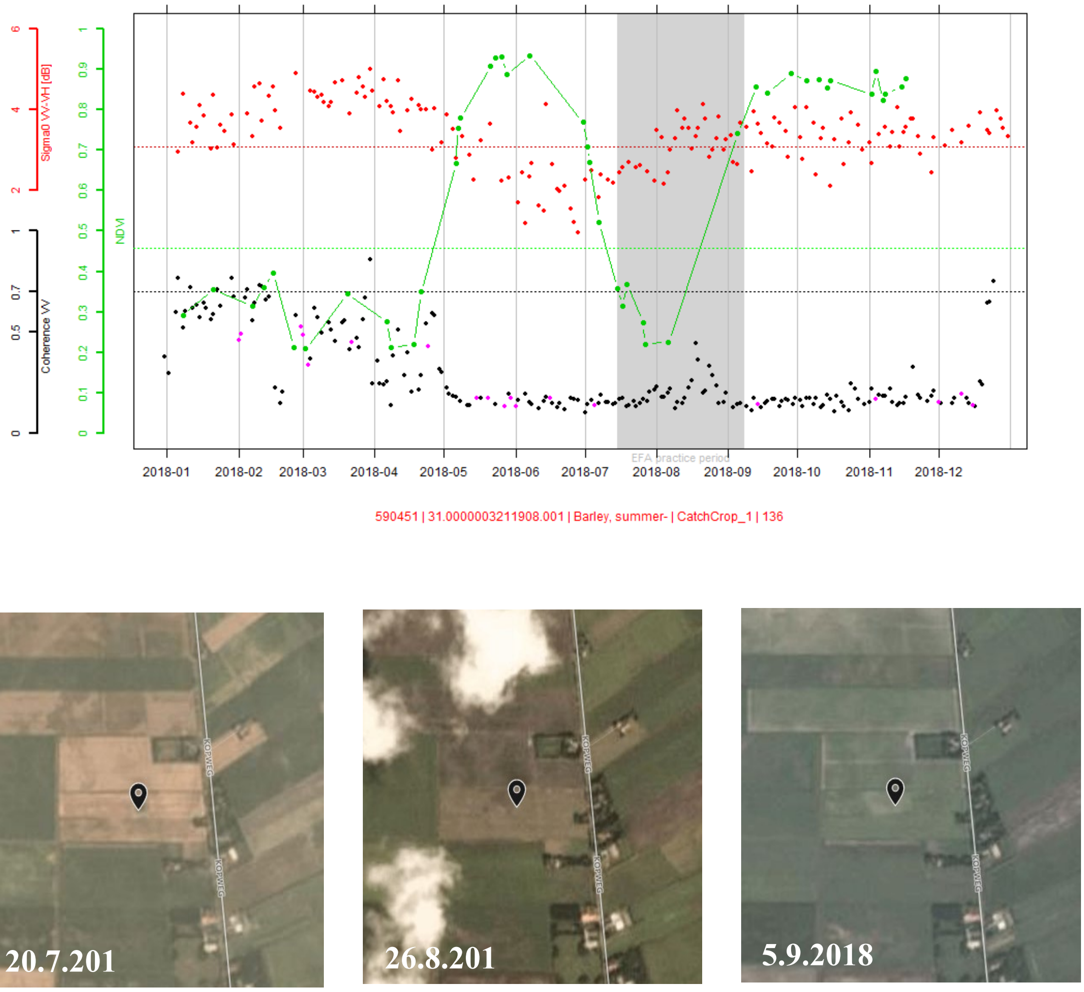


Figure 5-75. Example of the M8 false negative parcel. A decrease of NDVI values was detected in the product within the practice period (marked in gray) while the interpretation of the Planet data indicates no vegetation loss within the practice period.

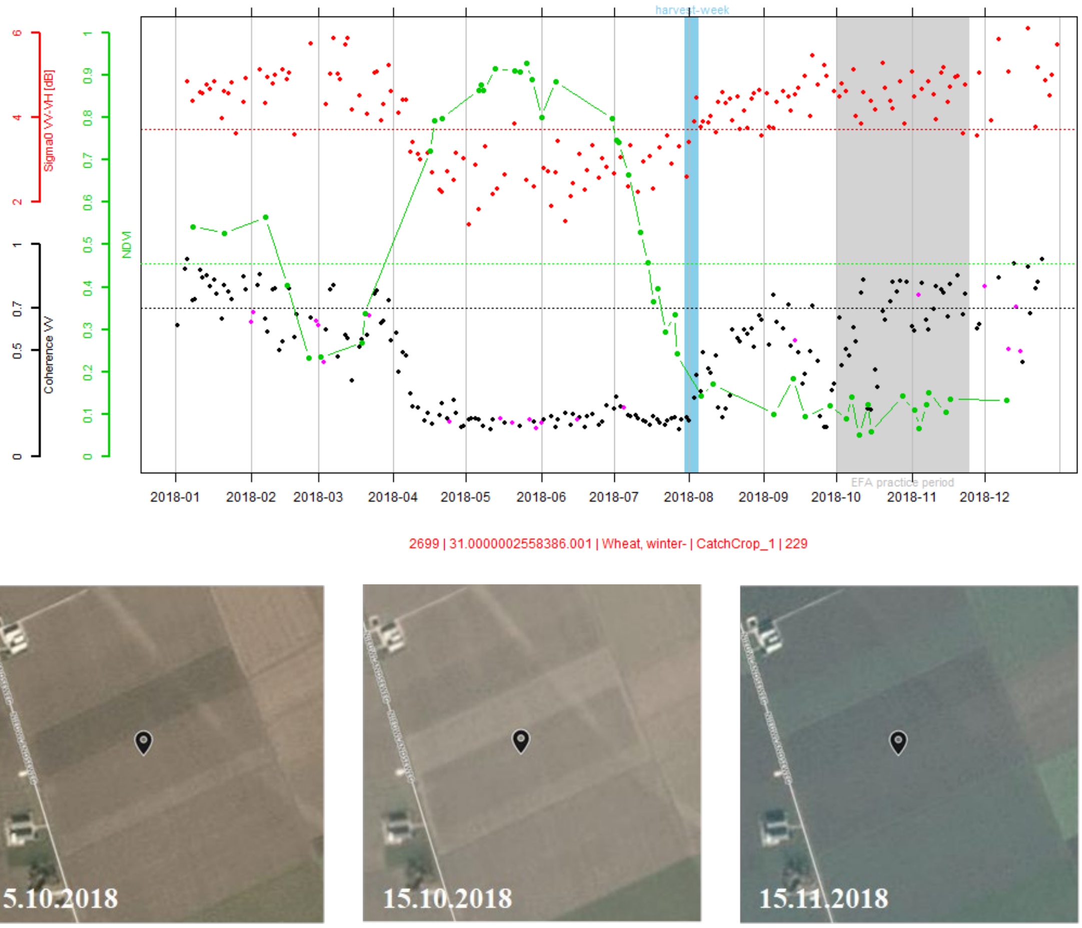


Figure 5-76. Example of the M9 false positive parcel. The SAR backscatter values are not increasing within the practice period (the practice period is marked in gray) while the interpretation of the Planet data indicates the vegetation was lost within the practice period

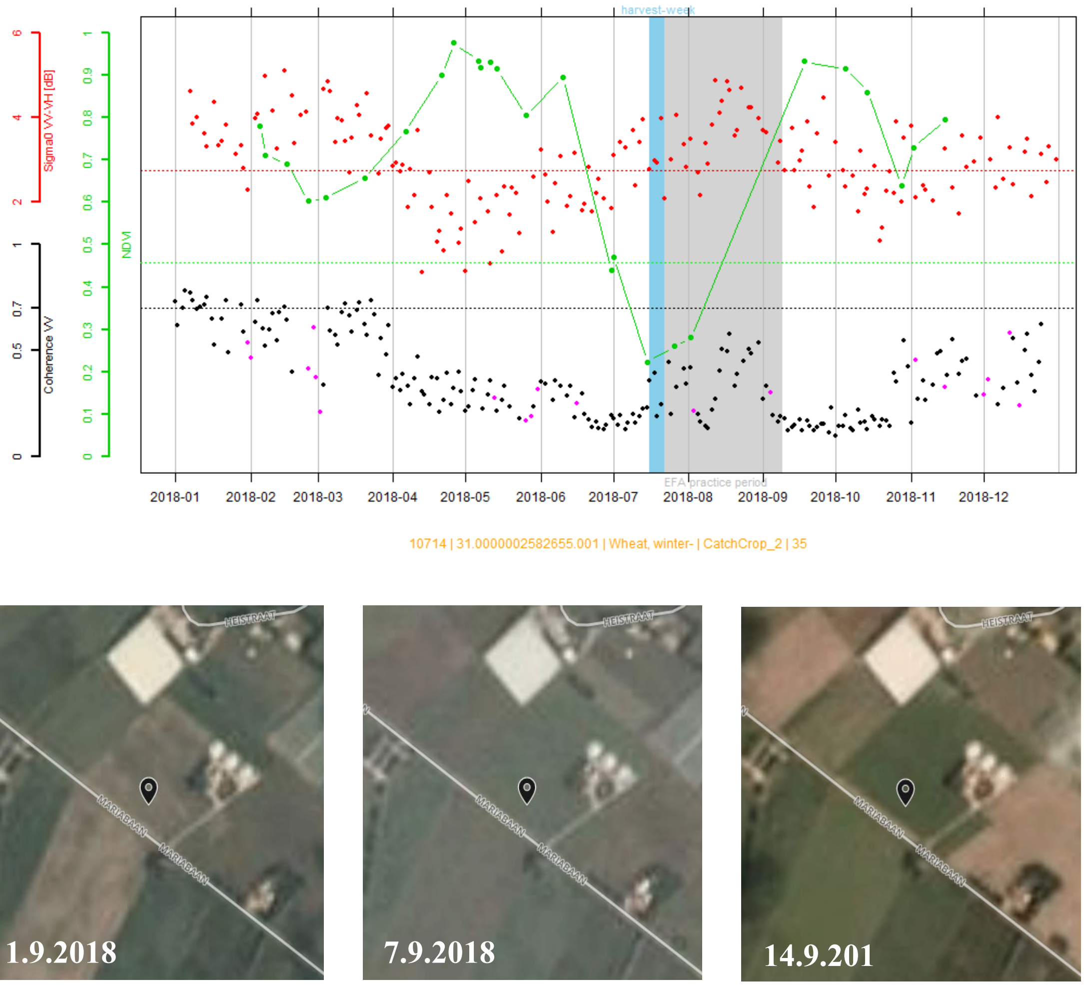
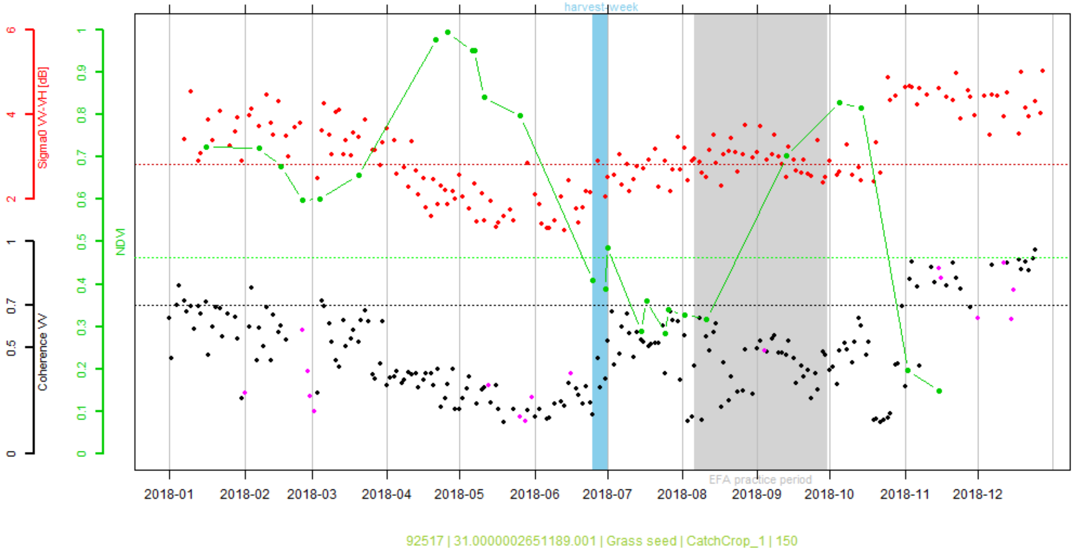
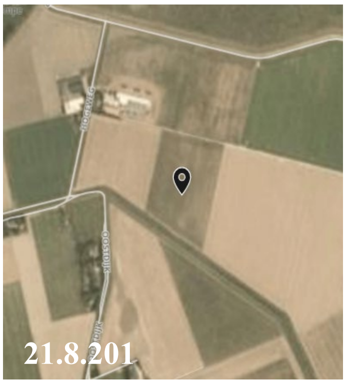
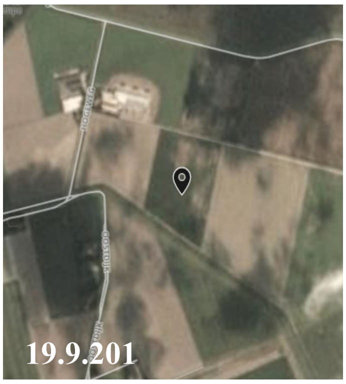


Figure 5-77. Example of the M9 false positive negative. There is an increase in the SAR backscatter values within the practice period (the practice period is marked in gray) while the interpretation of the Planet data indicates the vegetation was not lost within the practice period







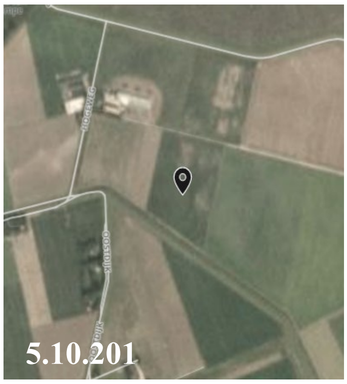


Figure 5-78. Example of the M10 false negative case. The SAR coherence values are high and increasing within the practice period (the practice period is marked in gray) while the interpretation of the Planet data indicates the vegetation was present within the practice period

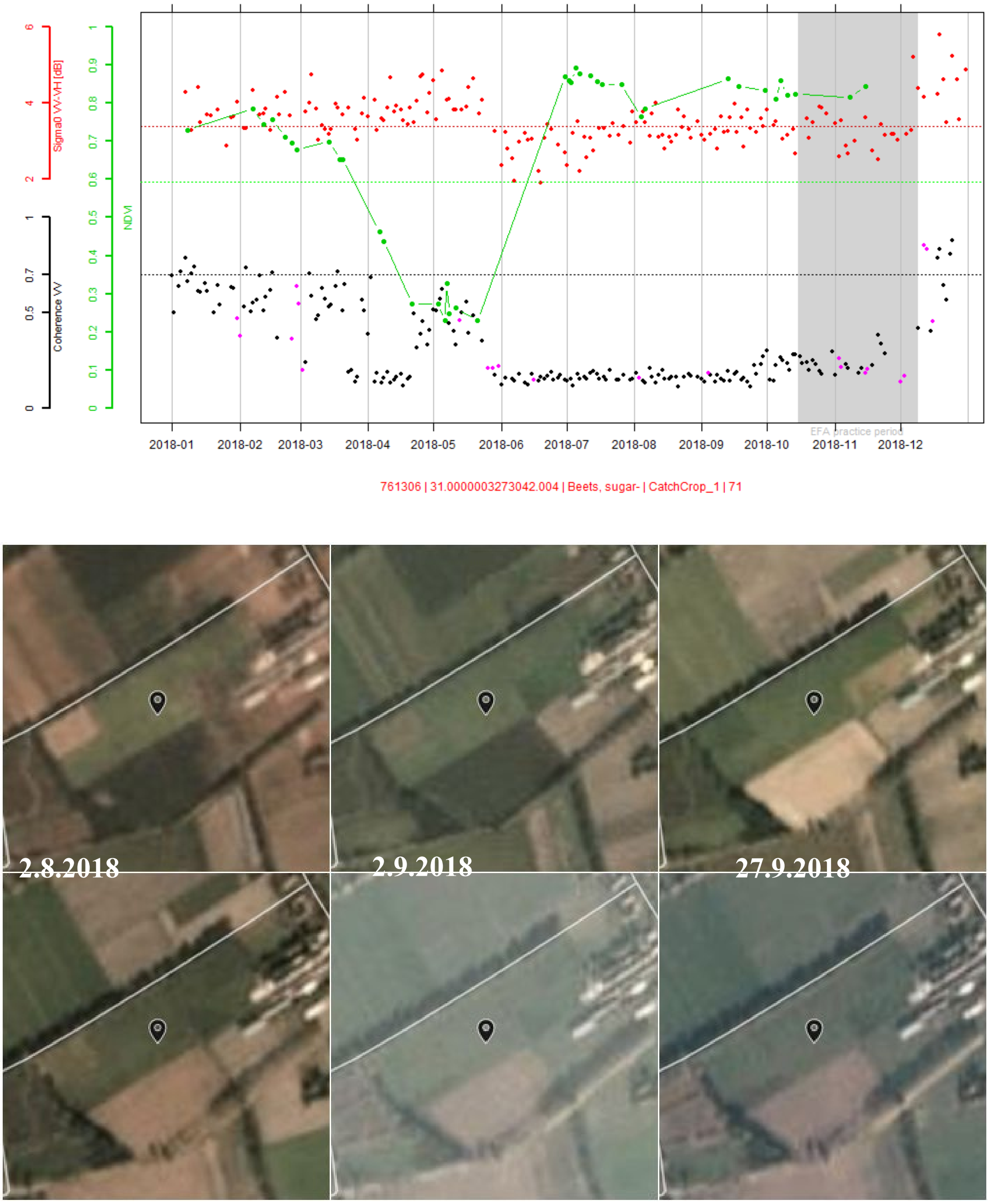


Figure 5-79. Example of a disagreement between information provided by the farmer (harvest occurred 27.8.2018) and EO data - both Sen4CAP analysis and interpretation of the Planet imagery do not indicate any harvest before the practice period (the practice period is marked in grey)

6. Quantitative validation of 2019 EO products

6.1 Biophysical indicator product

No validation dataset was available to assess the accuracy of the biophysical indicators.

6.2 Crop Type map

In the same way as for the 2018 demonstration, each L4A crop type map from 2019 was validated as required in [AD.4]. For each classification, a part of the parcels is used for the training of the classification model, while the rest of the classified parcels is used for the validation (independent validation). The validation results consist in:

- The **confusion matrix**;
- Based on the confusion matrix, the calculation of the **OA** and **Kappa values**;
- Based on the confusion matrix, for each classified crop type, the calculation of the **producer's and user's accuracy**, as well as the **F-Score**;

  The OA and Kappa value of the classification as well as the F-Score for all classified crop types sorted by area are grouped in a single dedicated illustration which was provided to the PAs with the product and which is also provided in this report;
- For the producer's and user's accuracy: **for the 15 main crops** in terms of area, the **3 crop types with which they are the most confused** (and the corresponding parcels %).

On top of that, because of the 2019 continuous (monthly) L4A crop type delivery, new validation figures, which report on **the evolution of these validation values through the season**, were computed at the end of the season.

Compared to the 2018 demonstration quantitative validation, the presentation is a bit a different: instead of presenting and analyzing all the validation results listed below, it was decided to focus on the following points:

- **Comparison with 2018 accuracy;**
- **Differences between countries**;
- **Accuracy evolution through the season**.

The results in terms of crop diversification use cases are also provided at the end.

6.2.1 Best Overall Accuracy

Table 6-1 presents the OA value obtained for all countries in 2019. The month in which the highest OA was achieved is indicated in the third column. Table 6-1 shows that for all the countries, the OA increased in 2019 compared to the 2018 demonstration.

It shall be noted that for the countries where the processing was done on distinct regions (FRA and ITA), the OA value provided in Table 6-1 is the average OA weighted by the parcels area. This is the same for Romania, which has been stratified in 6 regions classified independently.

Table 6-1. 2019 OA results and comparison with 2018

Country	Overall accuracy			
	2019	Month	2018	Compared to 2018
Spain - Castilla y León	84.80%	Aug	81.83%	2.97%
Czech Republic	91.14%	*Aug*	82.75%	8.39%
France - Ain and Normandie	92.71%	Sep	/	/
Italy - Campania, Puglia Friuli, Marche and Lazio	79.53%	Sep	72.37%	7.16%
Lithuania	88.08%	Aug	78.74%	9.34%
Netherlands	97.39%	Sep	94.95%	2.44%
Romania	75.46%	Sep	71.16%	4.30%

This increase in OA in 2019 can be explained by different factors:

- **More complete input dataset** (S1, S2 and L8 data);
- **Improvements in the S1 pre-processing**;
- **Improvements in the L4A crop type processor** (better selection and preparation of the calibration dataset);
- **Improved definition, in each country, of the L4A crop code LUTs** which make the link between the original crop code and the crop code used for the classification (with the PAs);
- **Better stratification** in the case of Romania.

However, as for the 2018 demonstration, there are still **relatively high differences between countries** (Figure 6-1). Again, different factors can explain these differences (not sorted by importance):

- **Climate**: a drier climate tends to flatten the vegetation profiles. Because of that, the differences in the satellite signal are less pronounced between the different crop types;
- **Biogeographical conditions diversity** inside the monitored region: the more the biogeographical conditions are different, the more it is difficult for the classifier to define the rules that detect each crop type and to dissociate the different crop types;
- **Agricultural practices diversity (by crop type)** inside the monitored region: the more the agricultural practices are different, the more it is difficult for the classifier to define the rules that detect each crop type and to dissociate the different crop types;
- **Proportion of dominant crops** and corresponding validation results: if a few crop types are dominant compared to the other ones and if the classification is performing well in these main crop types (what is often the case), the OA increases because, by definition, it is weighted by the number of parcels;
- **Delineation of the parcels**: the quality of the parcels' delineation affects the calculation of the features/markers by parcel and thus affects the accuracy of the classification;
- **"Purity" of the parcels**: the presence of "objects" such as trees in grassland parcels, affects the calculation of the features/markers by parcel and thus affects the accuracy of the classification;

- **L4A crop code LUT**: even if a same "level" of crop type grouping was applied for the classification in the different countries, the L4A crop code LUTs do not match perfectly between countries. For example, the fodder crops were grouped together in some countries but not in all; this affects the classification accuracy.

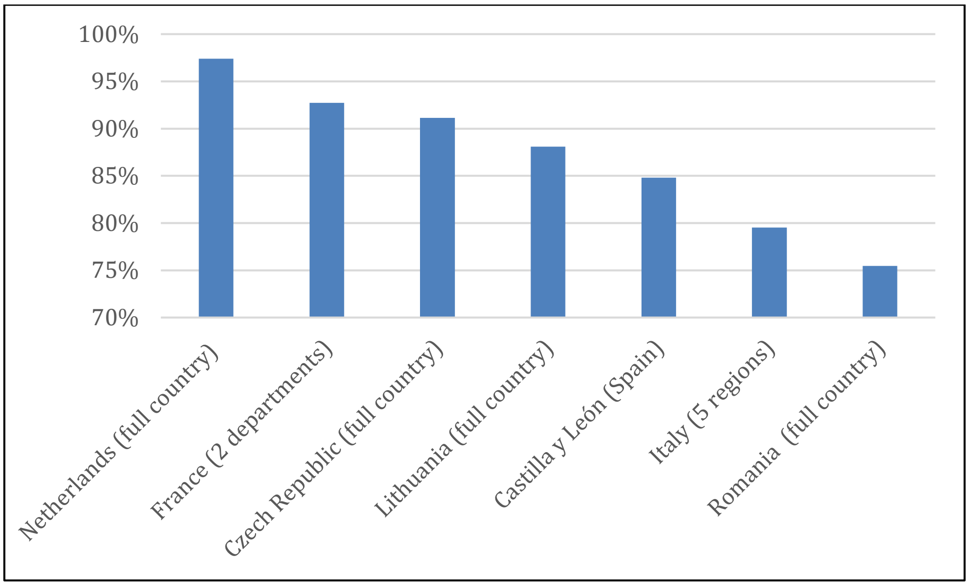


Figure 6-1. 2019 OA results: comparison between countries

6.2.2 Accuracy evolution along the season

Figure 6-2 presents the OA evolution along the season in the different countries.

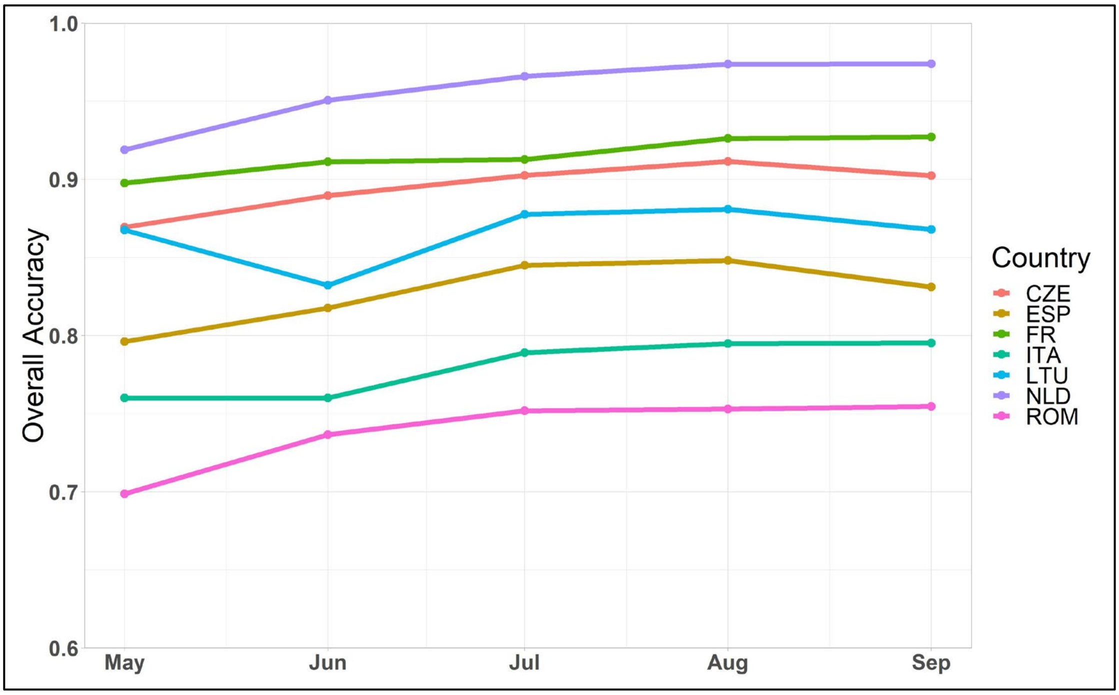


Figure 6-2. 2019 OA evolution along the season (by country)

It can be seen that:

- **OA reaches a kind of plateau in July, and continues to slightly increase until August in all countries**, except in Lithuania. In Lithuania, the uncommon high OA value in May is due to the fact that the results from May were derived over only 25% of the parcels (the ones available at that time), while the subsequent results (from June) were obtained over all the parcels. From June, the same continuous increase until August can be observed;
- **In France, Italy, the Netherlands and Romania, the OA still slightly increases in September**;
- **In Castilla y Leon, Czech Republic and Lithuania, the OA decreases from August to September**. This decrease can be explained by the fact that some crop types have been harvested in September and that different agricultural practices are applied after the harvest. Because of that, the classifier has more difficulties to distinguish between the different crop types;
- Already in **June**, **5** (on the 7) **monitored countries** have an **OA above 0.8**, and **2 above 0.9**.

The OA evolution through the season is driven by the accuracy evolution of the different crop types.

For each country, the evolution along the season of the **F-Score of the main crop types** was analyzed. The main crop types were selected as the ones that count for more than 1% of the parcels in the validation dataset.

These results by countries are provided from Figure 6-3 to Figure 6-12. In the countries where more than 2 classifications were processed by processing date (Italy, 5 regions, and Romania, 6 strata), the results are shown only for 2 regions/strata to avoid redundancy. These regions/strata were selected because of their differences in terms of biogeographical conditions and agriculture. In Italy, the regions of Friuli, from the North, and Puglia, from the Center-South, were selected. In Romania, the Western and Eastern strata were selected.

Because of the differences in the crop types nomenclature and the L4A crop code LUT among the countries, it was not possible to generalize the observations. This information can be used by each PA to understand the results and improve the classifications accuracy. In particular, the following elements should be looked at:

- The general **F-Score differences between the crop types**;
- The crop types that show a **substantial F-Score increase through the season**;
- The crop types that show a **F-Score decrease at the end of the season**.

Some notable features are identified here below:

- Logically, summer crops accuracy increases later than the one from winter crops;
- Oat is classified with a lower performance in several countries (CyL, CZE, ITA, ROU);
- Logically, fallow land is a class which has been challenging to map (FRA, ITA, ROU).

- The low accuracy of “maïs” in France: this crop should have been grouped with the “maïs – ensilage” one as it is the main crop (the distinction is only related to the use of the crop).

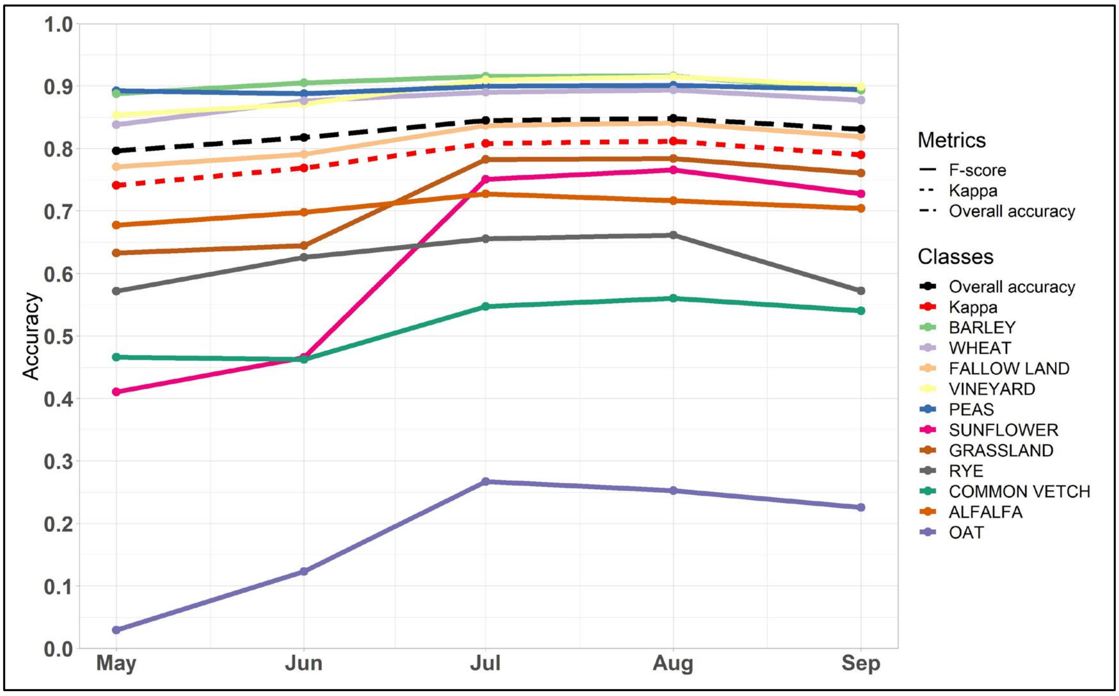


Figure 6-3. Main crops F-Score evolution along the season in CyL 2019

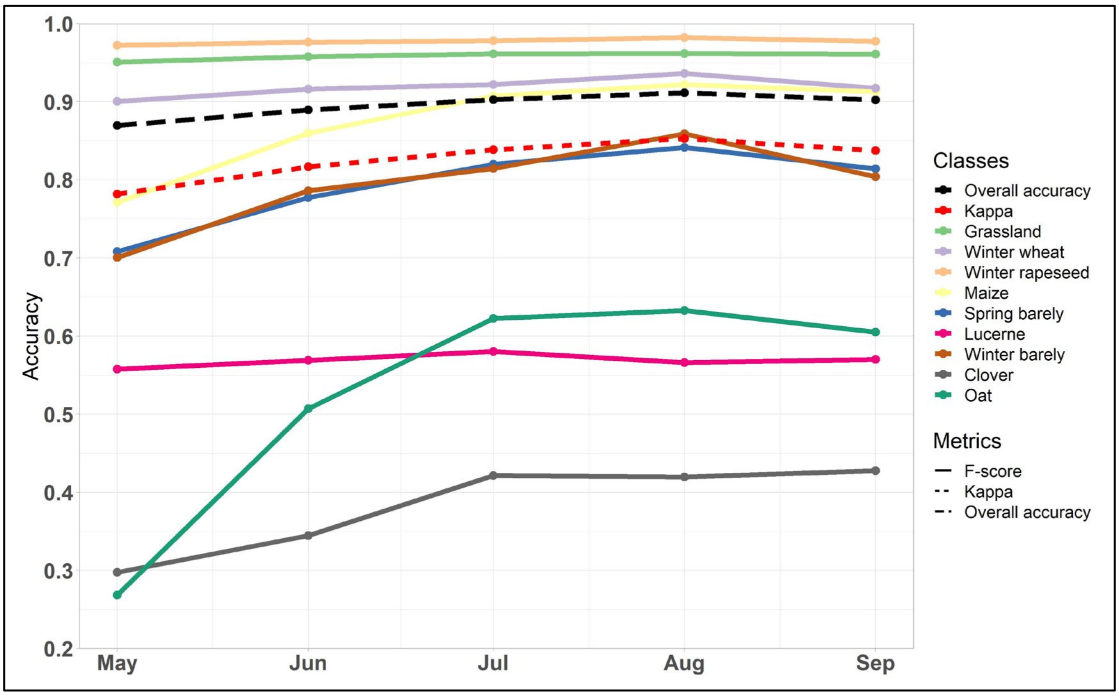


Figure 6-4. Main crops F-Score evolution along the season in CZE 2019

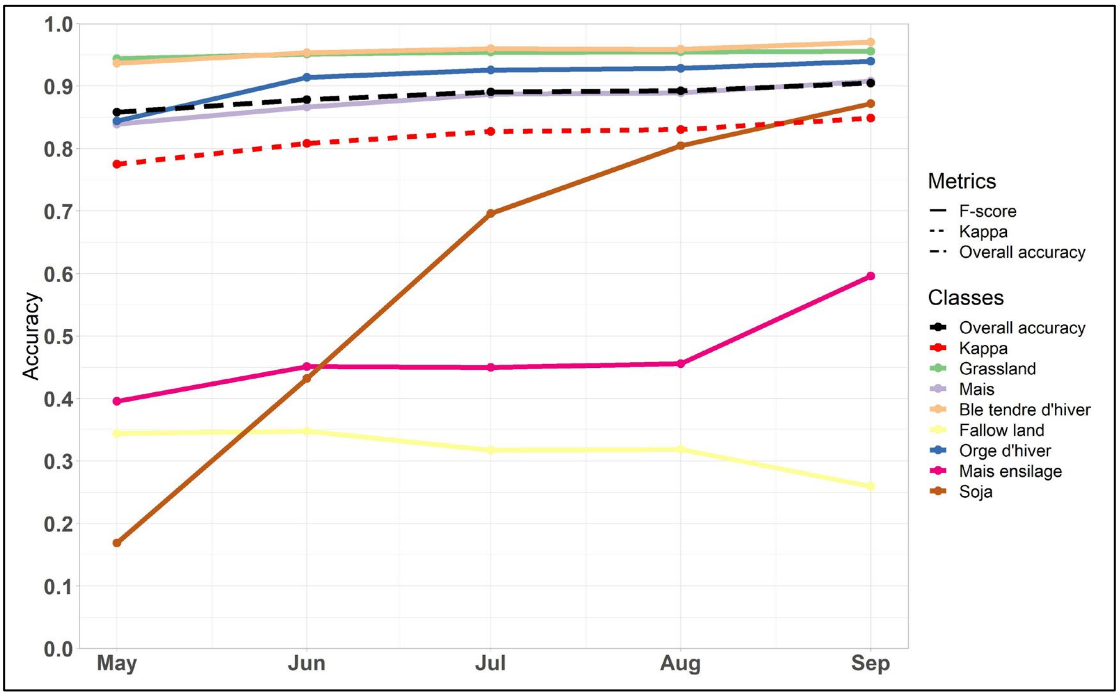


Figure 6-5. Main crops F-Score evolution along the season in Ain (FRA) 2019

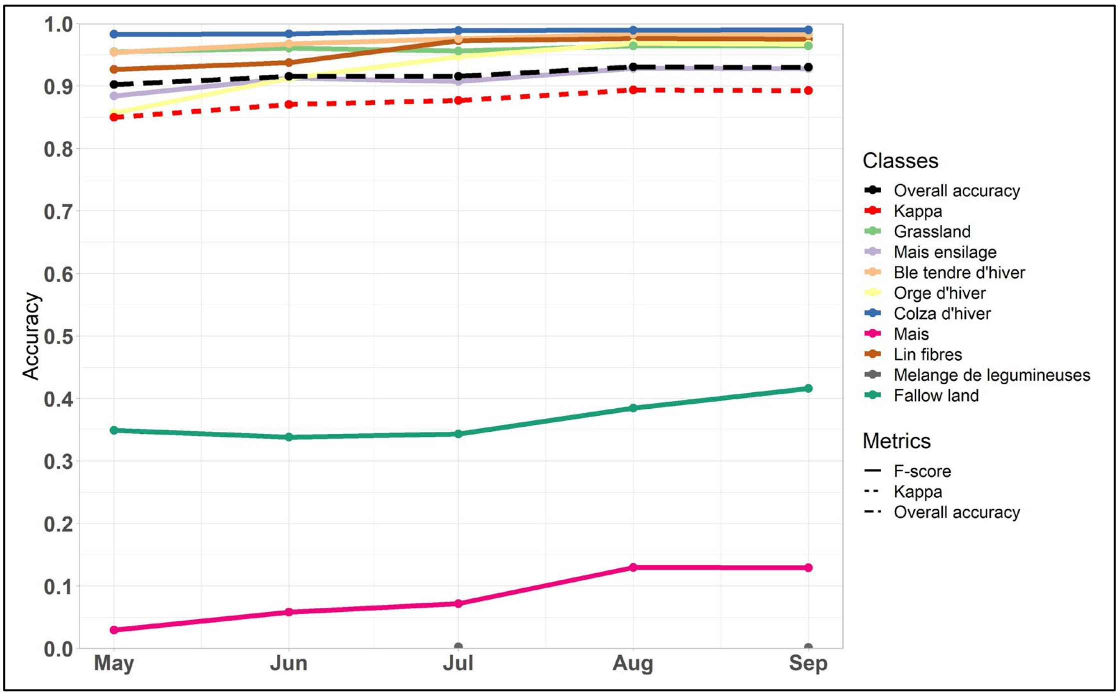


Figure 6-6. Main crops F-Score evolution along the season in Normandie (FRA) 2019

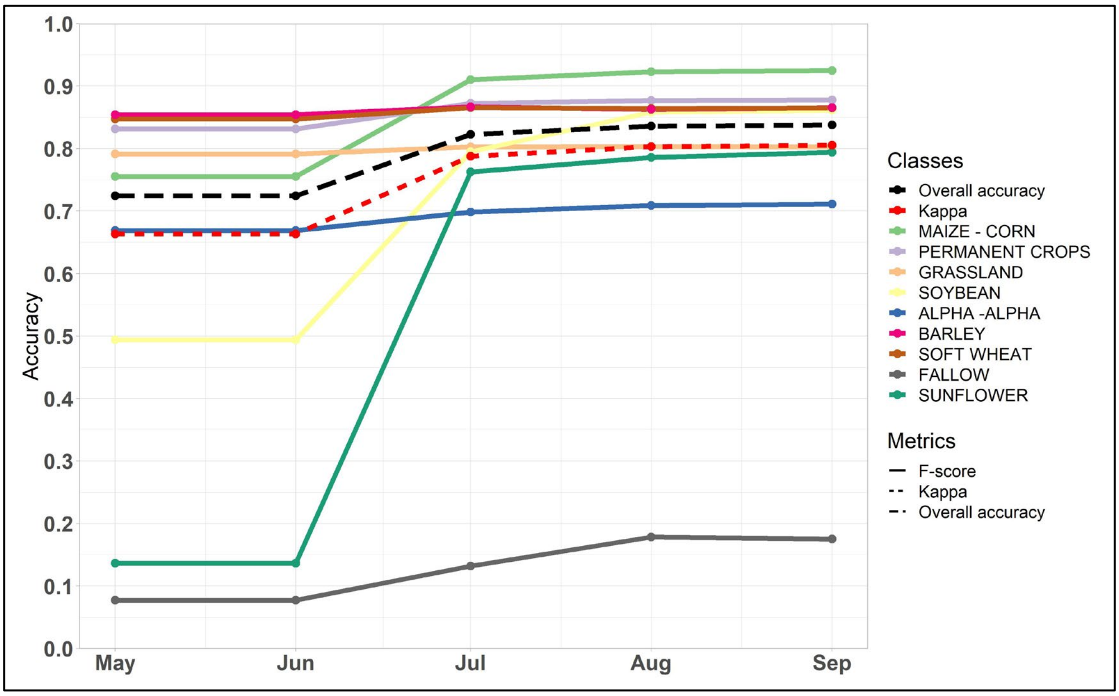


Figure 6-7. Main crops F-Score evolution along the season in Friuli (ITA) 2019

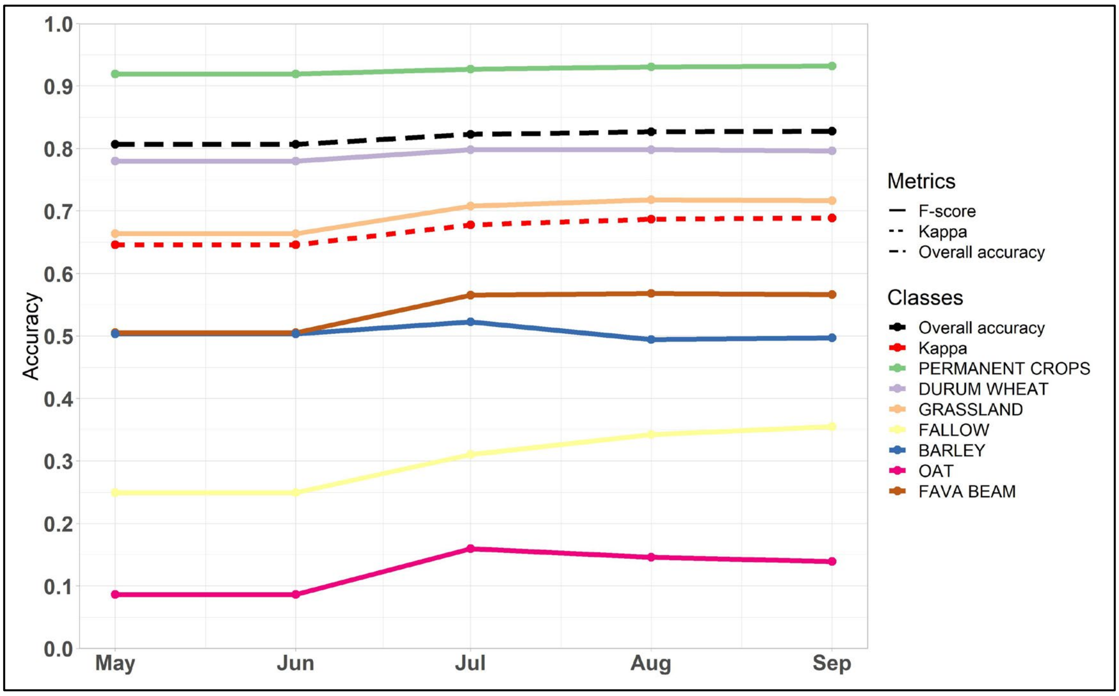


Figure 6-8. Main crops F-Score evolution along the season in Puglia (ITA) 2019

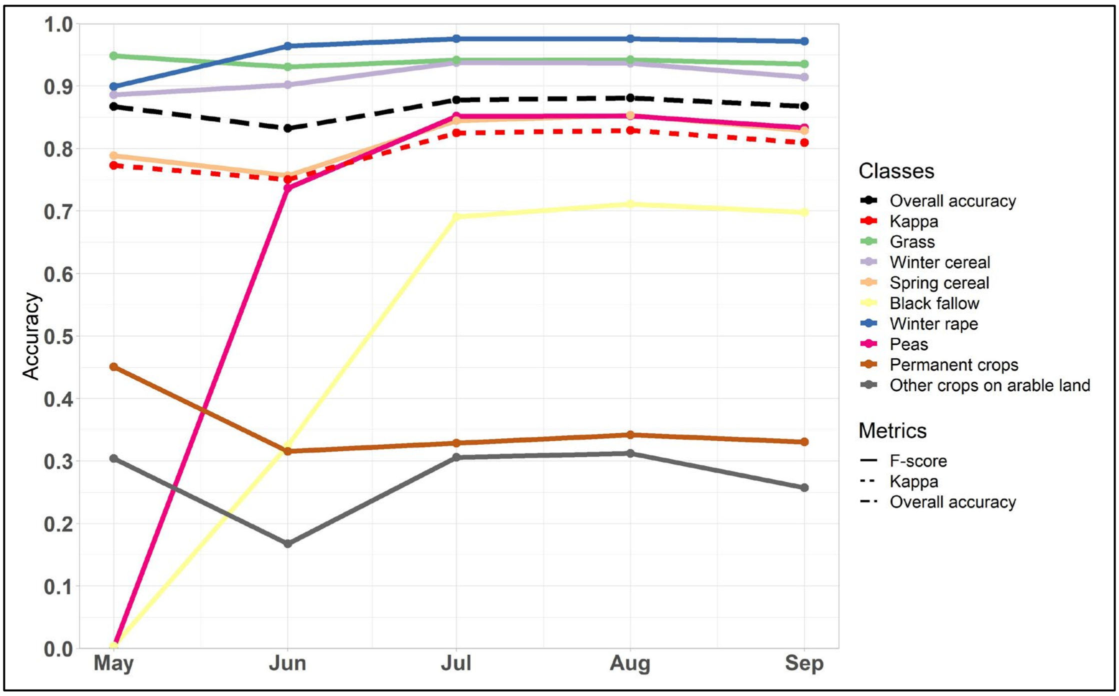


Figure 6-9. Main crops F-Score evolution along the season in LTU 2019

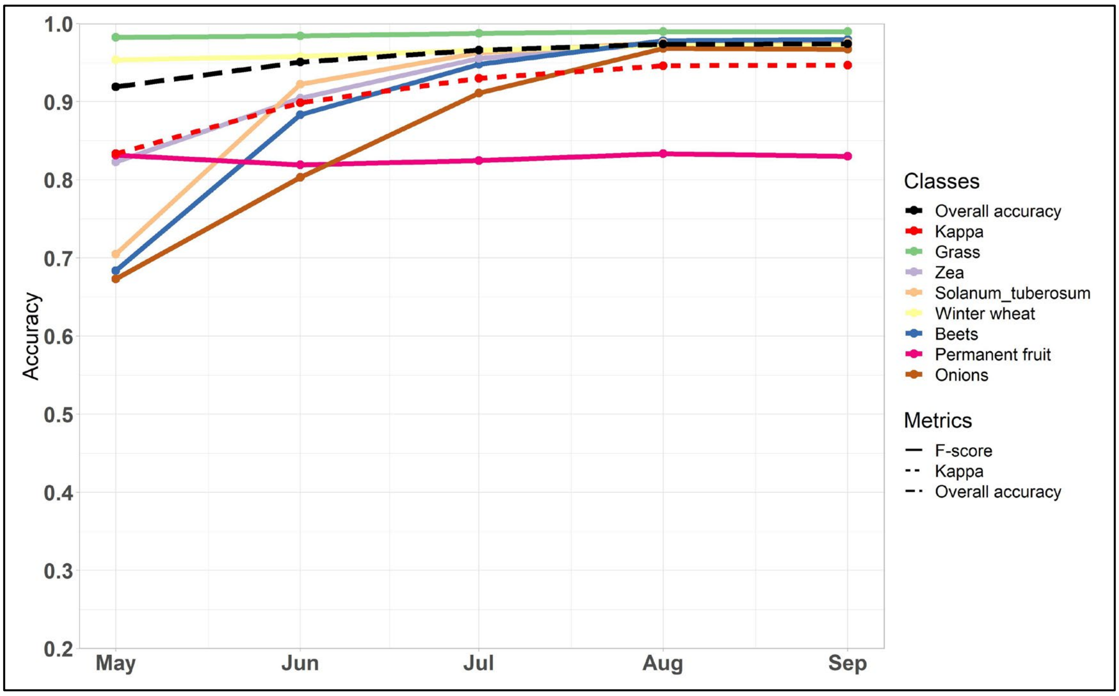


Figure 6-10. Main crops F-Score evolution along the season in NLD 2019

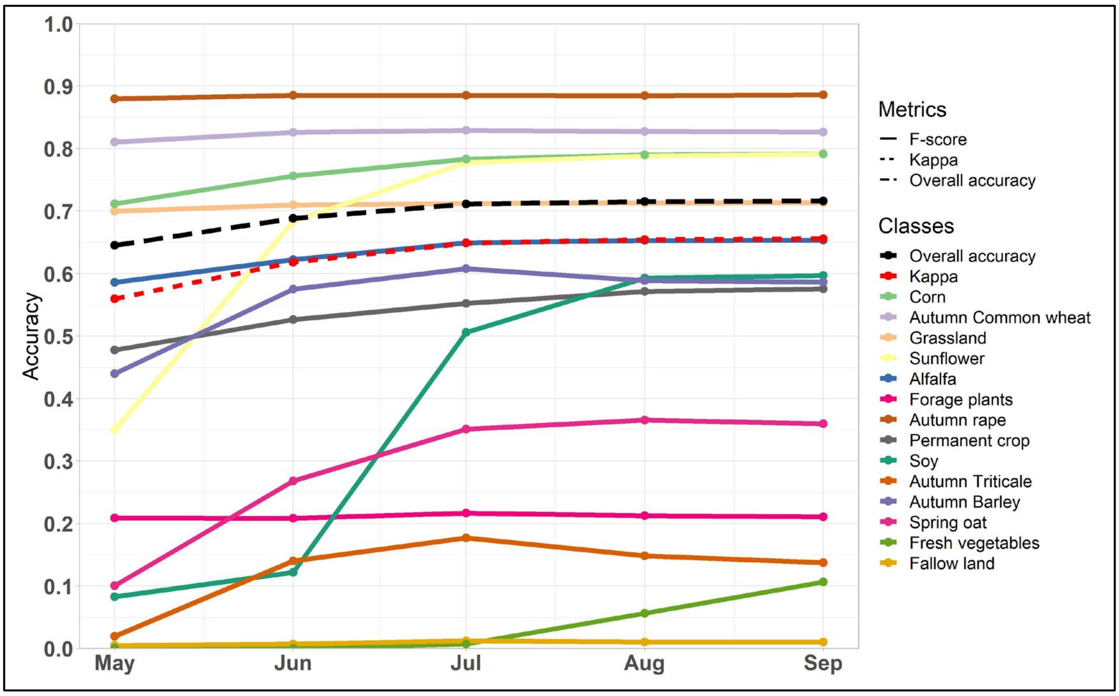


Figure 6-11. Main crops F-Score evolution along the season in ROU (Western) 2019

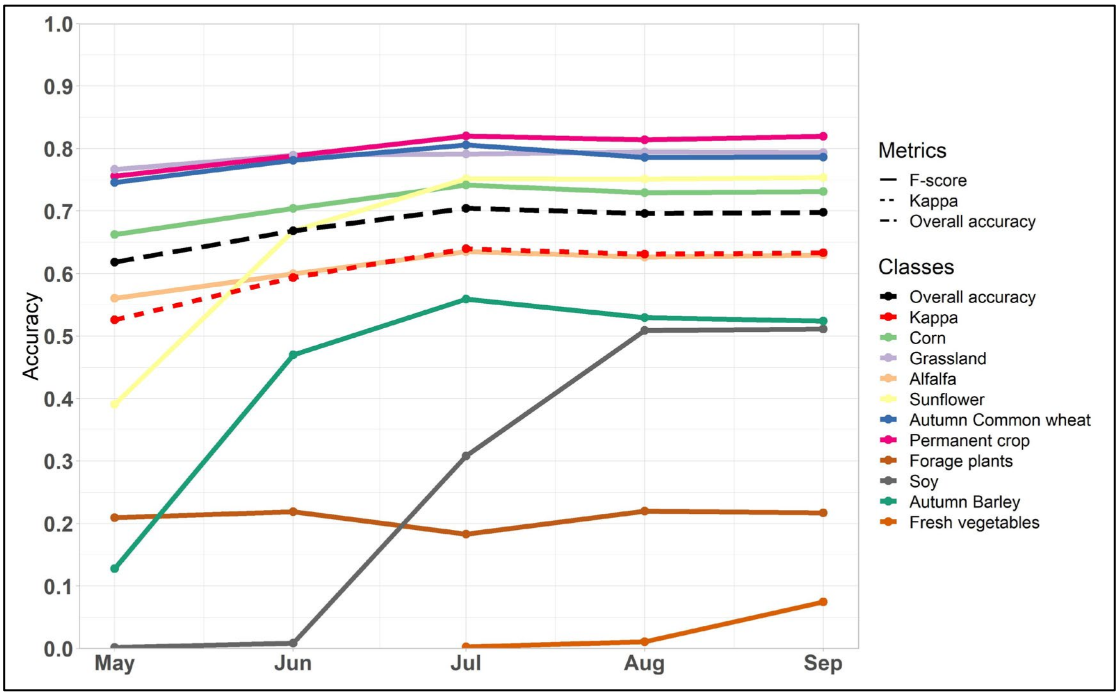


Figure 6-12. Main crops F-Score evolution along the season in ROU (Eastern) 2019

6.2.3 Crop diversification use case

6.2.3.1 Conformity assessment at the parcel level

The classification results are first used at the parcel-level, to make a **conformity assessment regarding the crop declarations**. Table 6-2 and Table 6-3 show the conformity assessment results in the 7 countries, in terms of **number of parcels** and

parcels area, respectively. These results are also represented in Figure 6-13, with a focus on the not classified parcels. The country results correspond to the version of the product that shows the best classification accuracy (August or September depending on the country).

Table 6-2. Conformity assessment results at the parcel level (number of parcels)

Nr of parcels	ESP	CZE	FR	ITA	LTU	NLD	ROM
Classified and conform	76.26%	87.42%	86.05%	26.88%	73.90%	80.33%	58.23%
Classified and not conform	4.32%	3.36%	1.68%	1.98%	3.93%	0.84%	6.75%
Not classified	19.42%	9.22%	12.27%	71.14%	22.17%	18.83%	35.01%

Table 6-3. Conformity assessment results at the parcel level (parcels area)

Parcels area	ESP	CZE	FR	ITA	LTU	NLD	ROM
Classified and conform	94.62%	96.77%	97.82%	75.43%	93.38%	93.82%	87.52%
Classified and not conform	3.21%	2.58%	1.12%	5.76%	3.19%	0.73%	4.56%
Not classified	2.17%	0.64%	1.06%	18.81%	3.43%	5.45%	7.92%

Regarding these results, **two main questions** were addressed:

1) Which countries do show a relatively high part of not classified parcels and why?
2) Is there a difference in the size distribution of the parcels that are classified as conform and not conform?

Figure 6-13. 2019 conformity assessment results

- **Reasons for not-classified parcels**

While in terms of number of parcels, the part of not classified parcels is high in some countries (Table 6-4), this part is **considerably reduced in terms of parcels area** (Table 6-5). However, 3 countries have more than 5% of the parcels area which is not classified: Italy (18.81%), Romania (7.92%) and The Nertherlands (5.45%). Table 6-5 shows that this is due mainly to parcels that are not classified because their land cover cannot be monitored by remote sensing (Italy and The Netherlands) and/or because of their size or shape (Italy and Romania). Size and shape refer to small and/or elongated parcels which don't cover at least 3 S2 pixels (in red in the table) or which are covered by 3 S2 pixels but not by any S1 pixel (in orange in the table). If desired, these last parcels (in orange) can be classified using only the S2 markers, which might strongly reduce the percentage of not classified parcels because of their size or shape.

Table 6-4. Aggregated conformity assessment results at the parcel level (number of parcels)

Nr of parcels	ESP	CZE	FR	ITA	LTU	NLD	ROM
Classified	80.58%	90.78%	87.73%	28.86%	77.83%	81.17%	64.99%
Not classified	19.42%	9.22%	12.27%	71.14%	22.17%	18.83%	35.01%
-> Land cover	1.17%	0.00%	4.24%	38.00%	3.12%	8.86%	0.39%
-> Size or shape	16.37%	8.86%	7.77%	33.10%	18.12%	9.16%	34.59%
Not 3 S2 pixels	8.38%	2.86%	4.81%	24.18%	6.83%	4.69%	9.73%
Not 1 S1 pixel	7.99%	6.00%	2.96%	8.92%	11.29%	4.47%	24.86%
-> Other	1.88%	0.36%	0.25%	0.04%	0.93%	0.81%	0.03%

Table 6-5. Aggregated conformity assessment results at the parcel level (parcels area)

Parcels area	ESP	CZE	FR	ITA	LTU	NLD	ROM
Classified	97.83%	99.36%	98.94%	81.19%	96.57%	94.55%	92.08%
Not classified	2.17%	0.64%	1.06%	**18.81%**	3.43%	**5.45%**	**7.92%**
-> Land cover	0.05%	0.00%	0.42%	**13.51%**	1.45%	**3.72%**	0.05%
-> Size or shape	0.75%	0.40%	0.43%	**5.17%**	1.30%	0.94%	**7.81%**
Not 3 S2 pixels	0.19%	0.07%	0.20%	1.84%	0.26%	0.28%	1.39%
Not 1 S1 pixel	0.56%	0.34%	0.24%	3.33%	1.03%	0.66%	6.42%
-> Other	1.37%	0.24%	0.21%	0.12%	0.68%	0.78%	0.06%

- **Not classified parcels due to "land cover"**

Most land cover types that are not monitored in **Italy** (Table 6-6) are **not included in the definition of Eligible Agricultural Area (EAA)**: woodland, artifact, non-agricultural use, etc. It also includes a class named "Arable land" which is too broad in terms of definition to be included in the classifications. Finally, the "Greenhouse" class is quite negligible (only 0.46%). It has to be noted that even if these crop types are not classified, if they are defined as EAA in the L4A crop code LUT, they are included in the crop diversification assessment at the holding-level.

Table 6-6. Not monitored land cover types in ITA 2019

Crop type	Area
Woodland	55.82%
Artifact	15.50%
Arable land	15.05%
Non-agricultural use with tare	4.06%
Non-agricultural use	3.05%
Not agronomic area	2.68%
Alberate hedges and bands	1.08%
Greenhouse	0.46%
Tree group	0.38%
Other	1.92%

In **The Netherlands**, like in Italy, most of the land cover types that are not monitored (Table 6-7) are **not included in the definition of EAA**: natural areas, forest, parks, etc.

Table 6-7. Not monitored land cover tyes in NLD 2019

Crop type	Area
Nature areas (incl. Heath)	54.73%
Forest permanent with reproductive duty	8.22%
lane / park trees settlers open ground	4.30%
Forest and hay plants open ground	3.56%
Ornamental conifers open ground	3.44%
Forest without reproductive duty	2.36%
Ornamental gardens and climbing plants open ground	1.72%
Water other	1.60%
Solid plants open ground	1.54%
Other	18.52%

As a conclusion, in these 2 countries, the relatively high part of not classified parcels is explained (only partly in the case of Italy) by the fact that the parcels dataset include more parcels declarations (in terms of number of parcels and parcels area) of land cover types that do not need to be monitored in CAP framework.

- **Not classified parcels due to their size or shape**

Concerning the parcels that are not classified because of their size or shape, there is a big difference in **size distribution** between Italy and Romania (Figure 6-14). In **Italy**, most parcels are very small, with an area below 0.25 ha. In **Romania**, most of the parcels are larger, with an area between 0.25 and 0.5 ha, while one half of the remaining parcels are below 0.25 ha and the other half are above 0.5 ha. It shows that, on top of the size, the **shape of the parcels** also plays a role in Romania. Indeed, some regions in Romania are characterized by many narrow and elongated parcels. This conclusion confirmed by the relatively high part of parcels that are not classified because of the missing number of S1 pixels (20-m wide), instead of the number of S2 pixels which are only 10-m wide (Table 6-4 and Table 6-5).

As already mentioned, the number of not-classified parcels because of their size or shape can be **significantly reduced** by performing a second classification based only on the S2 markers. The results of this second classification are used only to monitor the parcels that are covered by the minimum number of S2 pixels (3), but that are not covered by any S1 pixel. It enables to reduce the part of the not classified parcels because of their size or shape from **5.17% to 1.82% in Italy**, and **from 7.81% to 1.39% in Romania**, in terms of parcels area (Table 6-5Table 6-3). The only drawback is the classification accuracy of this second classification, which can be lower because of the non-use of S1 markers.

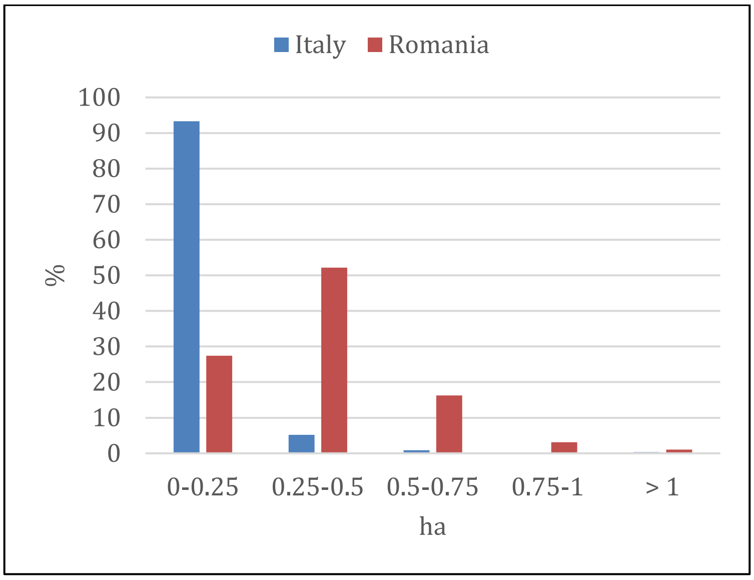


Figure 6-14. Size distribution of the not classified parcels because of their size or shape, in Italy and Romania

- **Classified parcels size distribution**

Except in Czech Republic and Italy, the **parcels size distributions between conform and not conform parcels are different** (Figure 6-15). Not conform parcels count a higher proportion of small parcels, while conform parcels count a higher proportion of big parcels. This tendency is the strongest in France and Romania. In Castilla y Leon, not conform parcels account for a higher proportion in both small and big parcels.

Figure 6-15. Size distribution of the conform (in green) and not conform (in red) parcels in the seven countries in 2019

6.2.3.2 Crop diversification assessment

The classification results and conformity assessment results at the parcel-level are used to assess the compliancy of the holdings regarding crop diversification rules. This is done in two steps: **first, the category of the holding** is defined; **second, the compliancy of the holding** regarding the rules that correspond to this category is assessed. Figure 6-16 and Figure 6-17 show the results of the crop diversification assessment corresponding to the version of the crop type map that shows for each country the best classification accuracy (August or September depending on the country). Castilla y Leon is not part of these results because the PA was not interested in this use case.

Regarding the crop diversification assessment, a **part of the holdings cannot be assessed** because we apply the worst-case scenario following the JRC guidelines. This scenario assumes the worst case for all parcels where we don't know, i.e. not-classified parcels and parcels classified but no conform. This proportion of holding where the assessment cannot be done with EO outputs is a **key indicator for the PAs**. In 2019, this part of "Missing_info" holdings is between 2.31 and 4.50% (Table 6-8), which is a significant improvement with respect to 2018. Even if more crop diversification rules were added in 2019 (which makes it harder to give an assessment), this part is reduced compared to 2018 in Czech Republic, Italy and Romania, driven by the classification accuracy improvements.

Table 6-8 Not assessed holdings for crop diversification because of lack of information: 2019 results and comparison with 2018

Country	Not assessed holdings because of lack of information		
	2019	2018	Compared to 2018
Spain - Castilla y León	/	3.16%	/
Czech Republic	4.50%	14.50%	-10.00%
France - Ain and Normandie	2.88%	/	/
Italy - Campania, Puglia Friuli, Marche and Lazio	3.82%	6.63%	-2.81%
Lithuania	3.50%	1.80%	1.70%
Netherlands	4.22%	1.27%	2.95%
Romania	2.31%	4.86%	-2.55%

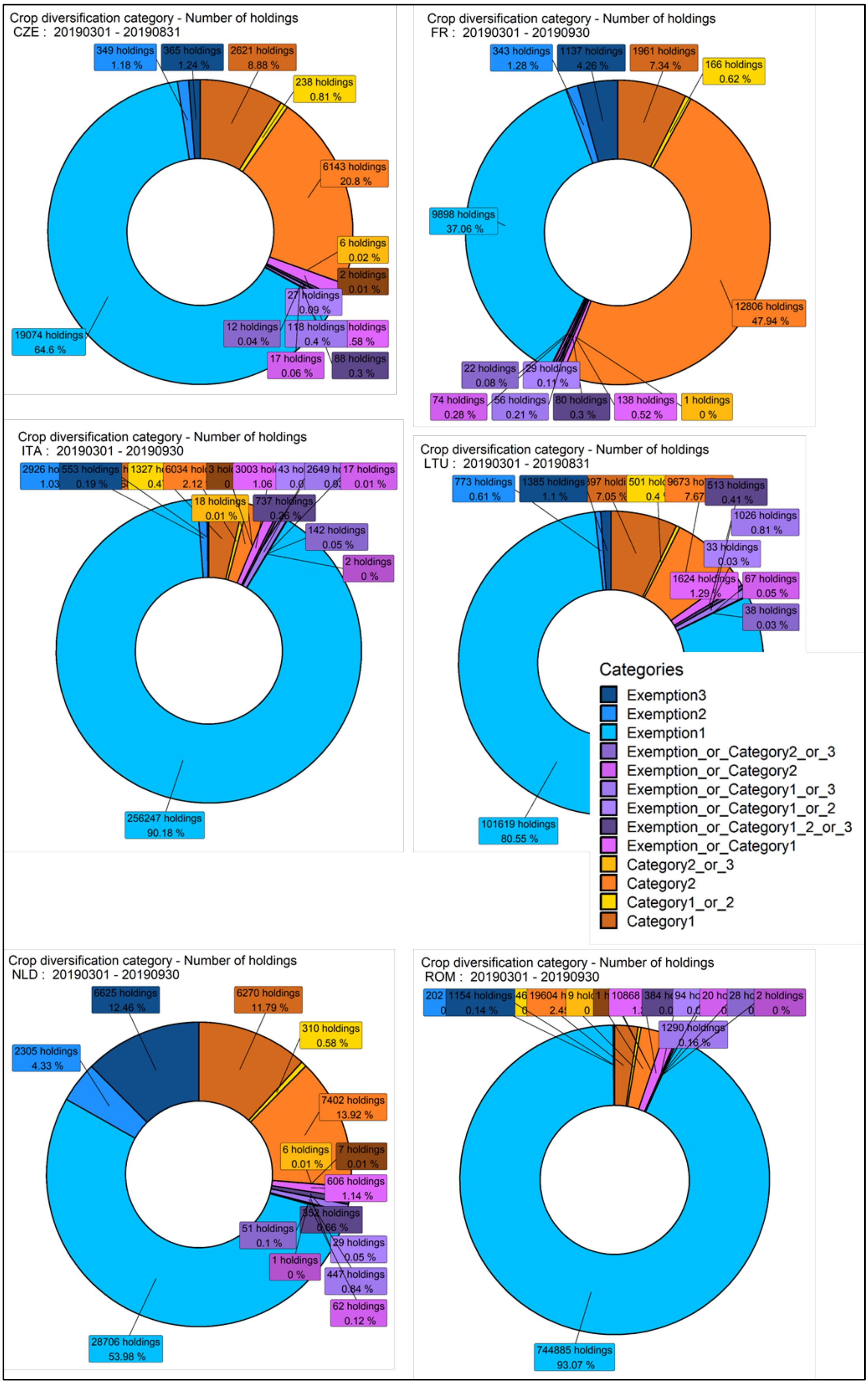


Figure 6-16. 2019 crop diversification category results

Figure 6-17. 2019 crop diversification assessment results

6.3 Grassland Mowing detection product

The 2019 products were validated using datasets coming from Planet data interpretation as explained in Section 3.3. A further validation based on the farmer interviews will be included in the Exploitation Report. The methodology followed for this validation is explained below. The results are then presented country by country.

1) Validation datasets preparation

For each country, a sample of parcels has been randomly selected in order to be statistically representative of national grassland parcels characteristics. To this end, a preliminary analysis has been performed to characterize the grassland parcels distribution in terms of (i) crop type and (ii) parcel size as described in Section 5.3.

The parcels to be visually interpreted on the Planet dataset have been chosen according to the following criteria:

- Selection of a number of parcels ranging **from 100 to 200 parcels**;
- Parcels selection **following the crop type national distribution**, with a **minimum of five parcels per crop type**.;
- Parcels selection **uniformly distributed within the 5 classes of size** (< 0.5 ha, 0.5 ha - 1 ha, 1 ha - 2 ha, 2 ha - 5 ha, > 5 ha), in order to evaluate the impact of parcel area on the detection accuracy;
- Parcel's sampling in order to have a **uniform spatial density over the entire countries/region of interest** that, especially for larger ones, can be characterized by different mowing practices or frequency, and different grassland phenological behavior (drought, etc.) during the growing season.

The Planet validation dataset is obtained by the visual interpretation of the Planet temporal series (mean resolution: 3.5 m), in order to identify the:

- mowing start date, corresponding to the last available cloud-free Planet image where the grassland seems to be not mowed;
- mowing end date, corresponding to the first available cloud-free Planet image where the grassland seems to be mowed;
- percentage of parcel mowed.

2) Validation datasets reliability

See Section 5.3.

3) Validation approach

See Section 5.3.

4) Validation results

The validation results (recall and precision) are extracted according to the following two condition tests (Table 6-9):

Table 6-9. Validation scenarios for grassland mowing detection

Validation type	Truth dataset	Percentage of parcel mowed
Validation 1	Planet	Partial mowing (< 100%)
Validation 2	Planet	Complete mowing (100%)

In addition to highlight the impact of the validation dataset quality, the scope of this analysis is to understand the impact of a partial mowing on the detection capability.

6.3.1 Spain - Castilla y Leon

6.3.1.1 Grassland parcels characteristics

Figure 6-18 and Figure 6-19 describe the distribution of the grassland parcels in terms of crop type and size in CyL in 2019. With respect the grassland types analyzed in 2018, in 2019 the CyL PA reduced the list of crops of interest to alfa-alfa and pasture. The graphs show that:

- the largest part of grassland parcels belongs to grassland pasture;
- more than 50% of grassland parcels are smaller than 0.5 ha.

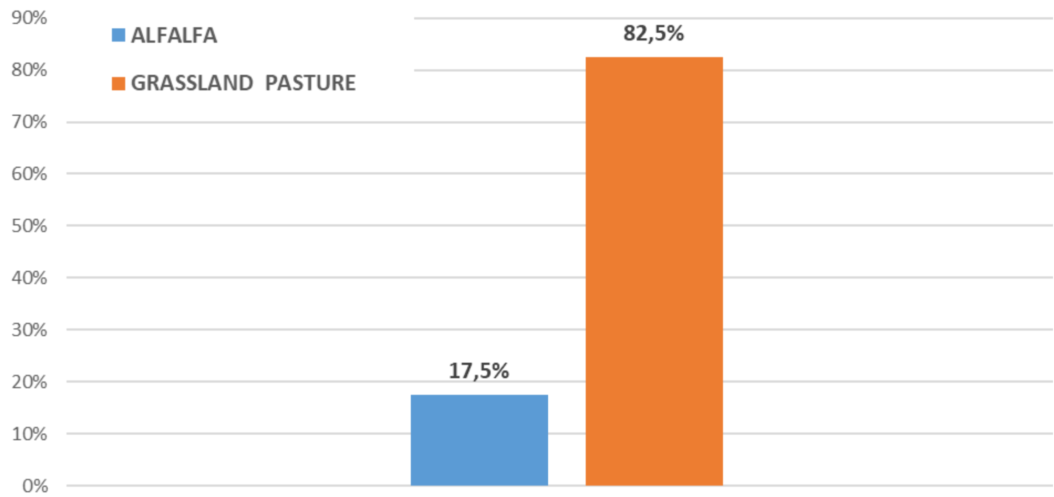


Figure 6-18. 2019 CyL grassland parcel type distribution, expressed as an histogram

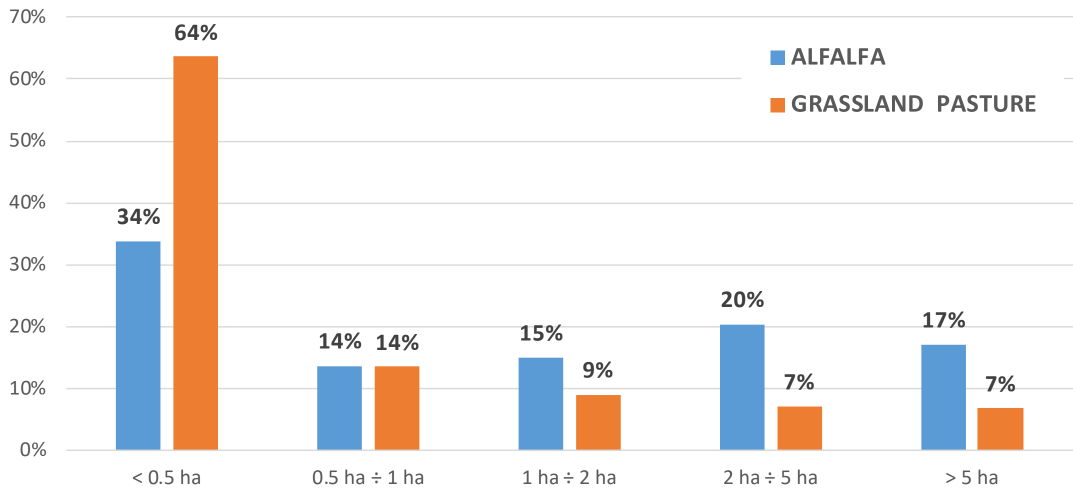


Figure 6-19. 2019 CyL grassland parcel size distribution, expressed as an histogram

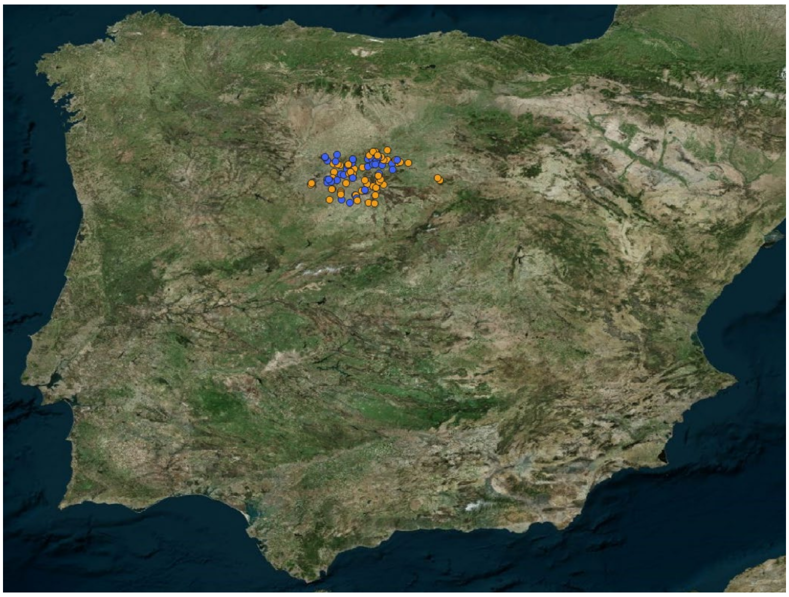
6.3.1.2 Validation datasets characteristics

The validation datasets derived from the Planet interpretation is described in Table 6-10 and Figure 6-20. The parcels selected for Planet interpretation do not reflect the national grassland parcel distribution in terms of crop type, because grassland pasture is probably usually managed by grazing instead mowing. For this reason, it has been preferred to enlarge the subset of alfa-alfa parcels.

Table 6-10. CyL Planet validation dataset characterization in terms of crop type

Crop name	Crop code	Planet parcel number
Alfalfa	2	41
Grassland Pasture	85	53
Total parcels (number)		**94**

Figure 6-20. Spatial distribution of the 2019 CyL parcels selected for Planet interpretation



6.3.1.3 Validation results

The results obtained with the different scenarios are presented in Table 6-11 and Figure 6-21.

Table 6-11. Validation results for grassland mowing detection in CyL 2019, based on the Planet data, considering any percentage of mowing (top) or only the complete mowing (bottom)

Percentage of parcel mowed: any							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	153	65	55	32	24	67%	54%
0 ha - 0.5 ha	96	54	33	27	2	67%	62%
0.5 ha - 1 ha	74	41	28	21	0	66%	59%
1 ha - 2 ha	52	29	22	15	0	66%	57%
2 ha - 5 ha	24	16	9	5	0	76%	64%

Percentage of parcel mowed: 100%							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	141	58	52	27	24	68%	53%
0 ha - 0.5 ha	84	47	30	22	2	68%	61%
0.5 ha - 1 ha	65	36	27	17	0	68%	57%
1 ha - 2 ha	44	24	21	12	0	67%	53%
2 ha - 5 ha	17	11	8	3	0	79%	58%

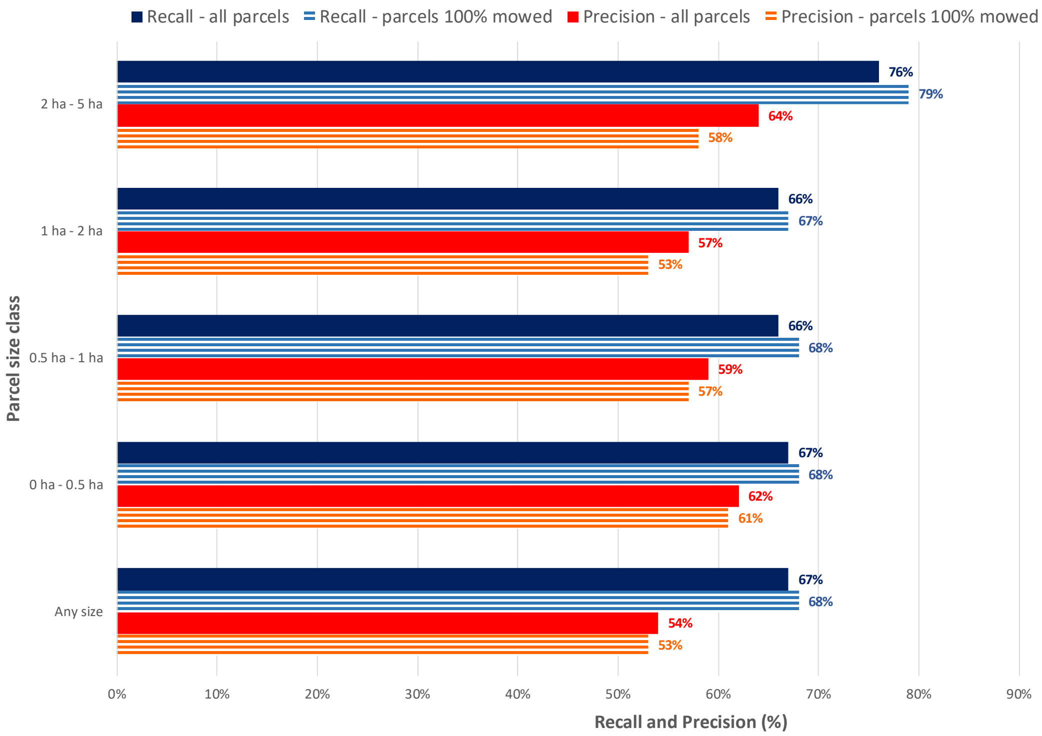


Figure 6-21. 2019 CyL validation results (scenarios 1 and 2 – Planet dataset)

6.3.2 Czech Republic

6.3.2.1 Grassland parcels characteristics

Figure 6-22 and Figure 6-23 describe the distribution of 2019 Czech grassland parcels in terms of crop type and size. They show that:

- the largest part of grassland parcels belongs to a single crop type, which is “Permanent grassland”;
- the parcels size is quite uniformly distributed.

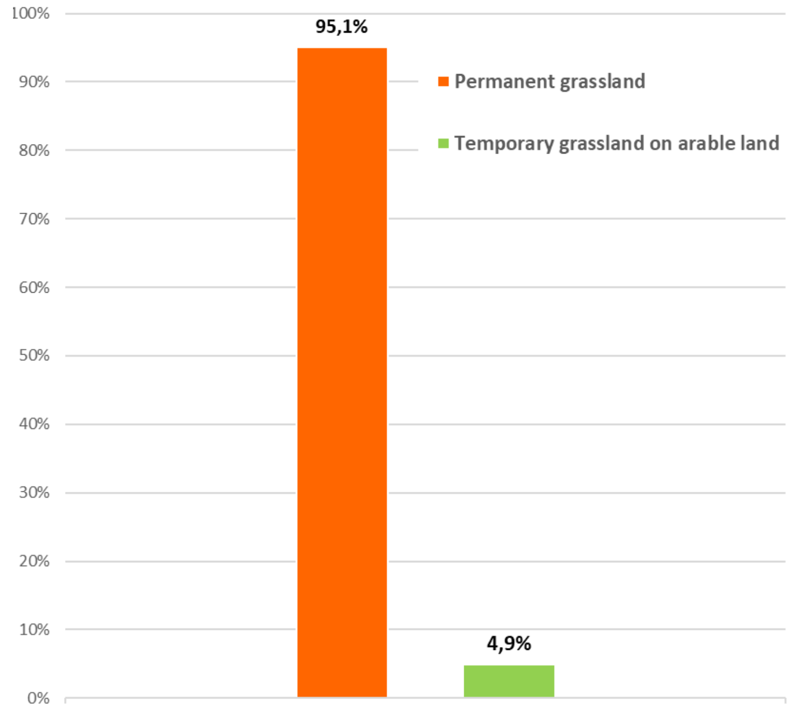


Figure 6-22. 2019 CZE grassland parcel type distribution, expressed as an histogram

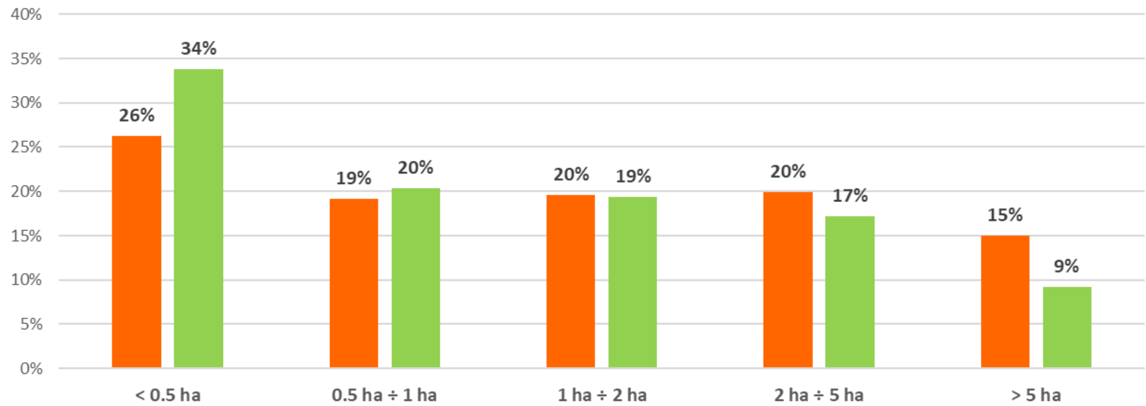


Figure 6-23. 2019 CZE grassland parcel size distribution, expressed as an histogram

6.3.2.2 Validation datasets characteristics

The validation dataset derived from the Planet interpretation is described in Table 6-12 and Figure 6-22. The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

Table 6-12. CZE Planet validation dataset characterization in terms of crop type

Crop name	Crop code	Planet parcel number
Temporary Grassland	350	5
Permanent Grassland	3001	187
Total parcels (number)		**192**

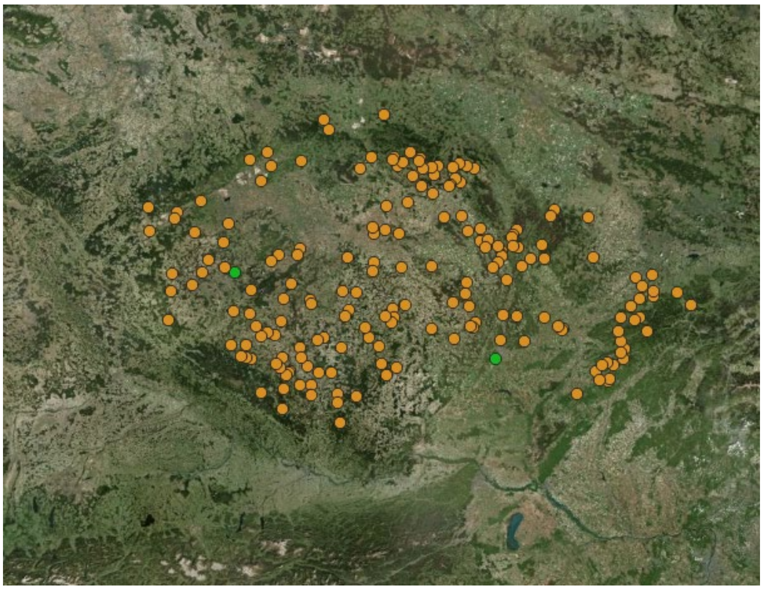


Figure 6-24. Distribution of 2019 CZE parcels selected for Planet interpretation

6.3.2.3 Validation results

The results obtained with the different scenarios are presented in Table 6-13 and Figure 6-25.

Table 6-13. Validation results for grassland mowing detection in CZE 2019, based on the Planet data and considering any percentage of mowing (top) or only the complete mowing (bottom)

Percentage of parcel mowed: any							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	266	163	46	80	12	67%	78%
0 ha - 0.5 ha	216	139	38	61	7	69%	79%
0.5 ha - 1 ha	161	105	31	44	5	70%	77%
1 ha - 2 ha	106	70	25	25	5	74%	74%
2 ha - 5 ha	58	34	15	16	2	68%	69%

Percentage of parcel mowed: 100%							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	246	154	49	69	12	69%	76%
0 ha - 0.5 ha	197	130	41	51	7	72%	76%
0.5 ha - 1 ha	142	96	34	34	5	74%	74%
1 ha - 2 ha	90	62	28	17	5	78%	69%
2 ha - 5 ha	46	28	17	10	2	74%	62%

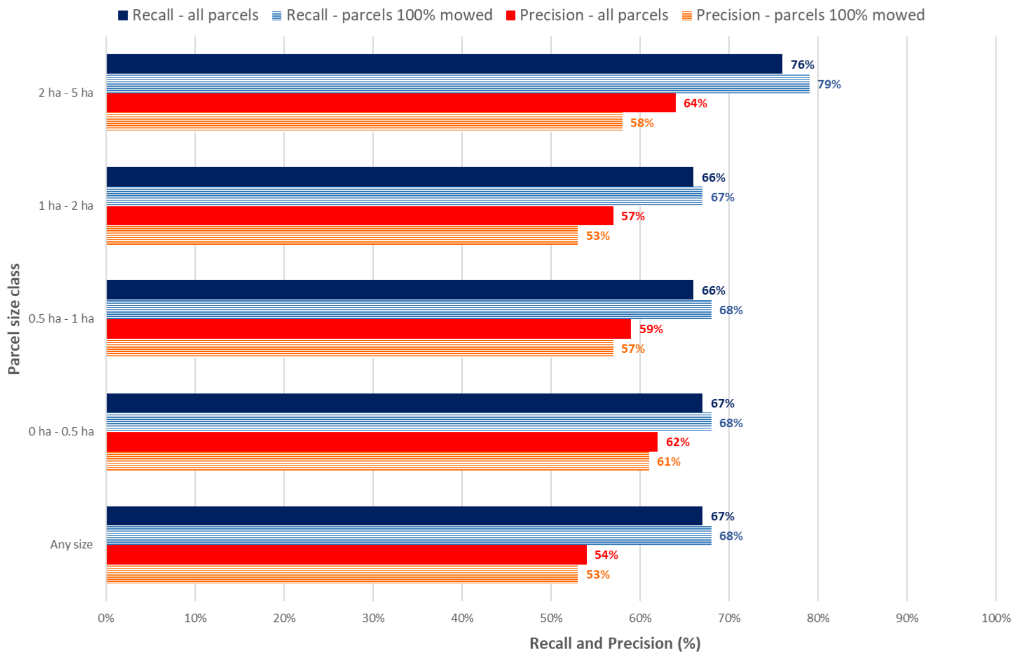


Figure 6-25. 2019 CZE Validation results (scenarios 1 and 2 – Planet dataset)

6.3.3 Italy

6.3.3.1 Grassland parcels characteristics

Figure 6-26 and Figure 6-27 describe the distribution of 2019 Italian grassland parcels in terms of crop type and size. They show that:

- the largest part of grassland parcels belongs to 6 main crop types;
- more than 70% of grassland parcels cover an area smaller than 0.5 ha.

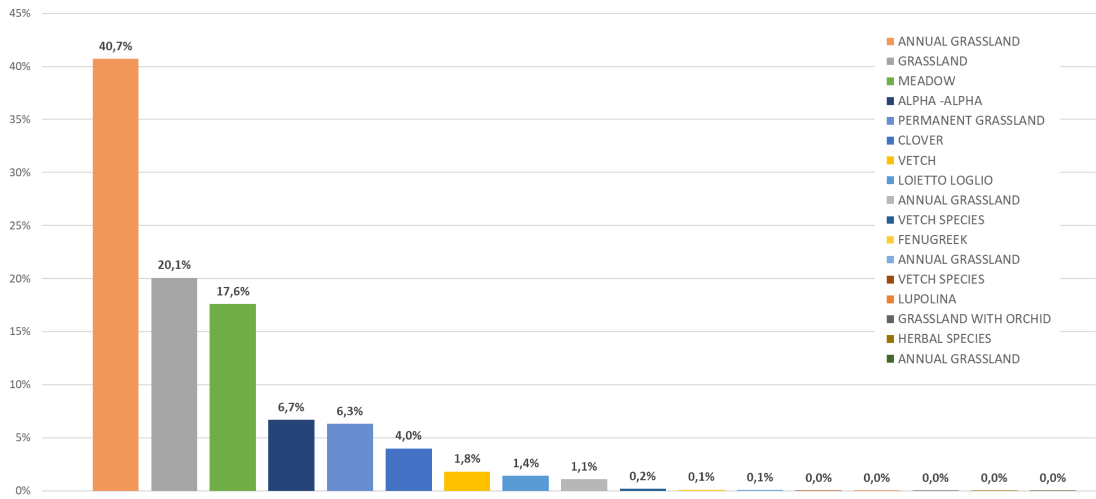


Figure 6-26. 2019 ITA grassland parcel type distribution, expressed as an histogram

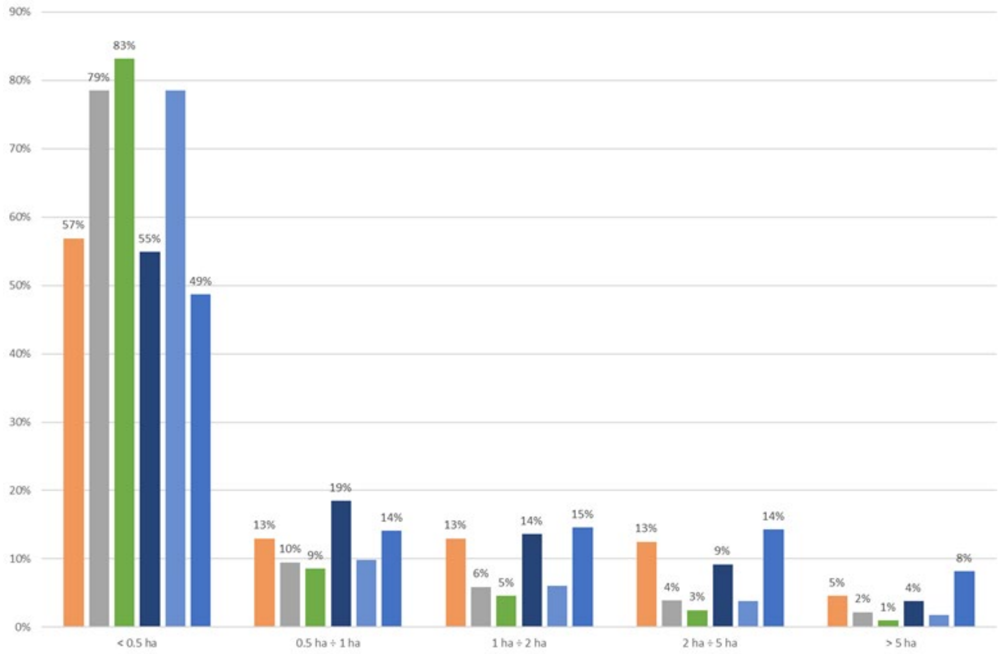


Figure 6-27. 2019 ITA 6 more frequent grassland parcel size distribution, expressed as an histogram

6.3.3.2 Validation datasets characteristics

The validation dataset derived from the Planet interpretation is described in Table 6-14 and Figure 6-28. The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

Table 6-14. ITA Planet validation dataset characterization in terms of crop type

Crop name	Crop code	Planet parcel number
CLOVER	152	5
MEADOW	336	20
VETCH SPECIES	389	5
VETCH SPECIES	390	5
GRASSLAND WITH ORCHID	460	5
HERBAL SPECIES	461	1
ALPHA -ALPHA	562	5
ANNUAL GRASSLAND	581	3
ANNUAL GRASSLAND	612	5
ANNUAL GRASSLAND	800	50
ANNUAL GRASSLAND	840	5
FENUGREEK	862	5
PERMANENT GRASSLAND	899	5
Total parcels (number)		**119**

Figure 6-28. Distribution of 2019 ITA parcels selected for Planet interpretation (left)

6.3.3.3 Validation results

The results obtained with the different scenarios are presented in Table 6-15 and Figure 6-29.

Table 6-15. Validation results for grassland mowing detection in ITA 2019, based on the Planet data and considering any percentage of mowing (top) or only the complete mowing (bottom)

Percentage of parcel mowed: any							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	130	91	48	11	9	89%	65%
0 ha - 0.5 ha	108	80	41	7	7	92%	66%
0.5 ha - 1 ha	81	59	34	6	4	91%	63%
1 ha - 2 ha	80	58	33	6	4	91%	64%
2 ha - 5 ha	78	56	33	6	4	90%	63%

Percentage of parcel mowed: 100%							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	118	79	43	11	9	88%	65%
0 ha - 0.5 ha	96	68	36	7	7	91%	65%
0.5 ha - 1 ha	70	48	30	6	4	89%	62%
1 ha - 2 ha	69	47	29	6	4	89%	62%
2 ha - 5 ha	68	46	29	6	4	88%	61%

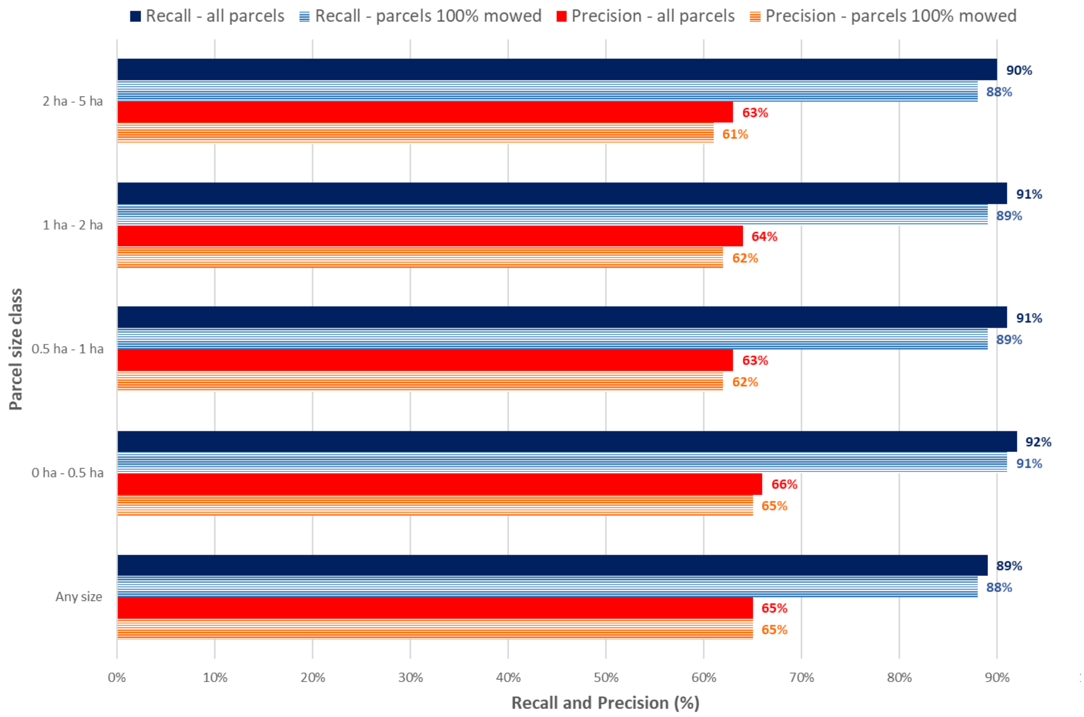


Figure 6-29. 2019 ITA validation results (scenarios 1 and 2 – Planet dataset)

6.3.4 Lithuania

6.3.4.1 Grassland parcels characteristics

Figure 6-30 and Figure 6-31 describe the distribution of 2019 Lithuanian grassland parcels in terms of crop type and size. They show that:

- the largest part of grassland parcels belongs to 2 main crop types, which are (i) "Perennial pasture or meadow 5 years or more" and (ii) "Pasture or meadow, perennial grass up to 5 years or more";
- the parcels size is quite uniformly distributed.

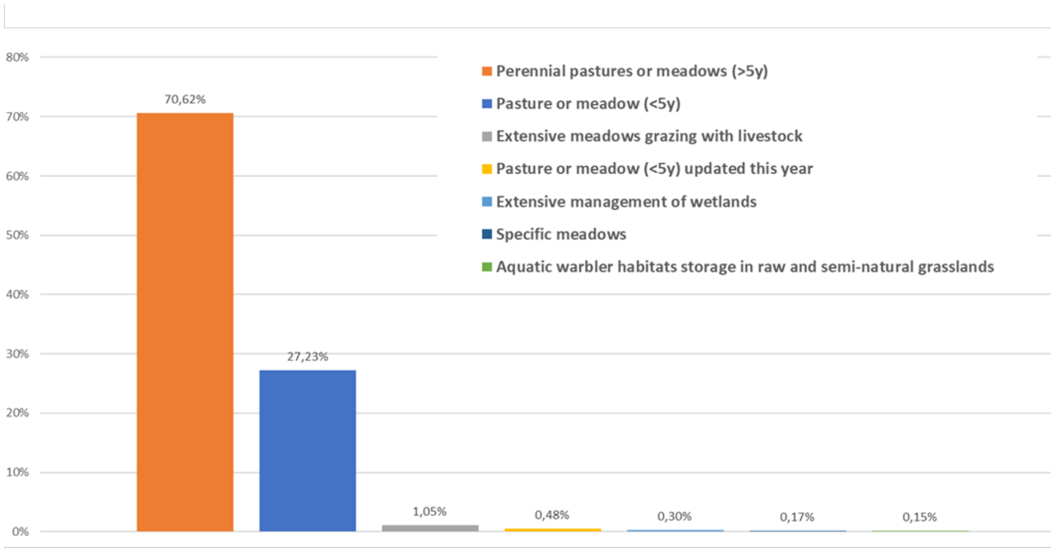


Figure 6-30. 2019 LTU grassland parcel type distribution, expressed as an histogram

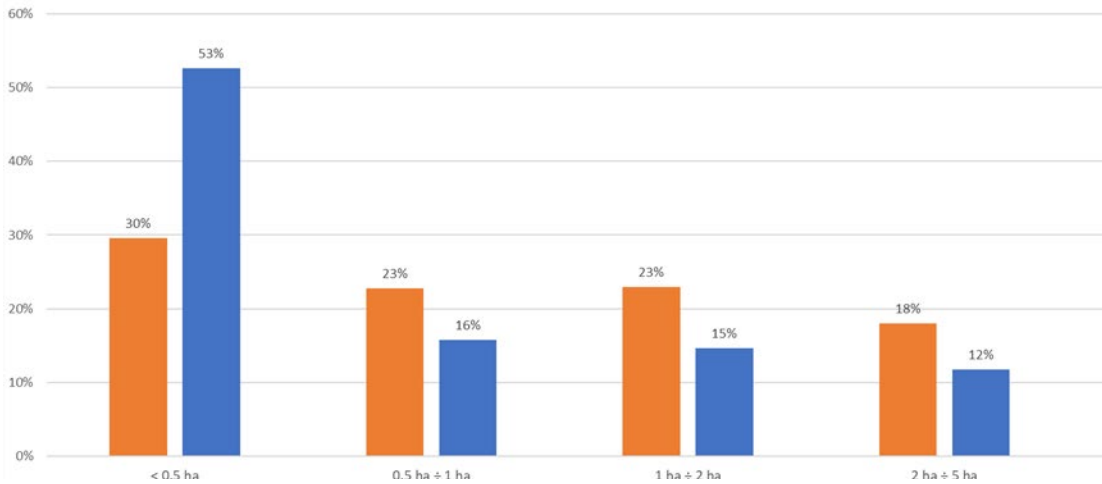


Figure 6-31. 2019 LTU grassland parcel size distribution, expressed as an histogram

6.3.4.2 Validation datasets characteristics

The validation dataset derived from the Planet interpretation is described in Table 6-16 and Figure 6-32.

The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

Table 6-16. LTU Planet validation dataset characterization in terms of crop type

Crop name	Crop code	Planet parcel number
Perennial pastures or meadows (>5y)	DGP	83
Extensive meadows grazing with livestock	EPT	5
Pasture or meadow (<5y) updated this year	GPA	5
Pasture or meadow (<5y)	GPZ	25
Total parcels (number)		**118**

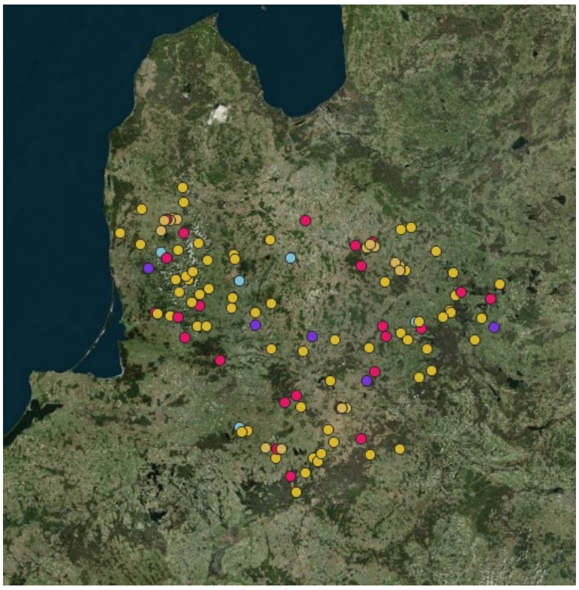


Figure 6-32. Distribution of 2019 LTU parcels selected for Planet interpretation

6.3.4.3 Validation results

The results obtained with the different scenarios are presented in Table 6-17 and Figure 6-33. Lower precision figures are observed than in the other countries, which is due to the application of different thresholds in the S1 detection chain. At the beginning of the season (May and mid of June), the LTU PA reported us that a significant number of mowing events were omitted by the algorithm. This was due to a lower performance of the S2-based detections caused by the high cloud coverage. In order to compensate it, less restrictive thresholds were applied in the S1 processing chain, with a higher risk of false detection.

Table 6-17. Validation results for grassland mowing detection in LTU 2019, based on the Planet data and considering any percentage of mowing (top) or only the complete mowing (bottom)

Percentage of parcel mowed: any							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	307	213	224	58	8	79%	49%
0 ha - 0.5 ha	278	197	211	51	5	79%	48%
0.5 ha - 1 ha	242	178	191	43	2	81%	48%
1 ha - 2 ha	197	149	164	32	0	82%	48%
2 ha - 5 ha	81	60	71	15	0	80%	46%

Percentage of parcel mowed: 100%							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	257	176	200	45	8	80%	47%
0 ha - 0.5 ha	229	161	186	38	5	81%	46%
0.5 ha - 1 ha	196	144	168	31	2	82%	46%
1 ha - 2 ha	153	117	142	20	0	85%	45%
2 ha - 5 ha	64	46	66	12	0	79%	41%

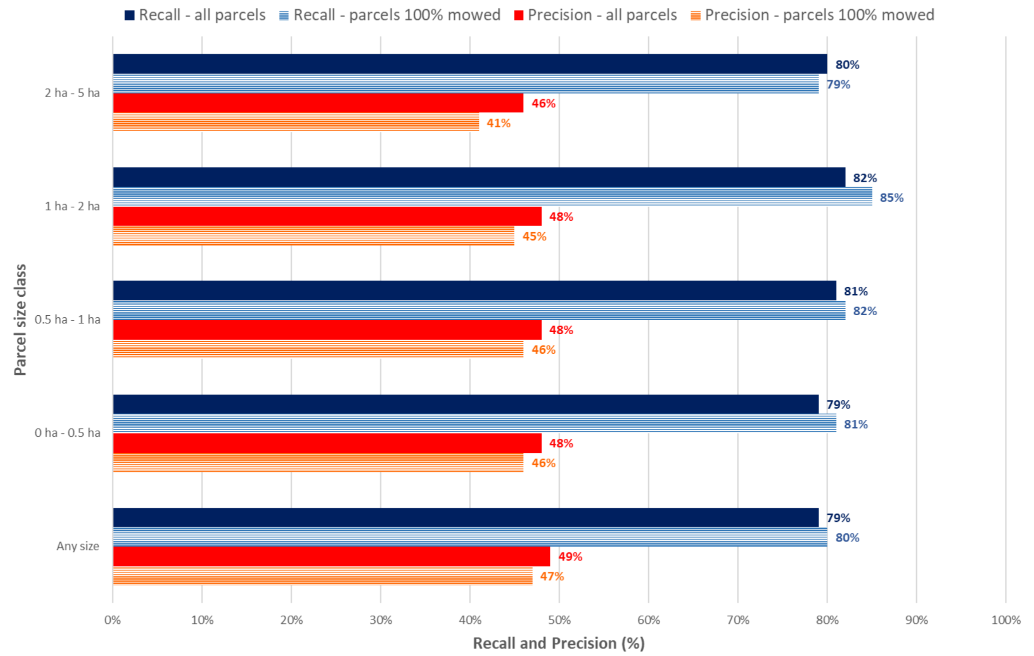


Figure 6-33. 2019 LTU validation results (scenarios 1 and 2 – Planet dataset)

6.3.5 Netherlands

6.3.5.1 Grassland parcels characteristics

Figure 6-34 and Figure 6-35 describe the distribution of 2019 Netherlands grassland parcels in terms of crop type and size. With respect the grassland types analyzed in 2018, in 2019 the NLD PA included the list of crops of interest also temporary grassland parcels. The graphs show that:

- the largest part of grassland parcels belongs to a single crop type, which is "Grassland permanent";
- the parcels size is quite uniformly distributed.

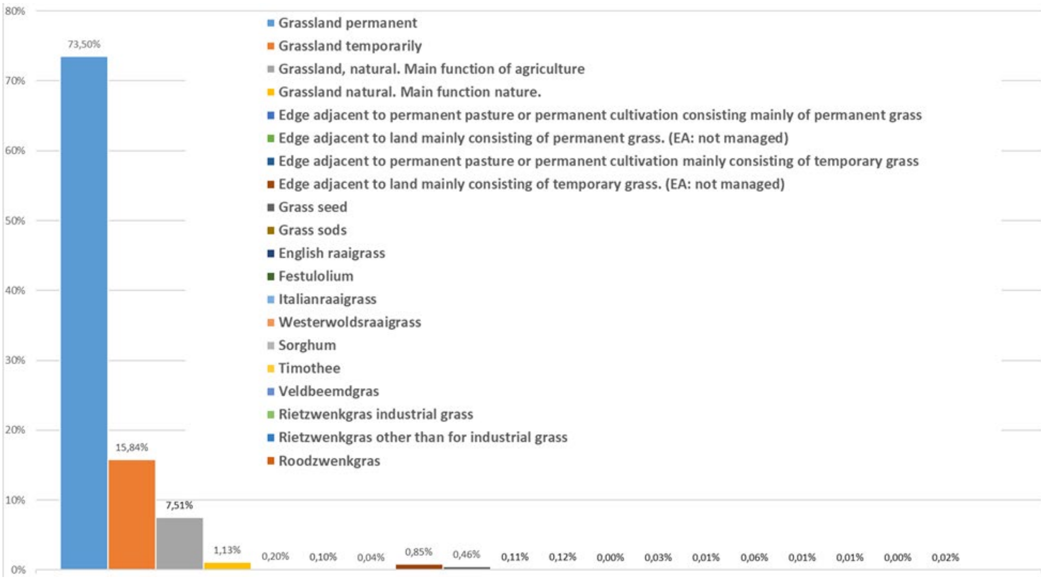


Figure 6-34. 2019 NLD grassland parcel type distribution, expressed as an histogram

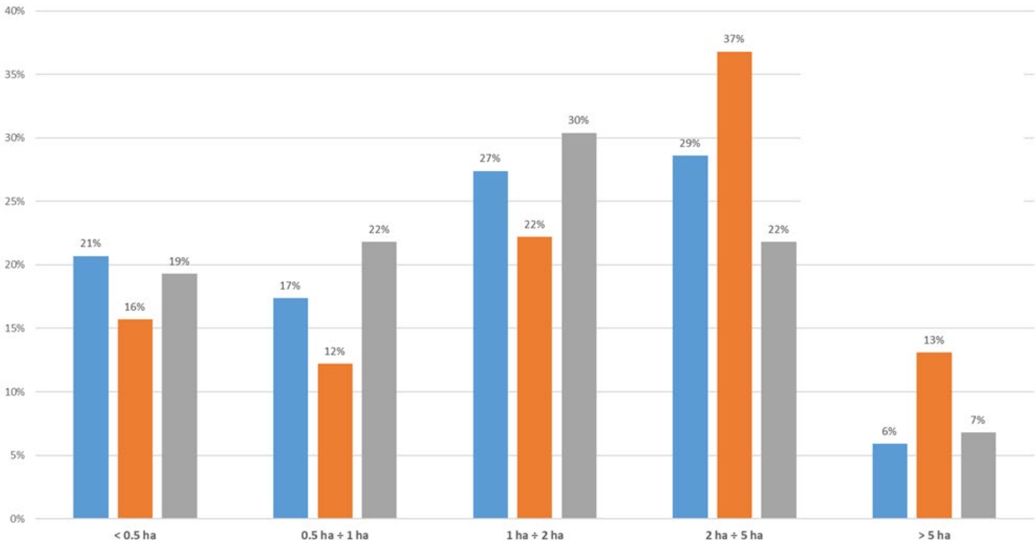


Figure 6-35. 2019 NLD grassland parcel size distribution, expressed as an histogram

6.3.5.2 Validation datasets characteristics

The validation dataset derived from the Planet interpretation is described in Table 6-18 and Figure 6-36. The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

Table 6-18. NLD Planet validation dataset characterization in terms of crop type

Crop name	Crop code	Planet parcel number
Grassland permanent	265	95
Grassland temporarily	266	40
Grassland, natural. Main function of agriculture	331	5
Grassland natural. Main function nature.	332	5
Edge adjacent to land mainly consisting of temporary grass. (EA: not managed)	372	5
Total parcels (number)		**145**

Figure 6-36. Distribution of 2019 NLD parcels selected for Planet interpretation

6.3.5.3 Validation results

The results obtained with the different scenarios are presented in Table 6-19 and Figure 6-37.

Table 6-19. Validation results for grassland mowing detection in NLD 2019, based on the Planet data and considering any percentage of mowing (top) or only the complete mowing (bottom)

Percentage of parcel mowed: any							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	243	175	55	56	2	76%	76%
0 ha - 0.5 ha	243	175	55	56	2	76%	76%
0.5 ha - 1 ha	243	175	55	56	2	76%	76%
1 ha - 2 ha	242	175	53	56	2	76%	77%
2 ha - 5 ha	224	166	48	48	2	78%	78%

Percentage of parcel mowed: 100%							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	217	158	62	47	2	77%	72%
0 ha - 0.5 ha	217	158	62	47	2	77%	72%
0.5 ha - 1 ha	217	158	62	47	2	77%	72%
1 ha - 2 ha	216	158	60	47	2	77%	72%
2 ha - 5 ha	202	150	55	42	2	78%	73%

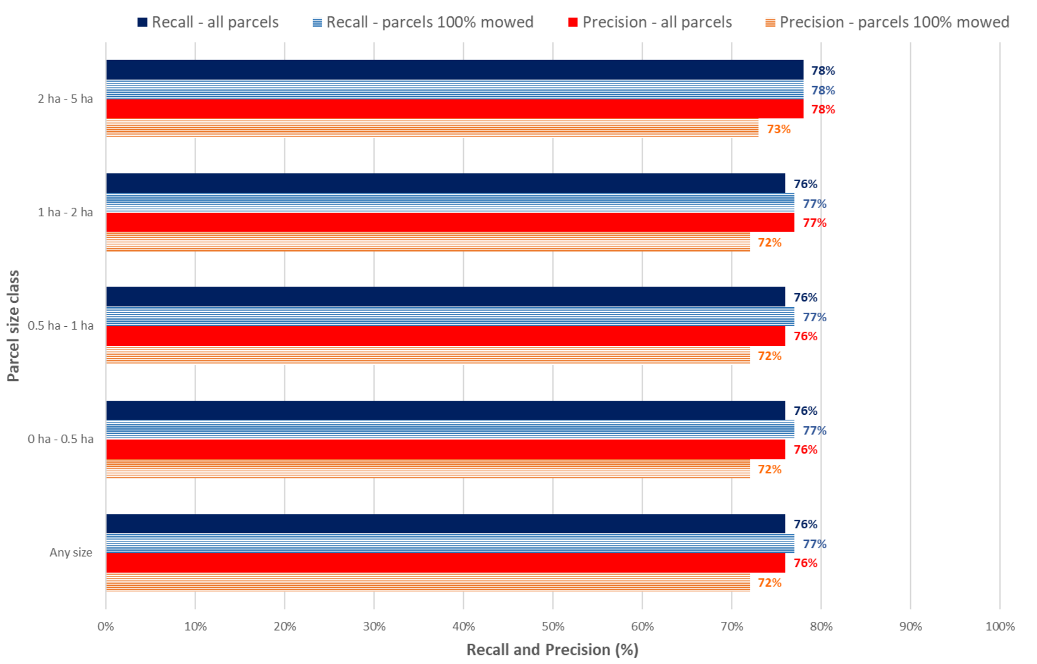


Figure 6-37. 2019 NLD Validation results (scenarios 1 and 2 – Planet dataset)

6.3.6 Romania

6.3.6.1 Grassland parcels characteristics

Figure 6-38 and Figure 6-39 describe the distribution of 2019 Romanian grassland parcels in terms of crop type and size. They show that:

- the largest part of grassland parcels belongs mainly to 5 crop types;
- more than 45% of grassland parcels are smaller than 0.5 ha.

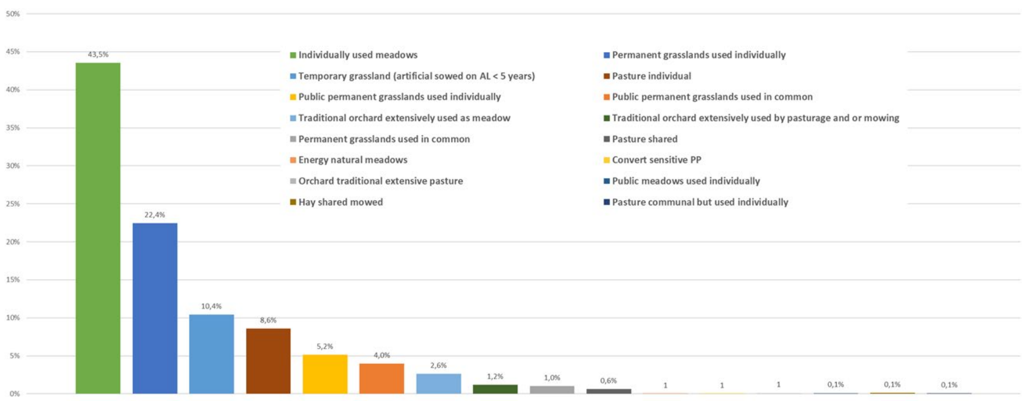


Figure 6-38. 2019 ROU grassland parcel type distribution, expressed as a bar chart

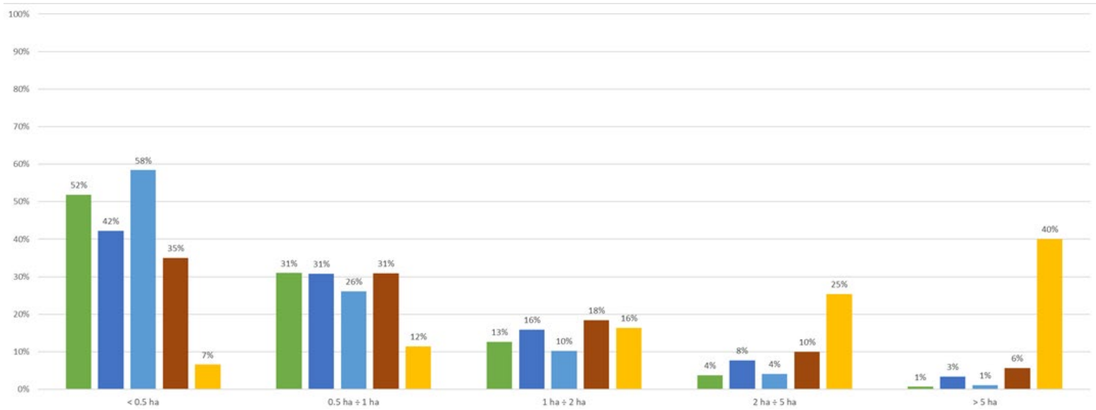


Figure 6-39. 2019 ROU grassland parcel size distribution, expressed as an histogram

6.3.6.2 Validation datasets characteristics

The validation dataset derived from Planet interpretation is described in Table 6-20 and Figure 6-40. The parcels selected for Planet interpretation reflect the national grassland parcel distribution in terms of crop type.

Table 6-20. ROU Planet validation dataset characterization in terms of crop type

Crop name	Crop code	Planet parcel number
Temporary grassland (artificial sowed on AL < 5 years)	450	10
Public permanent grasslands used in common	603	5
Permanent grasslands used in common	604	5
Public permanent grasslands used individually	605	5
Permanent grasslands used individually	606	20
Individually used meadows	607	40
Public meadows used individually	608	5
Pasture individual	609	5
Pasture shared	610	5
Hay shared mowed	611	5
Pasture communal but used individually	612	5
Traditional orchard extensively used by pasturage and or mowing	660	5
Traditional orchard extensively used as meadow	661	5
Energy natural meadows	662	1
Orchard traditional extensive pasture	663	5
Convert sensitive PP	671	4
Total parcels (number)		**130**

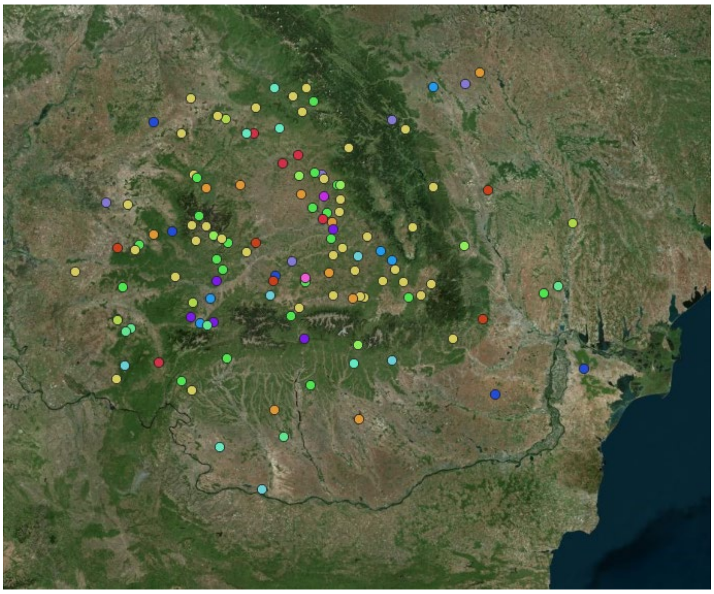


Figure 6-40. Distribution of 2019 ROU parcels selected for Planet interpretation

6.3.6.3 Validation results

The results obtained with the different scenarios are presented in Table 6-21 and Figure 6-41.

Table 6-21. Validation results for grassland mowing detection in ROU 2019, based on the Planet data and considering any percentage of mowing (top) or only the complete mowing (bottom)

Percentage of parcel mowed: any							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	144	43	31	21	59	67%	58%
0 ha - 0.5 ha	118	35	26	20	45	64%	57%
0.5 ha - 1 ha	90	25	18	18	34	58%	58%
1 ha - 2 ha	63	21	11	11	23	66%	66%
2 ha - 5 ha	33	13	3	3	15	81%	81%

Percentage of parcel mowed: 100%							
Parcel size class	Total Truth	TP	FP	FN	TN	Recall	Precision
Any size	118	31	30	7	59	82%	51%
0 ha - 0.5 ha	93	23	25	7	45	77%	48%
0.5 ha - 1 ha	66	14	16	5	34	74%	47%
1 ha - 2 ha	47	13	11	3	23	81%	54%
2 ha - 5 ha	27	9	2	1	15	90%	82%

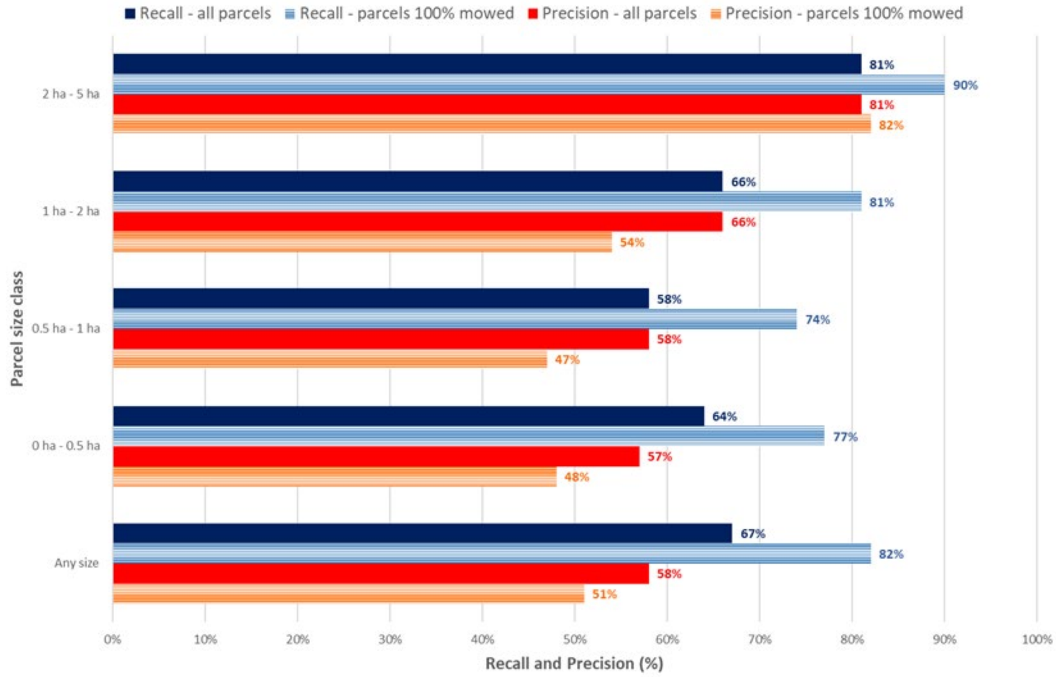


Figure 6-41. 2019 ROU Validation results (scenarios 1 and 2 – Planet dataset)

6.3.7 France

6.3.7.1 Validation datasets characteristics

The validation activity for France has been focused on grassland mowing products generated on the Ain and Normandie regions on 2019. The validation dataset provided by the FRA PA (inspectors on site control) consists in 2 groups of parcels:

- Mowed at the date of the field visit;
- Not mowed at the date of the field visit.

Table 6-22 and Figure 6-42 describe their characteristics and geographical distribution.

Table 6-22. 2019 FRA validation dataset characteristics

In situ data	Parcel (n°)	Crop code
Mowed	33	MLG, PPH, PRL, PTR
Not mowed	296	MLG, PPH, PRL, PTR

From the validation dataset, it seems that more that 88% of parcels were not mowed at the date of the field visits. The dates of the field visit are unknown but, considering the percentage of un-mowed parcels, it seems that the survey does not cover the entire monitoring season of grassland parcels.

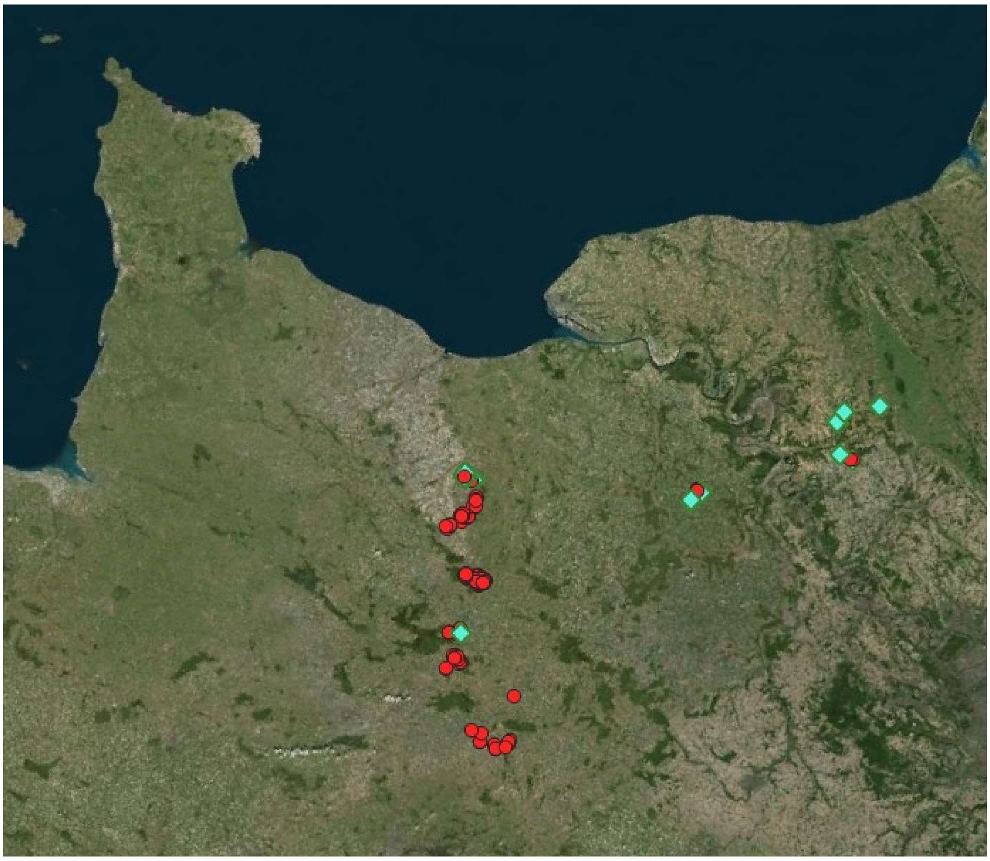


Figure 6-42. Distribution of 2019 FRA PA validation dataset

The grassland mowing product to be validated was the last delivered to the PA, covering the entire period of monitoring, from the 1st of April to the 31st of October 2019 (Sen4CAP_L4B_MOWD_FRA_20190401-20191031).

From the truth dataset, for the validation, only the parcels that match by position with the grassland parcels monitored, have been selected. Indeed, it was not possible to search a matching between truth parcels and product parcels by ID because they do not correspond (Figure 6-43, Figure 6-44).

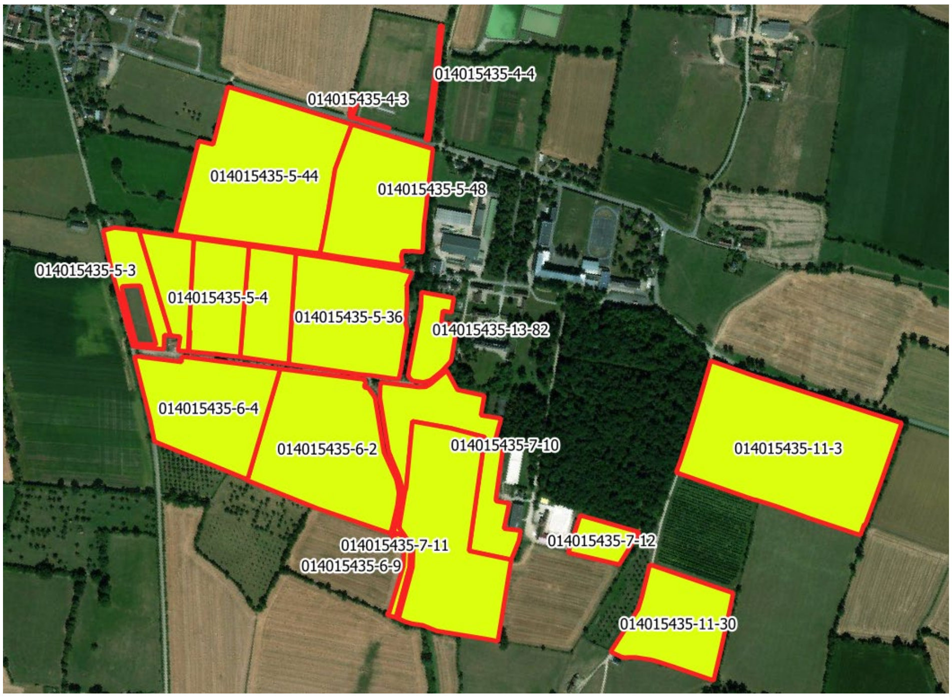


Figure 6-43. Grassland parcels processed from GSAA (sample)

Figure 6-44. Grassland parcels available as truth (sample)

6.3.7.2 Validation results

After the matching by position, it has been realized that in most cases, product and truth parcels differ also from a geometry point of view: multiple truth parcels (Figure 6-44) correspond to one product parcel (Figure 6-43).

Considering that the grassland mowing processor works at parcel-level, in the cases where there is not a unique correspondence among product parcel and truth parcel, the truth parcels have to be discarded from the validation dataset.

At the end of this analysis, the number of suitable parcels for the accuracy analysis resulted really small with regard to the initial dataset (less the 100 parcels). This aspect, combined with the fact that the survey dates are unknown, did not allow to extract reliable validation results.

6.3.8 Summary on 2019 validation

1) The analysis of the results and the validation performed on 2018 has driven on 2019 some improvements of the grassland mowing algorithm, specifically aimed to reduce problems related to the false mowing detection (low precision): improvement of the temporal series analysis in order to identify and discard potential out-layers, due to potential lacks in the cloud and cloud-shadow detections, finer tuning of the thresholds applied to VI decreasing, and VI decreasing rate, to remove as much as possible the false alarms due to the seasonal grassland drying.

Comparing the results of the 2 seasons (2018 and 2019) it is possible to highlight a relevant increase in precision, in the face of a limited decrease of the recall, for all countries (Figure 6-45).

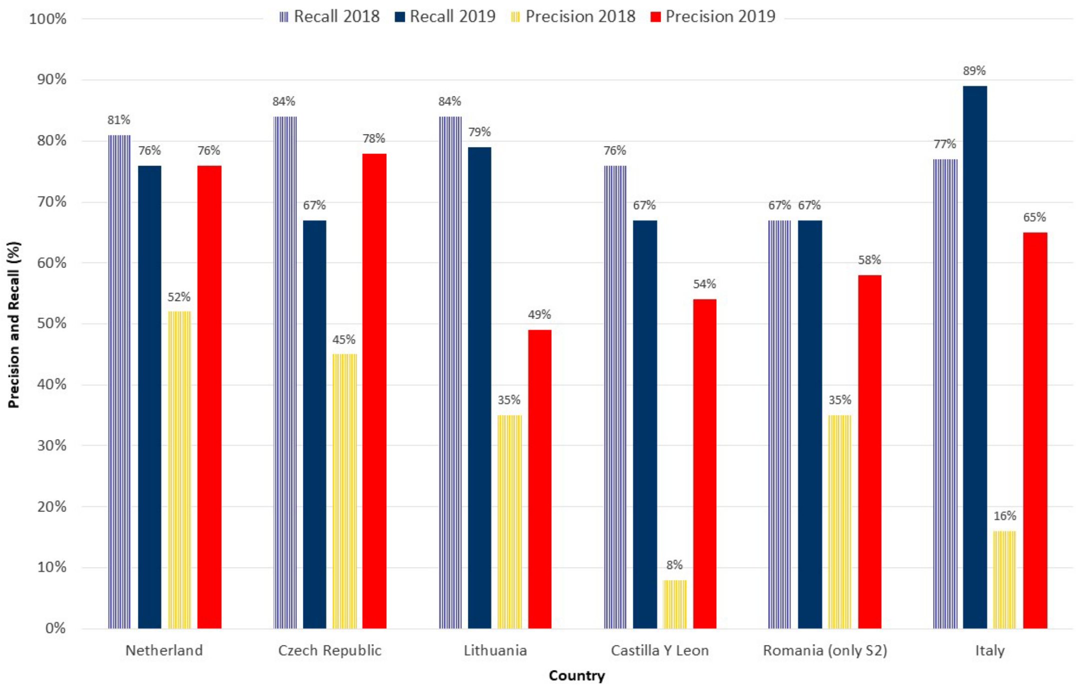


Figure 6-45. 2018/2019 results comparison (Planet dataset, products monitoring period from April to October)

2) The precision of Southern countries as Italy, Castilla y Leon and Romania is lower with respect to the Northern countries. This could be due to two main reasons:

- Higher impact of grassland drying

- Diffusion of the pasture practice. Grazing, not detectable by Planet interpretation and therefore not included as truth, could be sometimes detected by the algorithm and considered in the validation process as false mowing).

3) The precision of Lithuania is lower if compared to other Northern countries as Netherland and Czech Republic. It can be explained considering that, because of the reports received form the LTU PA about missed detections at the beginning of the season (May and mid of June), less restrictive thresholds (higher risk of false detection) in the S1 processing chain, with respect the other 2 countries, they have been applied in order to supply the missed S2 detections caused by the high cloud coverage.

4) In 2019, for all the countries with the exception of Romania, the products have been delivered on a monthly basis. This allowed analyzing how the accuracy varies over time, to turn out that the maximum of the accuracy is reached with the products of August\September (including all the mowing up to October\September).

Additionally, it has to highlight that in the products delivered in October, there is a decreasing of the precision in Lithuania and a decreasing of the recall in Castilla y Leon. The reasons have to be better investigated.

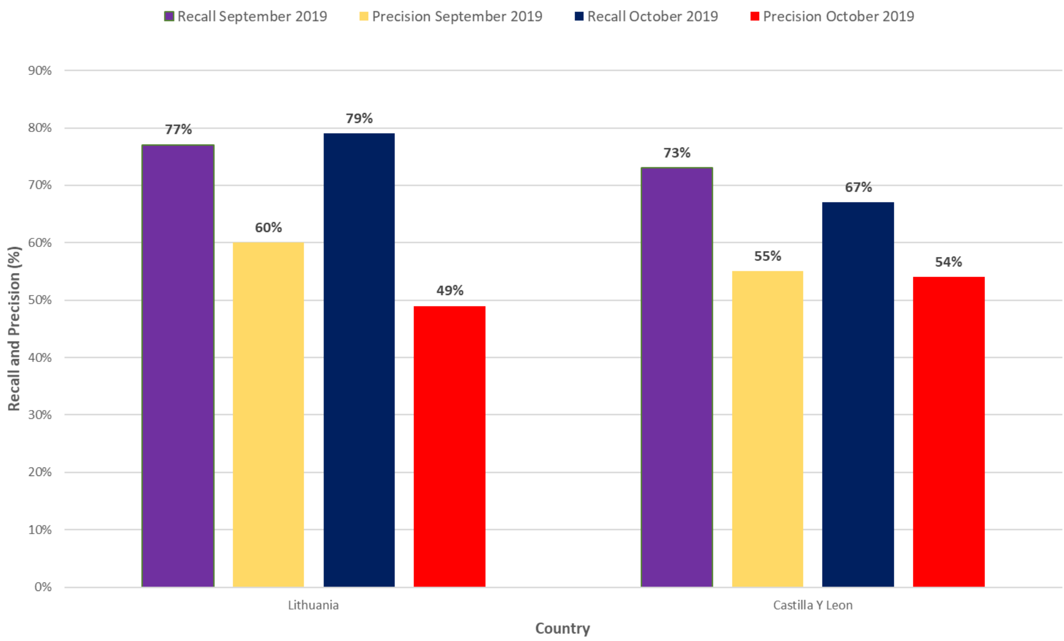


Figure 6-46. September/October 2019 results comparison

5) Some considerations coming from the analysis of the 2018 results are still valid for the 2019 ones:

- The accuracy of the algorithm slightly (2%-3%) increases if larger parcels are considered. To highlight this behavior, the validation is performed considering incremental classes of parcel sizes, starting from parcels of any size (including those smaller than 0.5 ha) up to parcels greater than 5 hectares.
- The accuracy of the algorithm increases in a more relevant way if completely mowed parcels are considered. This is reasonable, because the algorithm is based on the temporal indexes (NDVI, Coherence, etc.) averaged on the parcel

areas, therefore a partial mowing (e.g. 50%) affect the measured index variation and actually reduce the algorithm sensitivity to the mowing.

6.4 Agricultural Practices monitoring product

The validation activities in 2019 have been planned in two steps:

- Validation of harvest detection based on interpretation of Planet imagery:

  Stratified random sampling approach has been applied to generate a sample of 250 reference parcels respecting the share of main crops in each country. All parcels within these samples were subject of visual interpretation to detect harvest events on Planet imagery;

- Validation of agricultural practices based on reference data provided by PAs:

  Unfortunately, some PAs have not provided any reference datasets and the data provided by other PAs were rather limited. In case of harvest detection, the systematic validation performed using Planet imagery was complemented by validation based on data delivered by PAs of three pilot countries (CZE, LTU, NLD).

  The only case when the data provided by PAs could be used to validate agricultural practices was the dataset about nitrogen fixing crops provided by the Czech PA. Thus, to prove and demonstrate the reliability of the validation results of 2018, two countries were selected (CZE, ESP) and additional interpretation using Planet imagery has been performed to present the validation on marker level using the same procedure as in 2018.

6.4.1 Harvest detection

6.4.1.1 Czech Republic

The validation results of harvest detection for Czechia (using Planet imagery and data provided by farmers) are presented in Table 6-23.

Table 6-23. Accuracy of main crop harvest detection based on Planet data – CZE 2019

Difference	Reference	Accuracy		Reference	Accuracy	
[weeks]	Farmers	Category	Cumulative	Planet	Category	Cumulative
0-1	183	61%	61%	194	78%	78%
2	53	18%	78%	27	11%	88%
3	24	8%	86%	15	6%	94%
> 3	27	9%	95%	10	4%	98%
Not detect.	14	5%	100%	4	2%	100%
Total	**301**	**100%**		**250**	**100%**	

The relation between harvest detection accuracy and crop category analysed on the Planet sample is presented in Table 6-24. The differences of validation results among the three crop categories are not considered significant (the "other crops" category is quite diverse which has an impact on different detection accuracy comparing to winter, spring and summer crops).

Table 6-24. Accuracy of harvest detection by crop category – CZE 2019

Difference	CZE					
[weeks]	**winter and spring**		**summer**		**other**	
0-1	141	77%	35	88%	18	64%
2	21	12%	2	5%	4	14%
3	12	7%	2	5%	1	4%
> 3	8	4%	0	0%	2	7%
Not detect.	0	0%	1	3%	3	11%
Total	**182**	**100%**	**40**	**100%**	**28**	**100%**

6.4.1.2 Spain (Castilla y Leon)

The validation results of harvest detection for Spain (Castilla y Leon) using Planet imagery are presented in Table 6-25.

Table 6-25. Accuracy of main crop harvest detection based on Planet data – CyL 2019

Difference	Reference	Accuracy	
[weeks]	**Planet**	**Category**	**Cumulative**
0-1	132	53%	53%
2	40	16%	69%
3	30	12%	81%
> 3	44	18%	98%
Not detect.	4	2%	100%
Total	**250**	**100%**	

The relation between harvest detection accuracy and crop category analysed on the Planet sample is presented in Table 6-26. It is confirmed that the results for winter and spring crops are biased due to the problem with crop senescence stage that is often detected as harvest. This problem is encountered especially in southern countries for cereals.

Table 6-26. Accuracy of harvest detection by crop category – CyL 2019

Difference	ESP					
[weeks]	**winter and spring**		**summer**		**other**	
0-1	102	48%	26	79%	4	80%
2	38	18%	1	3%	1	20%
3	30	14%	0	0%	0	0%
> 3	42	20%	2	6%	0	0%
Not detect.	0	0%	4	12%	0	0%
Total	**212**	**100%**	**33**	**100%**	**5**	**100%**

6.4.1.3 Lithuania

The validation results of harvest detection for Lithuania (using Planet imagery and data provided by farmers) are presented in Table 6-27.

Table 6-27. Accuracy of main crop harvest detection based on Planet data – LTU 2019

Difference	Reference	Accuracy		Reference	Accuracy	
[weeks]	Farmers	Category	Cumulative	Planet	Category	Cumulative
0-1	56	82%	82%	196	73%	73%
2	7	10%	93%	38	14%	87%
3	3	4%	97%	22	8%	95%
> 3	1	1%	99%	10	4%	99%
Not detect.	1	1%	100%	4	1%	100%
Total	**68**	**100%**		**270**	**100%**	

The relation between harvest detection accuracy and crop category analysed on the Planet sample is presented in Table 6-31. The differences of validation results among the three crop categories are not considered significant (the “other crops” category is quite diverse which has an impact on different detection accuracy comparing to winter, spring and summer crops).

Table 6-28. Accuracy of harvest detection by crop category – LTU 2019

Difference	LTU					
[weeks]	winter and spring		summer		Other	
0-1	156	69%	3	60%	37	93%
2	38	17%	0	0%	0	0%
3	20	9%	2	40%	0	0%
> 3	9	4%	0	0%	1	3%
Not detect.	2	1%	0	0%	2	5%
Total	**225**	**100%**	**5**	**100%**	**40**	**100%**

6.4.1.4 Netherlands

The validation results of harvest detection for Netherlands (using Planet imagery and data provided by farmers) are presented in Table 6-29.

Table 6-29. Accuracy of main crop harvest detection based on Planet data – NLD 2019

Difference	Reference	Accuracy		Reference	Accuracy	
[weeks]	Farmers	Category	Cumulative	Planet	Category	Cumulative
0-1	18	64%	64%	214	86%	86%
2	1	4%	68%	11	4%	90%
3	2	7%	75%	1	0%	90%
> 3	6	21%	96%	3	1%	92%
Not detect.	1	4%	100%	21	8%	100%
Total	**28**	**100%**		**250**	**100%**	

The relation between harvest detection accuracy and crop category analysed on the Planet sample is presented in Table 6-30. The differences of validation results among the three crop categories are rather small,l which confirms good performance of the detection no matter which crop is grown on the parcel.

Table 6-30. Accuracy of harvest detection by crop category – NLD 2019

Difference	NLD					
[weeks]	winter and spring		summer		other	
0-1	50	88%	140	82%	42	82%
2	4	7%	7	4%	1	2%
3	1	2%	2	1%	0	0%
> 3	1	2%	5	3%	3	6%
Not detect.	1	2%	16	9%	5	10%
Total	57	100%	170	100%	51	100%

6.4.1.5 Italy

The validation results of harvest detection for Italy using Planet imagery are presented in Table 6-31.

Table 6-31. Accuracy of main crop harvest detection based on Planet data – ITA 2019

Difference	Reference	Accuracy	
[weeks]	Farmers	Category	Cumulative
0-1	174	70%	70%
2	29	12%	81%
3	11	4%	86%
> 3	29	12%	97%
Not detect.	7	3%	100%
Total	250	100%	

The relation between harvest detection accuracy and crop category analysed on the Planet sample is presented in Table 6-32. The differences of validation results among the three crop categories are around 10%, which confirms good performance of the detection no matter which crop is grown on the parcel.

Table 6-32. Accuracy of harvest detection by crop category – ITA 2019

Difference	ITA					
[weeks]	winter and spring		summer		other	
0-1	117	70%	33	65%	24	75%
2	25	15%	1	2%	3	9%
3	11	7%	0	0%	0	0%
> 3	14	8%	13	25%	2	6%
Not detect.	0	0%	4	8%	3	9%
Total	167	100%	51	100%	32	100%

6.4.1.6 Romania

The validation results of harvest detection for Romania using Planet imagery are presented in Table 6-33.

Table 6-33. Accuracy of main crop harvest detection based on Planet data – ROU 2019

Difference	Reference	Accuracy	
[weeks]	Farmers	Category	Cumulative
0-1	172	69%	69%
2	41	16%	85%
3	10	4%	89%
> 3	11	4%	94%
Not detect.	16	6%	100%
Total	250	100%	

The relation between harvest detection accuracy and crop category analysed on the Planet sample is presented in Table 6-34. The differences of validation results among the three crop categories are around 10%, which confirms good performance of the detection no matter which crop is grown on the parcel.

Table 6-34. Accuracy of harvest detection by crop category – ROU 2019

Difference	ROU					
[weeks]	winter and spring		summer		other	
0-1	47	75%	87	69%	38	63%
2	9	14%	25	20%	7	12%
3	2	3%	8	6%	0	0%
> 3	1	2%	6	5%	4	7%
Not detect.	4	6%	1	1%	11	18%
Total	63	100%	127	100%	60	100%

6.4.1.7 France

The validation results of harvest detection for France using Planet imagery are presented in Table 6-35.

Table 6-35. Accuracy of main crop harvest detection based on Planet data – FRA 2019

Difference	Reference	Accuracy	
[weeks]	Farmers	Category	Cumulative
0-1	195	78%	78%
2	15	6%	84%
3	6	2%	86%
> 3	17	7%	93%
Not detect.	17	7%	100%
Total	250	100%	

The relation between harvest detection accuracy and crop category analysed on the Planet sample is presented in Table 6-36. The differences of validation results among the three crop categories are below 10%, which confirms good performance of the detection no matter which crop is grown on the parcel.

Table 6-36. Accuracy of harvest detection by crop category – FRA 2019

Difference	**FRA**					
[weeks]	**winter and spring**		**summer**		**other**	
0-1	91	81%	73	74%	31	79%
2	11	10%	2	2%	2	5%
3	3	3%	1	1%	2	5%
> 3	7	6%	9	9%	1	3%
Not detect.	1	1%	13	13%	3	8%
Total	**113**	**100%**	**98**	**100%**	**39**	**100%**

The PA also provided some reference data allowing a limited validation of the harvest date (not enough information to validate also the agricultural practices). The validation of harvest detection has been done using the same approach as for other pilot countries. The reported harvest date has been compared with the week in which the harvest was detected by the system.

The basic checks and data cleaning were applied to remove the parcels with reported information not relevant for the applied analysis (e.g. the data did not relate to the main crop growing season).

The validation results are reported in Table 6-37.

Table 6-37. Accuracy of main crop harvest detection based of farmers' reports – FRA 2019

Difference	**Farmers**	**Accuracy**	
[weeks]	**No. of parcels**	**Category**	**Cumulative**
0-1	118	65%	65%
2	28	16%	81%
3	2	1%	82%
> 3	13	7%	89%
Not detect.	20	11%	100%
Total	**181**	**100%**	

The resulting accuracy figures correspond well with the results obtained in other pilot countries and confirm good and consistent performance of the system in case of harvest detection.

6.4.1.8 Comparison of 2018 and 2019 results

The comparison of harvest detection accuracy for 2018 and 2019 show very good consistency between both years. It may be concluded that except for Spain, the harvest detection method as implemented in the Sen4CAP system is robust and provides the results with accuracy above 70% (if one-week difference between real and detected event is considered) and above 80% (for two-week difference).

Table 6-38. Comparison of the harvest detection accuracy results obtained in 2018 and 2019 seasons

Harvest detection accuracy 2018 (cumulative)						
Difference [weeks]	**Czechia**	**Italy**	**Lithuania**	**Netherlands**	**Romania**	**Spain**
0-1	72%	76%	74%	83%	70%	53%
2	87%	88%	89%	91%	84%	69%
3	93%	94%	93%	94%	90%	81%
> 3	99%	100%	97%	94%	99%	95%
Not detected	100%	100%	100%	100%	100%	100%
Harvest detection accuracy 2019 (cumulative)						
Difference [weeks]	**Czechia**	**Italy**	**Lithuania**	**Netherlands**	**Romania**	**Spain**
0-1	78%	70%	73%	86%	69%	53%
2	88%	81%	87%	90%	85%	69%
3	94%	86%	95%	90%	89%	81%
> 3	98%	97%	99%	92%	94%	98%
Not detected	100%	100%	100%	100%	100%	100%

The crop harvest detection is implemented as continuous monitoring providing updated results every week. When such a monitoring is run operationally during the whole vegetation season, wide range of analyses can be done using the resulting dataset. As an example, Figure 6-47 shows the evolution of the percentage of the harvested parcels in all pilot countries in 2019.

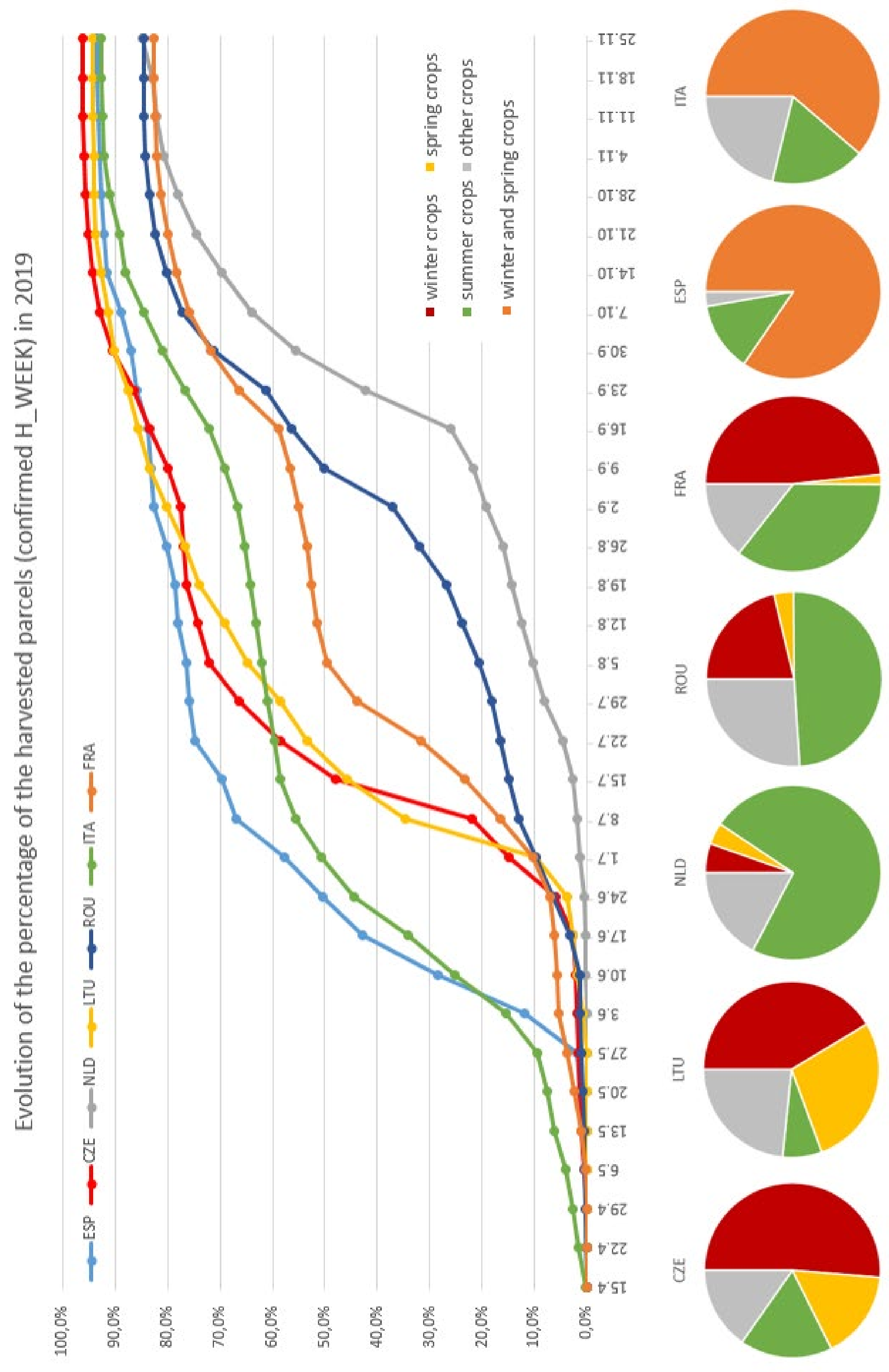


Figure 6-47. Evolution of the percentage of the harvested parcels in 2019 in the 7 pilot countries, with the proportion of the main crop categories within each country

6.4.2 Agricultural practices

As explained in the beginning of the chapter, it was agreed the validation of agricultural practices will be done on reference data provided by PAs. Unfortunately, except for Czech PA, the data provided by other PAs were rather limited and it was not possible to use it for validation.

It was therefore decided to select at least two countries (CZE, CyL) for which additional laborious interpretation of Planet imagery has been performed to present the validation on marker-level using the same procedure as in 2018.

All the results are based on the interpretation of Planet imagery (except for nitrogen fixing crops in CZE). The same approach as described in the previous chapter has been applied to generate the sample of 250 parcels (except for nitrogen fixing crops in CZE where the sample of 100 parcels has been based on the data provided by the PA).

6.4.2.1 Czech Republic

Monitoring of all three practices has been run in 2019 for Czech PA.

Validation results for catch crops for relevant markers and overall compliancy decision are presented in Table 6-39, Table 6-40 and Table 6-41.

Table 6-39. Markers 6 to 10 validation for catch crop monitoring in CZE 2019 (based on the sample of 250 parcels)

M6	Presence of vegetation based on NDVI				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**84,4**	1,2	6,8	92,4
	FALSE	1,2	**4,8**	0	6
	NR	1,6	0	**0**	1,6
	Total	87,2	6	6,8	**100**

M7	Growth of vegetation based on NDVI				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**71,2**	**13,2**	**8**	**92,4**
	FALSE	**0,4**	**5,6**	**0**	**6**
	NR	**1,6**	**0**	**0**	**1,6**
	Total	**73,2**	**18,8**	**8**	**100**

M8	No loss of vegetation based on NDVI				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**66**	4	5,6	75,6
	FALSE	7,2	**12,8**	2,8	22,8
	NR	1,6	0	**0**	1,6
	Total	74,8	16,8	8,4	**100**

M9	No loss of vegetation based on SAR backscatter

	%	TRUE	FALSE	NR	Total
Reference dataset	TRUE	**69,2**	4,8	1,6	75,6
	FALSE	14,8	**6**	2	22,8
	NR	1,6	0	**0**	1,6
	Total	85,6	10,8	3,6	**100**

M10	Presence of vegetation based on SAR coherence				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**50**	38,8	3,6	92,4
	FALSE	0	**6**	0	6
	NR	0	1,6	**0**	1,6
	Total	50	46,4	3,6	**100**

Table 6-40. Validation of the marker "Harvest of the main crop" before the catch crop period in CZE 2019 (based on the sample of 250 parcels)

M_H	Harvest of the main crop between 01.05. and P_START				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**94,4**	2,4	0	96,8
	FALSE	1,6	**1,6**	0	3,2
	NR	0	0	**0**	0
	Total	96	4	0	**100**

Table 6-41. Overall compliancy decision for the catch crop monitoring in CZE 2019 (based on the sample of 250 parcels)

COMPLIANCE (YES – STRONG, MODERATE / NO – POOR, WEAK)					
Reference dataset	%	STR,MOD	WEAK, POOR	NR	Total
	STRONG	**66,4**	9,2	0	75,6
	WEAK	4	**18,8**	0	22,8
	NR	1,6	0	**0**	1,6
	Total	72	28	0	**100**

Validation results for nitrogen fixing crops for relevant markers and overall compliancy decision are presented in Table 6-42, Table 6-43 and Table 6-44.

Table 6-42. Marker 6 validation for nitrogen fixing crops monitoring in CZE 2019 (based on the sample of 100 parcels)

M6	Presence of vegetation in the practice period (01.06.-15.07.)				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**100,0**	0	0	100,0
	FALSE	0,0	**0**	0	0,0
	NR	0	0	**0**	0
	Total	100	0	0	**100**

Table 6-43. Validation of the marker "Harvest of the main crop in the practice period" for nitrogen fixing crops in CZE 2019 (based on the sample of 100 parcels)

M_H	Harvest/clearance in the practice period (01.06.-15.07.)				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**14,0**	58,0	0,0	72,0
	FALSE	7,0	**21,0**	0,0	28,0
	NR	0,0	0,0	**0**	0
	Total	21	79	0	**100**

Table 6-44. Overall compliancy decision for the nitrogen fixing crops monitoring in CZE 2019 (based on the sample of 100 parcels)

	COMPLIANCE (YES – STRONG, MODERATE / NO – POOR, WEAK)				
Reference dataset	%	STR, MOD	WEAK, POOR	NR	Total
	STRONG	**21,0**	7	0	28,0
	WEAK	58,0	**14**	0	72,0
	NR	0	0	**0**	0
	Total	79	21	0	**100**

Validation results for fallow land for relevant markers and overall compliancy decision are presented in Table 6-45, Table 6-46 and Table 6-47.

Table 6-45. Marker 6 validation for fallow land monitoring in CZE 2019 (based on the sample of 250 parcels)

M6	Presence of vegetation in the practice period (01.04.-15.07.)				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**99,6**	0	0	99,6
	FALSE	0,4	**0**	0	0,4
	NR	0	0	**0**	0
	Total	100	0	0	**100**

Table 6-46. Validation of the marker "Harvest of the main crop in the practice period" for fallow land in CZE 2019 (based on the sample of 250 parcels)

M_H	Harvest/clearance in the practice period (01.04.-15.07.)				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**26**	21,6	0	47,6
	FALSE	2,4	**50**	0	52,4
	NR	0	0	**0**	0
	Total	28,4	71,6	0	**100**

Table 6-47. Overall compliancy decision for the fallow land monitoring in CZE 2019 (based on the sample of 250 parcels)

	COMPLIANCE (YES – STRONG, MODERATE / NO – POOR, WEAK)				
Reference dataset	%	STR, MOD	WEAK, POOR	NR	Total
	STRONG	**49,6**	2	0	52
	WEAK	22	**26**	0	48
	NR	0	0	**0**	0
	Total	71,6	28,4	0	**100**

6.4.2.2 Spain (Castilla y Leon)

Monitoring of nitrogen fixing crops and fallow land has been run in 2019 for Castilla y Leon's PA.

Validation results for nitrogen fixing crops for relevant markers and overall compliancy decision are presented in Table 6-48 and Table 6-49.

Table 6-48. Marker 6 validation for nitrogen fixing crops monitoring in CyL 2019 (based on the sample of 250 parcels)

M6	Presence of vegetation in the practice period (01.03.-31.08.)				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**92,4**	2	0	94,4
	FALSE	3,6	**2**	0	5,6
	NR	0	0	**0**	0
	Total	96	4	0	**100**

Table 6-49. Overall compliancy decision for the nitrogen fixing crops monitoring in CyL 2019 (based on the sample of 250 parcels)

	COMPLIANCE (YES – STRONG, MODERATE / NO – POOR, WEAK)				
Reference dataset	%	STR, MOD	WEAK, POOR	NR	Total
	STRONG	**92,4**	2	0	94,4
	WEAK	3,6	**2**	0	5,6
	NR	0	0	**0**	0
	Total	96	4	0	**100**

Validation results for fallow land for relevant markers and overall compliancy decision are presented in Table 6-50, Table 6-51 and Table 6-52.

Table 6-50. Marker 6 validation for fallow land monitoring in CyL 2019 (based on the sample of 250 parcels)

M6	Presence of vegetation in the practice period (01.02.-30.06.)				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**20,4**	30,4	0	50,8
	FALSE	1,6	**47,6**	0	49,2
	NR	0	0	**0**	0
	Total	22	78	0	**100**

Table 6-51. Validation of the marker "Harvest of the main crop in the practice period" for fallow land in CyL 2019 (based on the sample of 250 parcels)

M_H	Harvest/clearance in the practice period (01.04.-30.06.)				
Reference dataset	%	TRUE	FALSE	NR	Total
	TRUE	**3,6**	7,6	0	11,2
	FALSE	3,6	**85,2**	0	88,8
	NR	0	0	**0**	0
	Total	7,2	92,8	0	**100**

Table 6-52. Overall compliancy decision for the fallow land monitoring in CyL 2019 (based on the sample of 250 parcels)

	COMPLIANCE (YES – STRONG, MODERATE / NO – POOR, WEAK)				
Reference dataset	%	STR, MOD	WEAK, POOR	NR	Total
	STRONG	**85,2**	3,6	0	88,8
	WEAK	7,6	**3,6**	0	11,2
	NR	0	0	**0**	0
	Total	92,8	7,2	0	**100**

6.4.2.3 Comparison of 2018 and 2019 results

Comparison of **catch crops monitoring** results from 2018 and 2019 demonstration production show good agreement both on marker and overall compliancy level. Monitoring results for Czech Republic are presented in Table 6-53.

Table 6-53. Comparison of catch crops monitoring accuracy results from 2018 and 2019 seasons in CZE

Marker	Overall accuracy CZE [%]	
	2018	2019
M6	91	92
M7	76	92
M8	77	76
M9	77	76
M10	68	92
Harvest	98	97
COMPLIANCE	80	76

Comparison of **nitrogen fixing crops monitoring** results from 2018 and 2019 demonstration production show good agreement both on marker and overall compliancy level. Monitoring results for Czech Republic and Castilla y Leon are presented in Table 6-54.

The definition of eligible activities within the growing of nitrogen fixing crops monitoring is much stricter in Czech Republic (e.g. obligation of harvest within the period or optional mulching allowed) which makes the eligibility control more difficult.

It is usual practice to harvest/mulch NFC several times and quick re-growth of vegetation follows each harvest which makes detection of harvest within the EFA period rather difficult. Consequently, poorer performance of NFC monitoring in Czech Republic comparing to Spain is observed, due to the low accuracy of harvest detection (which is not checked in Castilla y Leon).

Table 6-54. Comparison of nitrogen fixing crops monitoring accuracy results from 2018 and 2019 seasons in CZE (top) and CyL (bottom)

Marker	Overall accuracy CZE [%]	
	2018	2019
M6	100	100
Harvest	41	35
COMPLIANCE	41	35

Marker	Overall accuracy ESP [%]	
	2018	2019
M6	99	94
COMPLIANCE	99	94

Comparison of **fallow land monitoring** results from 2018 and 2019 demonstration production show good agreement both on marker and overall compliancy level except for harvest marker in CyL. Monitoring results for Czech Republic and Castilla y Leon are presented in Table 6-55.

The significant improvement of performance of fallow land monitoring in Castilla y Leon in 2019 comparing to 2018 is caused by the change of reference period (moved to April – June) which makes the result based on Sentinel-1 data much more stable and consistent. The performance in 2019 is even better than in Czech Republic which is due to the fact that fallow land parcels in Castilla y Leon are rather dry which makes the control more straightforward.

Table 6-55. Comparison of fallow land monitoring accuracy results from 2018 and 2019 seasons in CZE (top) and CyL (bottom)

Marker	Overall accuracy CZE [%]	
	2018	2019
M6	99	100
Harvest	66	76
COMPLIANCE	66	76

Marker	Overall accuracy ESP [%]	
	2018	2019
M6	60	68
Harvest	48	89
COMPLIANCE	48	89

6.4.3 Summary

The demonstration of agricultural practices monitoring in 2019 has been successfully run for all pilot countries. Unfortunately, the continuous mode has been affected in some countries by problems in S1 data pre-processing (data gaps) and late provision of subsidy declaration datasets from PAs.

The performance of harvest detection is satisfactory and consistent within the diverse regions that were monitored and also in time as the results of motoring in 2018 and 2019 are very close. It may be concluded that except for Spain, the harvest detection method as implemented in the Sen4CAP system is robust and provides the results with accuracy above 70% (if one-week difference between real and detected event is considered) and above 80% (for two-weeks difference). More details can be found in the section 6.4.1.8. and Table 6-38.

Also, the implementation of agricultural practices monitoring show very good overall performance and consistency. The situation is much more complex, we have been dealing with diverse implementation of the same practice in different countries and also with changes in rules definitions between 2018 and 2019.

Table 6-56. Summary of compliance validation results of catch crop, nitrogen fixing crop and fallow land monitoring in 2018 and 2019 (only CZE and ESP)

Catch crop [%]						
Compliance	**CZE**	**ITA**	**LTU**	**NLD**	**ESP**	**ROU**
Validation accuracy 2018 (2019)	**80 (76)**	**n.a.**	**87**	**80**	**n.a.**	**88**
Nitrogen fixing crop [%]						
Compliance	**CZE**	**ITA**	**LTU**	**NLD**	**ESP**	**ROU**
Validation accuracy 2018 (2019)	**41 (35)**	**100**	**100**	**n.a.**	**99 (94)**	**83**
Fallow land [%]						
Compliance	**CZE**	**ITA**	**LTU**	**NLD**	**ESP**	**ROU**
Validation accuracy 2018 (2019)	**67 (76)**	**94**	**89**	**n.a.**	**48 (89)**	**n.a.**

The overall compliance accuracy is above 80% for most practices in most countries, the lower performance for nitrogen fixing crop and fallow land in CZE is explained in the chapter 6.4.2.3.

The method for agricultural practices monitoring implemented in the Sen4CAP system is largely based on the analysis of temporal profiles of optical and SAR based indices. Based on the experiences from the demonstration activities run within the project, it is proposed to focus on below issues to improve the reliability of the analysis and resulting accuracy:

- Poorer performance for small parcel size

All the parcels with at least single S1 pixel (20m) were monitored in 2019 (using the rule of at least single pixel centroid falls inside 10 meters parcel buffer);

- Poorer performance for non-uniform parcels

Homogeneous parcel cover and application of practices on entire parcel are assumed during the analysis;

- Gaps in the EO data time series

Missing data in S1 time series (both backscatter and coherence) has strong negative impact on the quality of results and checking the completeness of S1 time series should be integral part of the EO data pre-processing tasks.

7. Quantitative validation of 2020 EO products

In 2020, the consortium generated EO products for 3 pilot countries: Lithuania, Czech Republic and Romania. The other countries (Spain, Netherlands and Italy) did generate the products by themselves, except France which preferred investing in the link between Sen4CAP and NIVA.

7.1 Biophysical indicator product

No validation dataset was available to assess the accuracy of the biophysical indicators.

7.2 Crop Type map

Like in 2018 and 2019, each L4A crop type map from 2020 was validated as required in [AD.4]. For each classification, a subset of the parcels is used for the training of the classification model, while the remaining part is used to carry out an independent validation. The validation results consist in:

- The **confusion matrix**;
- Based on the confusion matrix, the calculation of the **OA** and **Kappa values**;
- Based on the confusion matrix, for each classified crop type, the calculation of the **producer's and user's accuracy**, as well as the **F-score**; the OA and Kappa value of the classification as well as the F-score for all classified crop types sorted by area are grouped in a single dedicated illustration which is provided to the PAs with the product and which is also provided in this report;
- For the producer's and user's accuracy: for all classified crop types sorted by area, the **3 crop types with which they are the most confused** (and the corresponding parcels %).

Compared to the two previous years, an **additional classification** was performed for each monitored period **using only S2 markers**. The results of this second classification are used **for the parcels that are not covered by any S1 pixel (because of their size or shape), but that are covered at least by three S2 pixels**. It enables to increase the number of parcels and area that is monitored by the crop type processor. The validation results of this second classification were also provided with the products. In this report, the validation results are compared between the different countries and through the season with S1 and S2 markers and S2 markers only. The impact of this second classification on the number of parcels and area that is monitored is also assessed.

In 2020, it was decided to focus the validation on the following points:

- **Best Overall Accuracy**:
    - Comparison with 2018 and 2019 validation results;
    - Comparison between the classifications with S1 and S2 markers and with S2 markers only.
- **Accuracy evolution of the main crops** through the season;
- **Impact of the second classification (using S2 markers only)** on the monitored parcels and area;

- **Crop diversification** assessment results.

In Romania, two separated regions were monitored in 2020. As a consequence, the validation results are shown separately for these two regions.

7.2.1 Best Overall Accuracy

7.2.1.1 Comparison with 2018 and 2019 results

Table 7-1 presents the best OA obtained in 2020. The month in which this best OA is achieved is also indicated. **In the three countries that were monitored in 2020, the OA results are very similar to 2019**. It demonstrates the **consistency of the system and of the sentinel data between these two monitored crop seasons**.

Table 7-1. 2020 OA values and comparison with 2018, 2019 and 2020

Country	Overall accuracy						
	2018		2019		2020		
	S1S2	Month	S1S2	Month	S1S2	S2 only	Month
Czech Republic	82.75%	Sep	91.14%	Aug	90.61%	88.19%	Sep
Lithuania	78.74%	Sep	88.08%	Aug	88.07%	82.62%	July
Romania (North)	71.16%	Sep	75.46%	Sep	76.66%	70.84%	Sep
Romania (South)	71.16%	Sep	75.46%	Sep	75.73%	73.05%	Sep

7.2.1.2 Comparison between countries

Like in 2018 and 2019, **the OA varies much from one country to the other** (Figure 7-1). The reasons of these differences have already been discussed in section 6.2.1.

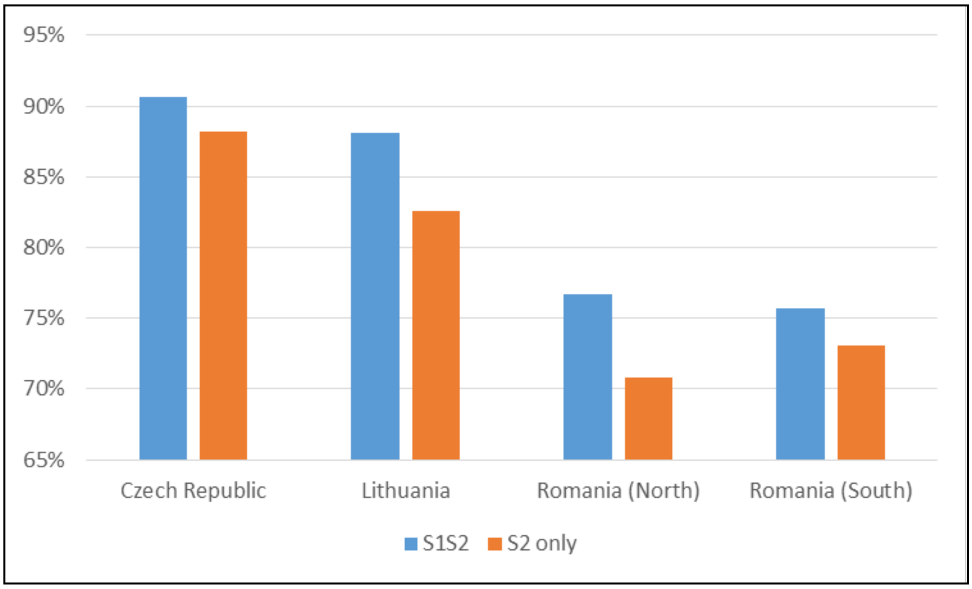


Figure 7-1. 2020 OA values: comparison between countries

7.2.1.3 Comparison between S1 and S2 markers and S2 markers only classifications

The decrease in terms of OA between the classifications using S1 and S2 markers and S2 markers only, is significant especially in Romania North (-5.82%) and in Lithuania

(-5.44%), while it is less significant in Romania South (-2.68%) and in Czech Republic (-2.42%) (Table 7-1). This shows the **added-value of the S1 markers in the classifications**.

7.2.2 Accuracy evolution along the season

7.2.2.1 Overall Accuracy

Figure 7-2 presents the OA accuracy evolution along the season in the three 2020 monitored countries.

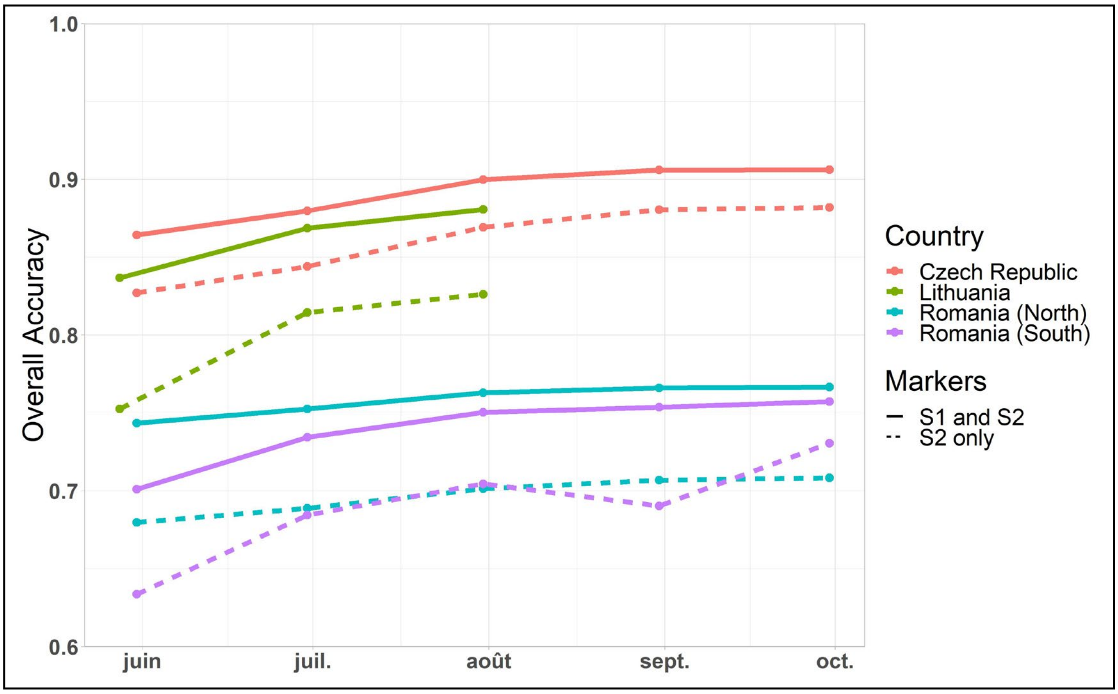


Figure 7-2. 2020 OA values evolution along the season (by country)

It can be seen that:

- In the three countries, the **OA increases much until end-of-July to reach a plateau after**;
- The **OA of the classifications with S2 markers only, follow the same trend as the ones with S1 and S2 markers**, a few percentages below;
- In Romania South, a decrease of OA is observed in the end-of-August S2 only product; a plausible explanation for this is a lack of cloud-free S2 data over this period.

On top of that, the two monitored regions in Romania enable another comparison. Romania North is characterized by a high proportion of grassland (55.88% in terms of parcels area) while Romania South is characterized by a high proportion of annual crops and a lower proportion of grassland (only 8.85% in terms of parcels area) (Figure 7-3). This influences the OA evolution. In Romania North, the OA trend is quite flat, with a relatively high OA already obtained as soon as the end-of-May. Indeed, at that time, the data archive is sufficient enough to distinguish quite well between grassland and annual crops. And because grassland covers the largest part of the region, the OA is influenced by the accuracy in the grassland class. On the contrary, in Romania South, the OA trend is steeper, with a relatively low OA obtained at the end-of-May, and an increase until the end-of-July. This is due to the fact that data from June and July are needed to distinguish between the different annual crops. And because the annual crops cover the largest part of the region, the OA is influenced by the accuracy in the annual crop classes.

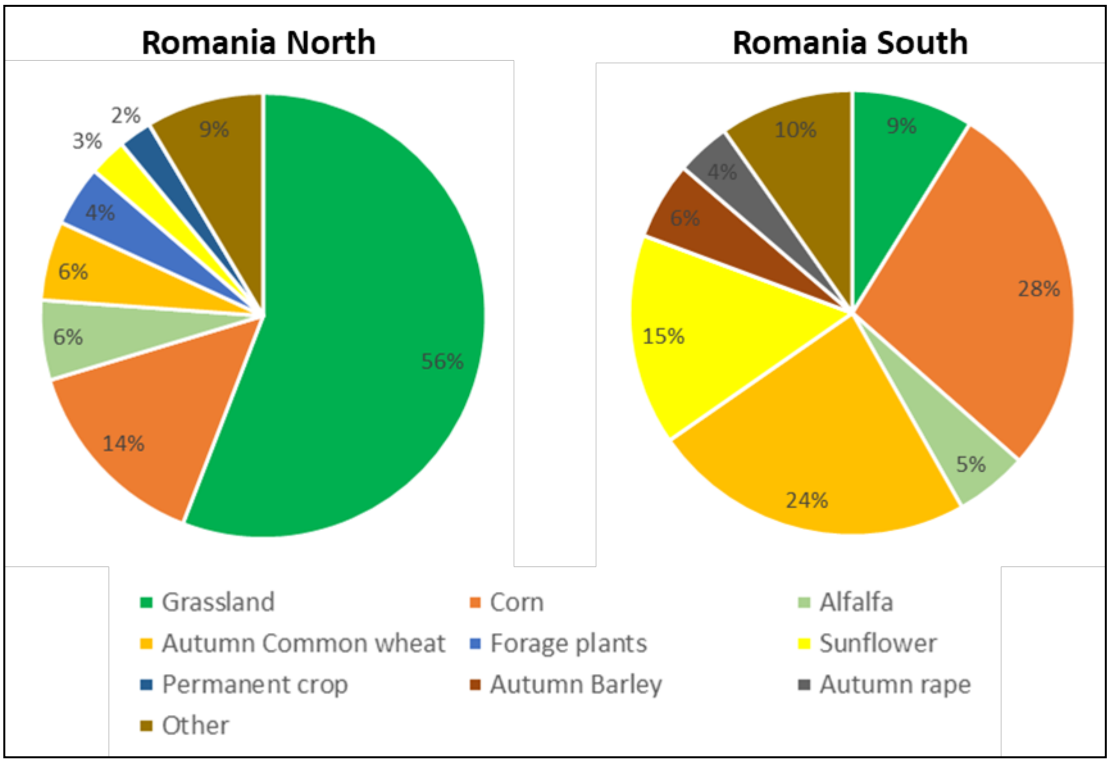


Figure 7-3. Area of the main crops in the two monitored regions in Romania (which cover more than 90% of the crop area altogether)

7.2.2.2 Main crops

In each country, the evolution of the main crops F-score values was analysed. The crops were sorted by parcels area and the main crops were defined as the ones that cover altogether more than 90% of the total area.

These results by country are provided from Figure 7-4 to Figure 7-7. This information can be used by each pilot country to understand the crop type results and improve the classifications accuracy. In particular, the following elements should be addressed:

- The general F-score differences between crops;
- The crops that show a substantial F-score increase along the season;
- The crops that show a F-score decrease at the end of the season.

In **Czech Republic**, the three main crops, **Grassland, Winter wheat and Winter rapeseed**, have **already a high accuracy (above 0.9) early in the season**, and this accuracy does not increase much during the season (Figure 7-4). On the contrary, apart from Lucerne, the accuracy of the other main crops increases constantly during the season. In particular, **Sugar beet and Oat show a strong increase**.

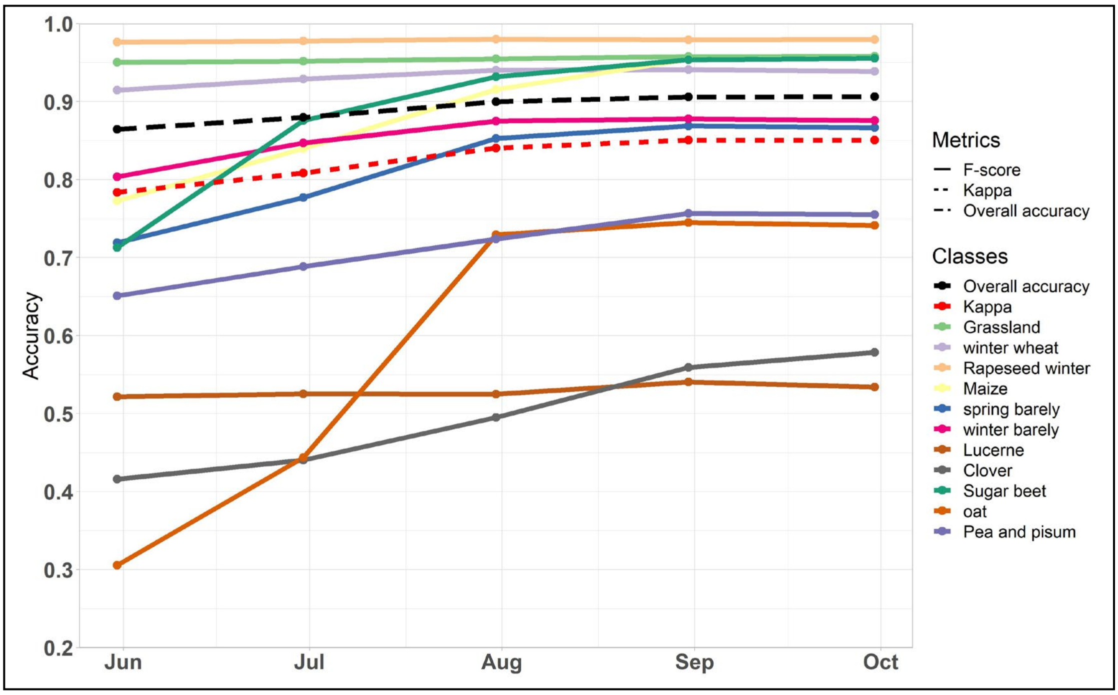


Figure 7-4. Main crops F-score evolution along the season in Czech Republic 2020

In Lithuania, three crops, **Winter cereal, Grass and Winter rape, have also a high accuracy (above 0.9) early in the season**, and this accuracy does not increase much during the season (Figure 7-5). Among the top four main crops, Spring cereal is particular with a lower accuracy (around 0.75 end-of-May) than the others, and a slight increase during the season. On the contrary, the other main crops (**Peas, Beans, Black fallow and Corn) are characterized by a strong increase of accuracy** during the season.

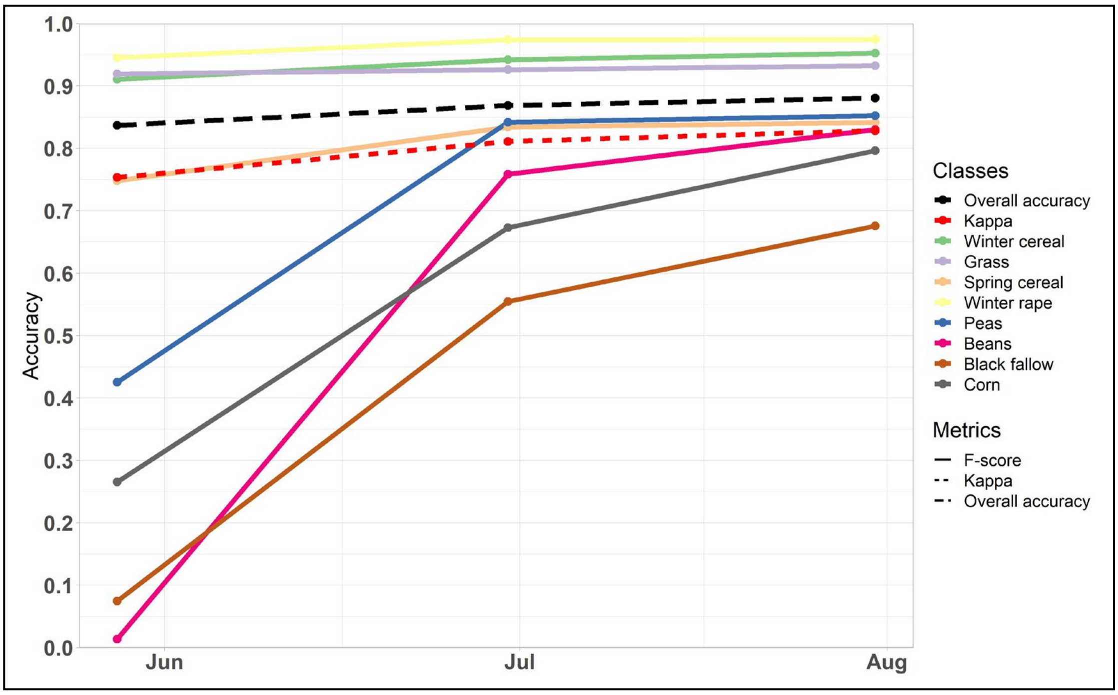


Figure 7-5. Main crops F-score evolution along the season in Lithuania 2020

In **Romania North**, the **differences of accuracy between the main crops** are more pronounced than in the other monitored areas and the accuracy of the permanent crop class is particularly low (Figure 7-6). Through the season, the **accuracy of the main crops does not increase much, except for Sunflower which shows a strong increase**.

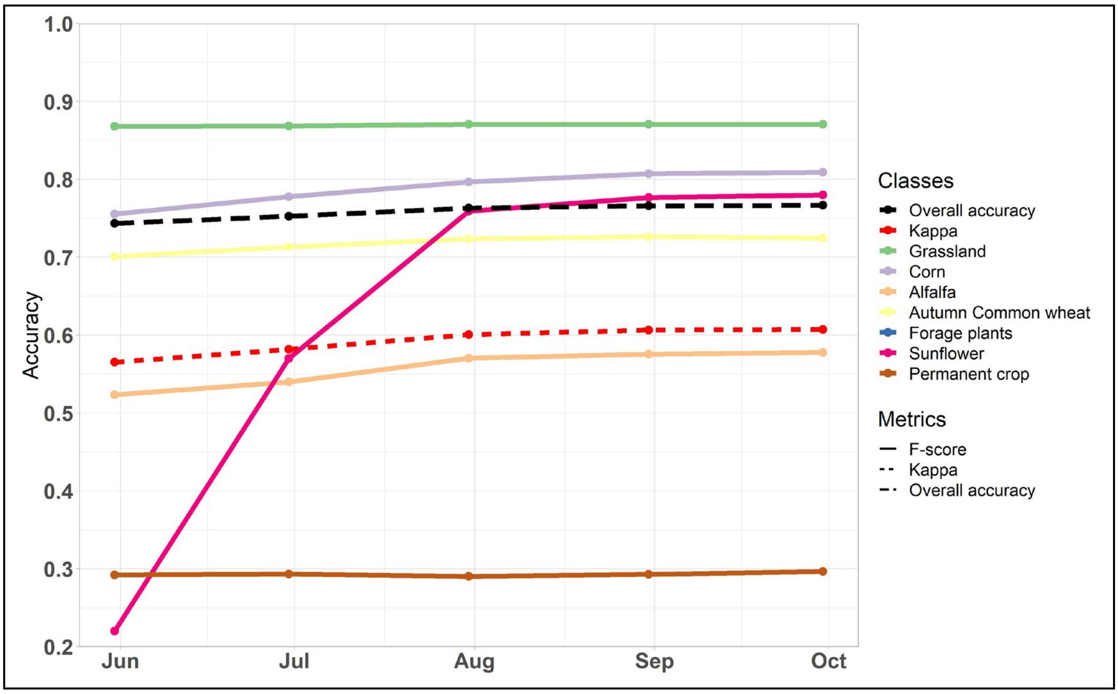


Figure 7-6. Main crops F-score evolution along the season in Romania North 2020

In **Romania South**, compared to Romania North, the differences of accuracy between the main crops are less pronounced, but the OA is slightly lower (Figure 7-7). As in Romania North, only one main crop, **Sunflower, shows a significant increase of accuracy** during the season.

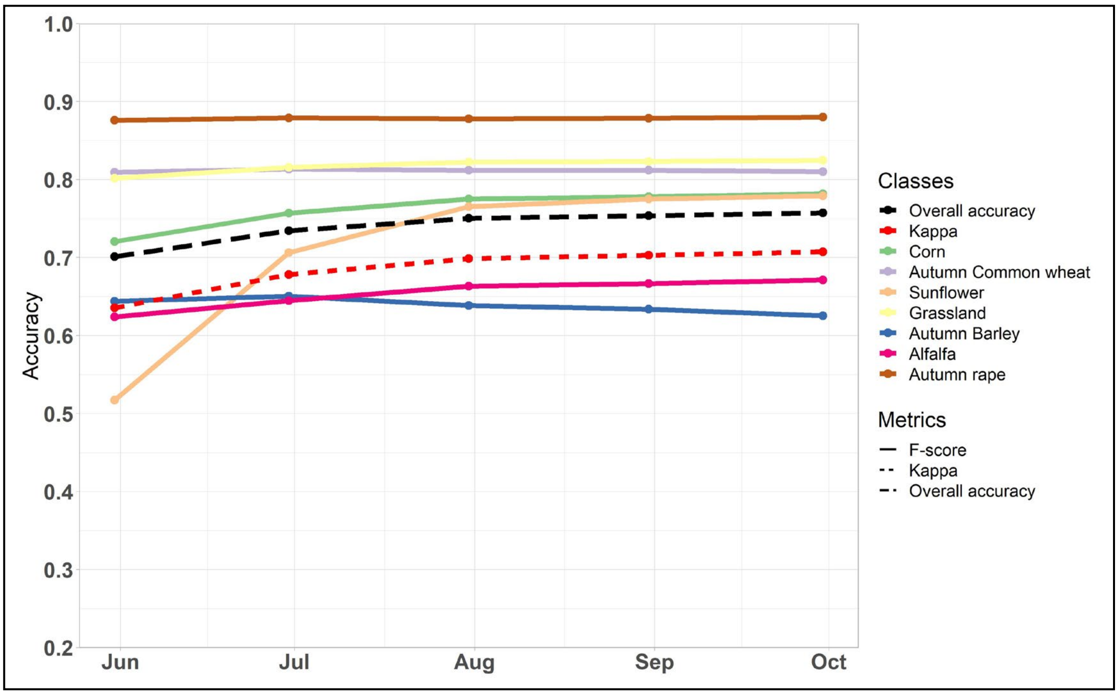


Figure 7-7. Main crops F-score evolution along the season in Romania South 2020

Along with all the crops F-score, the validation results delivered to the pilot countries also include a confusion matrix as well as two tables showing with which crops the different crops are the most confused, and in which proportion. The above observations about the main crops' accuracy evolution can be further developed via the analysis of these tables.

7.2.3 Impact of the second classification (using S2 markers only) on the monitored parcels and area

For each run, a second classification was applied using only S2 markers. The results of this second classification were used for the parcels that are not covered by any S1 pixel, because of their size or shape, but that are covered by minimum 3 S2 pixels. Depending on the country, it increases more or less the number of parcels and area which is monitored.

In **Czech Republic**, 90% of the parcels, covering 99% of the total parcels area, are monitored already with the S1 and S2 markers classification (Table 7-2). The **second classification with S2 markers only, enables to increase the number of classified parcels by 6%, but this represents only 0.38% of the total parcels area**. At the end, less than 0.1% of the total parcels area cannot be monitored by the L4A processor because of the size or shape of the parcels.

Table 7-2. Number of parcels and area classified with S1 and S2 markers and with S2 markers only (Czech Republic, 2020)

	Nr of parcels		Parcels area (ha)	
Total	620739	100.00%	3456440	100.00%
Classified S1+S2	557563	89.82%	3421999	99.00%
Classified S2 only	38539	6.21%	13034	0.38%
Not classified land cover	0	0.00%	0	0.00%
Not classified minS2pix	22115	3.56%	3220	0.09%
Other	2522	0.41%	18188	0.53%

In **Lithuania**, in comparison with Czech Republic, the number of parcels (78.68%) and parcels area (97.33%) which is monitored by the S1 and S2 markers classification is lower (Table 7-3). The **second classification based on S2 markers only, enables to increase the number of parcels which are monitored by 11.30%, and the parcels area by a bit more than 1%**. At the end, 0.26% of the parcels area cannot be monitored by the L4A processor because of the size or shape of the parcels.

Table 7-3. Number of parcels and area classified with S1 and S2 markers and with S2 markers only (Lithuania, 2020)

	Nr of parcels		Parcels area (ha)	
Total	1178899	100.00%	2943492	100.00%
Classified S1+S2	927534	78.68%	2864801	97.33%
Classified S2 only	133233	11.30%	30140	1.02%
Not classified land cover	33693	2.86%	37730	1.28%
Not classified minS2pix	82734	7.02%	7761	0.26%
Other	1705	0.14%	3060	0.10%

In **Romania North and South**, the parts of parcels that are monitored with the S1 and S2 markers classifications (72.07% and 64.51%, respectively) are the lowest among the monitored countries (Table 7-4 and Table 7-5). However, it still covers in both regions more than 90% of the total parcels area. The **second classification using S2 markers only, enables to increase the number of parcels that is monitored by more than 20% in both regions, and the parcels area that is monitored by 6.47% in Romania North and 4.16% in Romania South**. At the end, around 1% of the total parcels area cannot be monitored by the processor because of the size or shape of the parcels.

Table 7-4. Number of parcels and area classified with S1 and S2 markers and with S2 markers only (Romania North, 2020)

	Nr of parcels		Parcels area (ha)	
Total	1525449	100.00%	1556043	100.00%
Classified S1+S2	1099358	72.07%	1439513	92.51%
Classified S2 only	312046	20.46%	100711	6.47%
Not classified land cover	0	0.00%	0	0.00%
Not classified minS2pix	111256	7.29%	14572	0.94%
Other	2789	0.18%	1247	0.08%

Table 7-5. Number of parcels and area classified with S1 and S2 markers and with S2 markers only (Romania South, 2020)

	Nr of parcels		Parcels area (ha)	
Total	668076	100.00%	1951453	100.00%
Classified S1+S2	430986	64.51%	1848198	94.71%
Classified S2 only	160788	24.07%	81086	4.16%
Not classified land cover	0	0.00%	0	0.00%
Not classified minS2pix	71452	10.70%	20688	1.06%
Other	4850	0.73%	1481	0.08%

7.2.4 Crop diversification use case

7.2.4.1 Conformity assessment at the parcel-level

Table 7-6 and Table 7-7 show the results of the conformity assessment at the parcel level, in terms of number of parcels and parcels area. **As expected, compared to 2019, the part of parcels which are not classified is considerably reduced due to the second classification based on S2 markers only**. This is especially the case in Romania. However, as expected also, **this decrease is less important in terms of parcels area**, especially in Czech Republic where the decrease is negligible. In the three countries, the parcels area which is not classified goes from 0.62% (Czech Republic) to 1.65% (Lithuania). Concerning the classified parcels, the parcels area which is classified and conform goes from 92.51% (Romania North) to 96.47% (Czech Republic), and the parcels area which is classified but not conform goes from 2.91% (Czech Republic) to 6.47% (Romania North).

Table 7-6. 2020 conformity assessment results at the parcel level, and comparison with 2019 in terms of number of parcels

Nr of parcels	Czech Republic		Lithuania		Romania North		Romania South	
	2020	Compared to 2019	2020	Compared to 2019	2020	Compared to 2019	2020	Compared to 2019
Classified and conform	91.51%	+ 4.09%	83.18%	+9.28%	80.45%	+22.22%	77.24%	+19.01%
Classified and not conform	4.52%	+1.16%	6.80%	+2.87	12.08%	+5.33%	11.34%	+4.59%
Not classified	3.97%	-5.25%	10.02%	-12.15	7.48%	-27.53%	11.42%	-23.59%

Table 7-7. 2020 conformity assessment results at the parcel level, and comparison with 2019 in terms of parcels area

Parcels area	Czech Republic		Lithuania		Romania North		Romania South	
	2020	Compared to 2019	2020	Compared to 2019	2020	Compared to 2019	2020	Compared to 2019
Classified and conform	96.47%	-0.30%	94.73%	+1.35%	92.51%	+4.99%	93.64%	+6.12%
Classified and not conform	2.91%	+0.33%	3.62%	+0.43%	6.47%	+1.91%	5.22%	+0.66%
Not classified	0.62%	-0.02%	1.65%	-1.78%	1.02%	-6.90%	1.14%	-6.78%

7.2.4.2 Crop diversification assessment at the holding-level

The classification results and conformity assessment results at the parcel-level are used to assess the compliancy of the holdings regarding crop diversification rules. This is done in two steps: first, the category of the holding is defined; second, the compliancy of the holding regarding the rules that correspond to this category is assessed. Figure 7-8 and Figure 7-9 show the results of the crop diversification assessment.

In 2018 and 2019, if a parcel was classified and assessed as not conform at the parcel-level, it was used in the crop diversification worst case scenarios as a parcel which could be anything. **In 2020, an additional rule was added: if a parcel is classified and assessed as not conform at the parcel-level and if the confidence level of the classification in the first prediction is higher than 0.7, the predicted crop is used in the crop diversification worst case scenarios**. The objective of this additional rule is to reduce the number of holdings for which no assessment can be made, because they could belong to different categories and/or because it is not possible to be sure that they respect the crop diversification rules corresponding to the category.

In the **three countries, the big majority of the holdings belong to the exemption 1 category**, meaning that their Total Arable Land (TAL) area is below 10 ha. For these holdings, **no crop diversification is required**, as well as the holdings belonging to the other exemption categories. Regarding the categories which require crop diversification, the part of **holdings in category 2 (with a TAL greater than 30 ha and no other exemption) is higher in Czech Republic (21.33%) than in the other countries**.

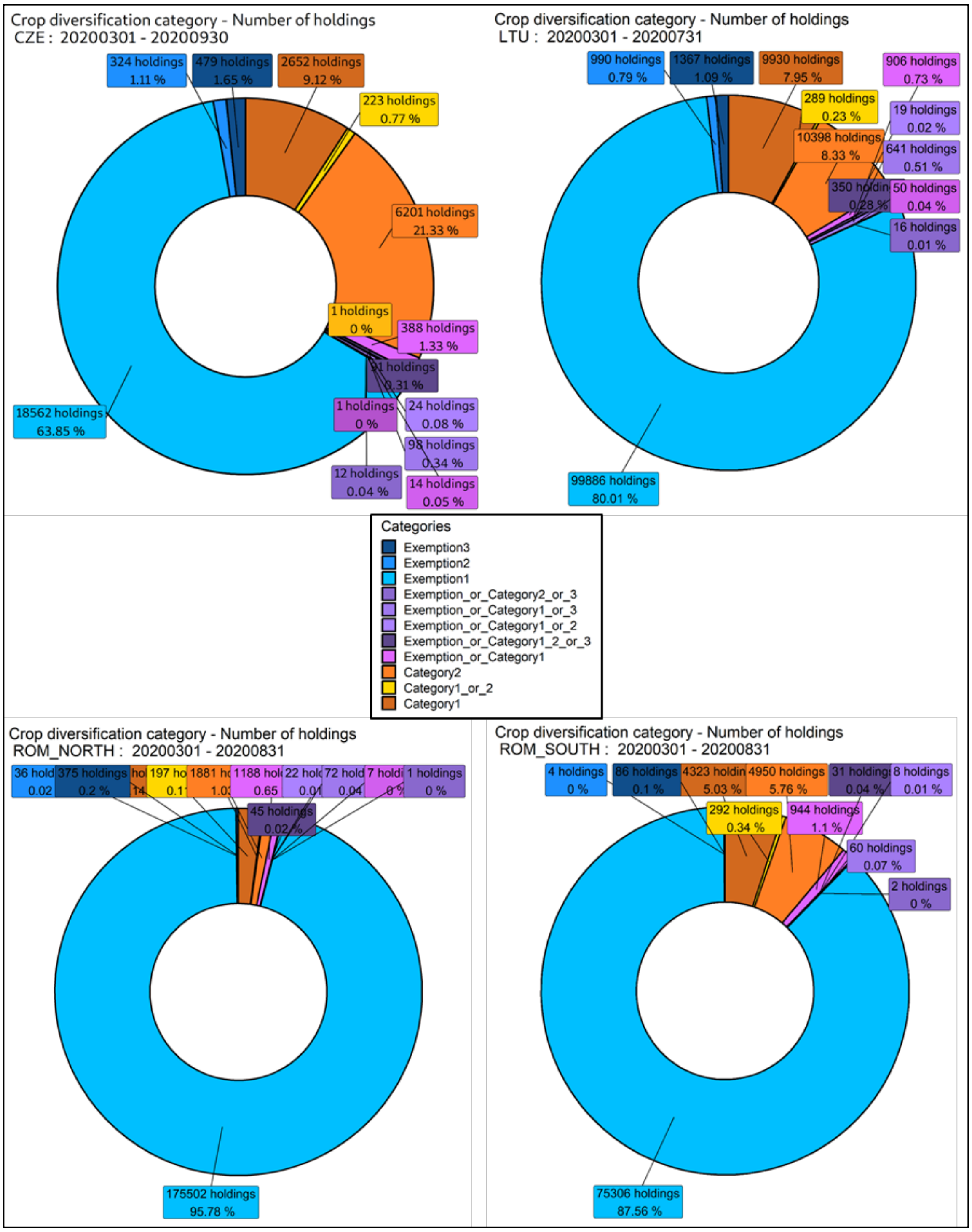


Figure 7-8. 2020 crop diversification category results

Concerning the final crop diversification assessment, **the part of holdings for which no assessment can be made was reduced in the three countries in 2020 compared to last year**: 3.61% in Czech Republic compared to 4.50% in 2019, 2.10% in Lithuania compared to 3.50% in 2019 and 1.03% and 2.25% in Romania compared to 2.31% in 2019. The **part of holdings assessed as not compliant** regarding the crop diversification rules applied in this use case, **is very limited in the three countries (less than 1%).**

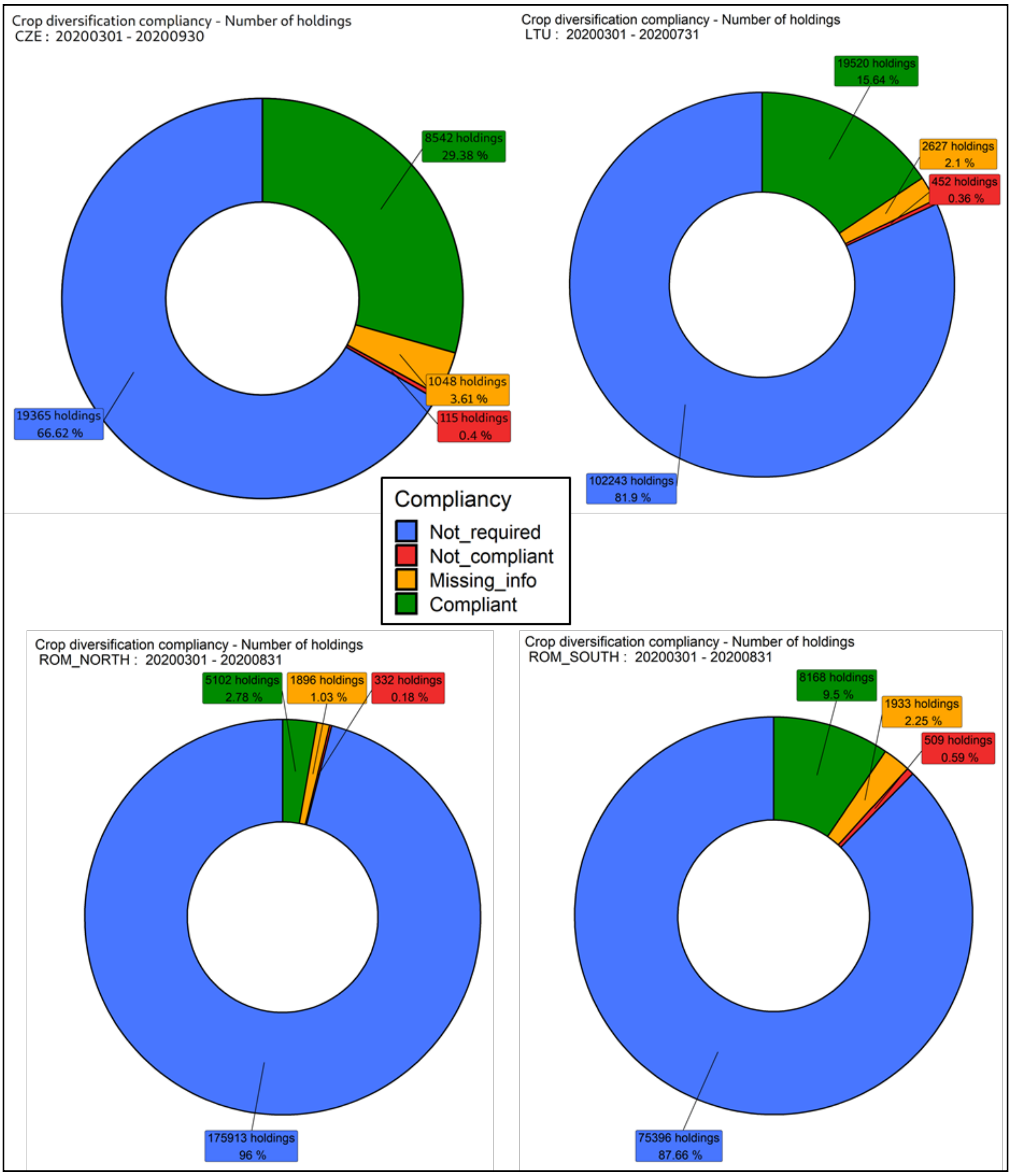


Figure 7-9. 2020 crop diversification assessment results

7.3 Grassland Mowing detection product

For 2020 products, the validation was more qualitative than in previous years, based on truth datasets provided by the Paying Agencies. The PAs that provided field data for this purpose are Czech Republic and Lithuania. The methodology followed for this validation has depended on the characteristics of validation data. It is the presented below, with the results, country by country.

7.3.1 Czech Republic

7.3.1.1 Validation datasets characteristics

The validation dataset provided by the CZE PA (inspectors on site control) consists in a set of parcels continuously monitored by field visits, with a bi-weekly frequency, from the mid of May to the mid of November 2020. For each parcel, grazing and mowing events observed for each date of survey are reported with also a synthetic final report that summarizes all the events detected on the field during the entire monitoring period.

Table 7-8 and Figure 7-10 describe their characteristics and geographical distribution.

Table 7-8. 2020 CZE PA validation dataset characteristics

In situ data	Parcel (n°)	Crop code
Mowed	318	T, G
Not mowed	3	T, G

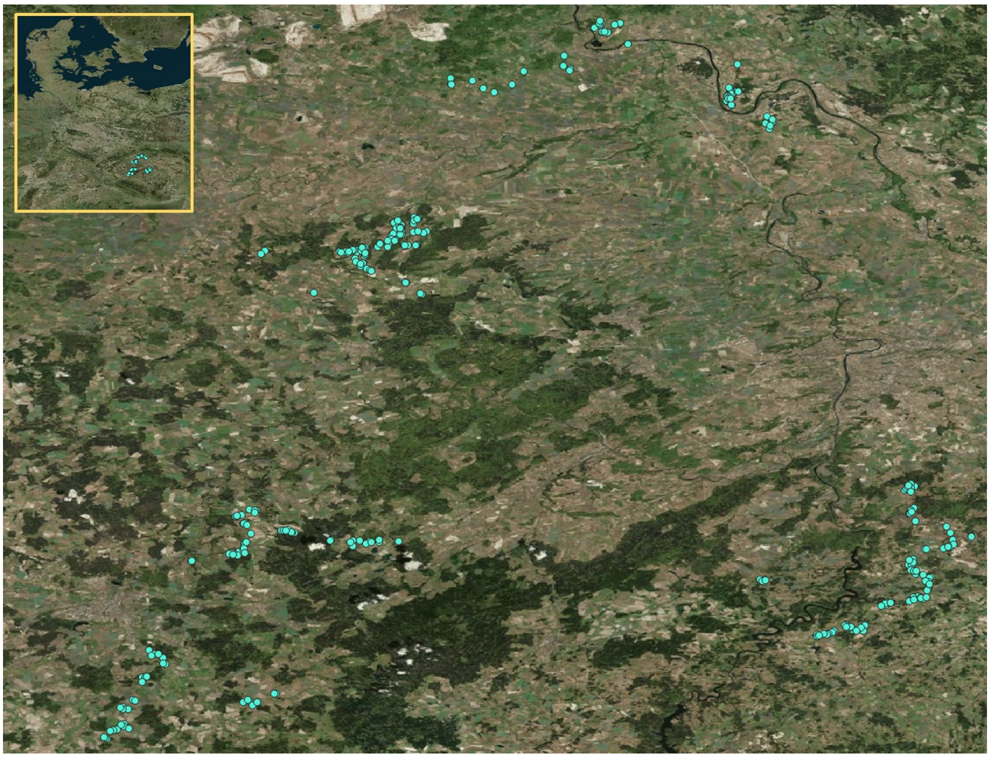


Figure 7-10. Distribution of 2020 CZE PA validation dataset

The grassland mowing product to be validated was the last delivered to the PA, covering the entire period of monitoring, from the 1st of April to the 31st of December 2020 (S2AGRI_S4C_L4B_PRD_S2_20210113T001410_V20200401T000000_20201231T000000).

Considering that the last surveys occurred during the first days of November 2020, the product mowing events considered for validation cover the limited period from the 1st of April to the 3rd of November 2020. From the truth dataset, for the validation, only the parcels that matched by parcel ID with the grassland parcels, have been selected for the accuracy analysis (285 parcels that were mowed, at least, 1 time or not mowed at all, excluding parcels just grazed).

7.3.1.2 Validation results

The validation approach is the same as the one described in the section 5.3. The results obtained with are presented in Table 7-9.

Table 7-9. Validation results for grassland mowing detection in CZE 2020, based on field survey

Percentage of parcel moved: any							
Parcel size class	Parcel n°	Total truth mowing events	TP	FP	FN	Recall	Precision
Any	285	453	341	215	109	76%	61%

7.3.2 Lithuania

7.3.2.1 Validation datasets characteristics

The validation dataset provided by the LTU PA (inspectors on site control) consists in 2 groups of parcels:

- Fully mowed or grazed within the deadline established by the regulation and therefore, compliant;
- Not mowed (or just partially mowed) or not grazed within the deadline established by the regulation and therefore, not compliant.

Table 7-10 and Figure 7-11 describe their characteristics and geographical distribution.

Table 7-10. 2020 LTU PA validation dataset characteristics

In situ data	Number	Crop code
Compliant	1569	DGP, GPA, GPZ
Not compliant	1638	DGP, GPA, GPZ

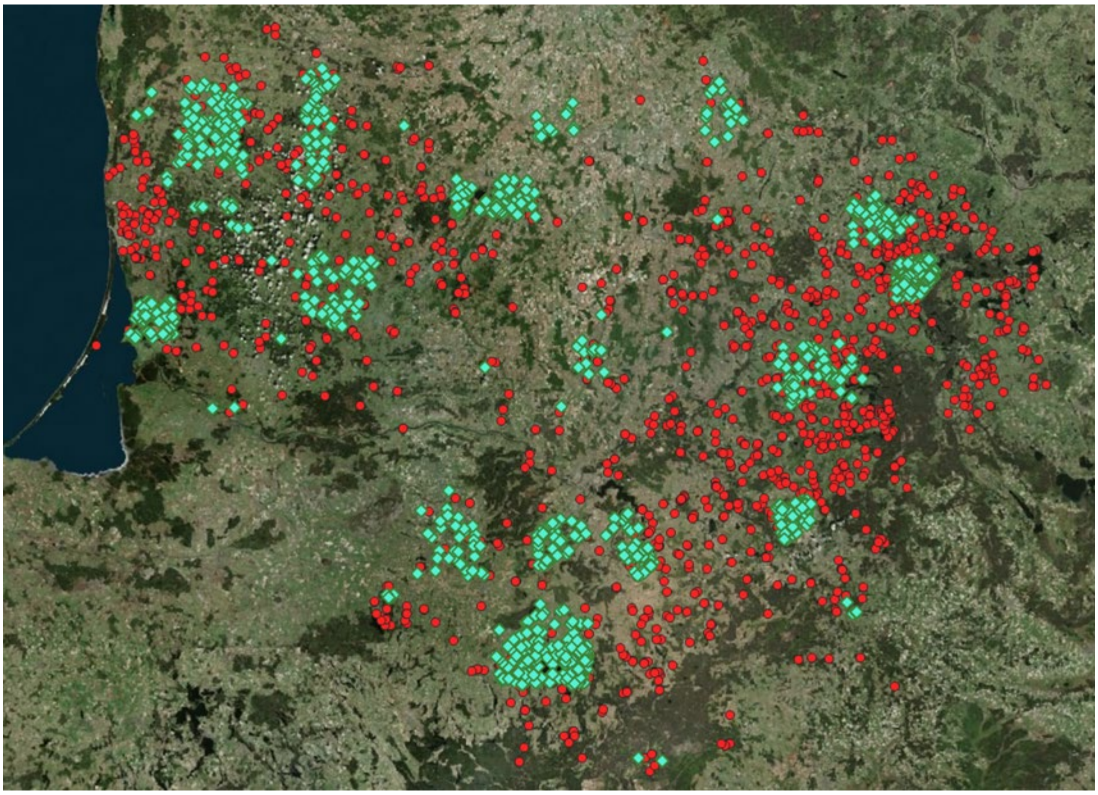


Figure 7-11. Distribution of 2020 LTU PA validation dataset

The grassland mowing product to be validated was the last delivered to the PA, covering the entire period of monitoring, from the 1st of April to the 21st of October 2020 (S2AGRI_S4C_L4B_PRD_S5_20201024T162402_V20200401T000000_20201021T000000). From the truth dataset, for the validation, only the parcels that matched by parcel ID with the grassland parcels monitored, have been selected (Table 7-11).

Table 7-11. 2020 LTU PA validation dataset characteristics used for the accuracy analysis

In situ data selected for validation	Number	Crop code
Compliant	1555	DGP, GPA, GPZ
Not compliant	1482	DGP, GPA, GPZ

7.3.2.2 Validation results

Considering that the validation dataset of LTU 2020 provides just information on compliant or not compliant parcels according to their regulation, but does not detail each mowing event occurred on the parcel, the product validation has been performed analysing the level of agreement between truth and grassland mowing product in terms of compliancy results.

The approach aimed at estimating the percentage of:

- Parcels correctly detected as compliant, that means parcels correctly detected as mowed within the deadline (Correct Compliancy/TP);
- Parcels correctly detected as not compliant, that means parcels correctly detected as no mowed within the deadline (Correct Compliancy/TN).

The results are shown in Table 7-12.

Table 7-12. Validation results for grassland mowing detection in LTU 2020, based on OTSC data

In situ data	Truth parcel (n°)	Product parcel (n°)	% Correct compliancy	% Uncorrect compliancy
Compliant	1555	1282	82% (TP)	18% (FN)
Not compliant	1482	1140	77% (TN)	23% (FP)

The validation dataset provided by the LTU PA includes also information about not compliancy due to partial mowing. Therefore, considering that the algorithm works at parcel-level and that, in case of partial mowing (especially for those covering the larger part of the parcel) it is not possible to distinguish partial events, an additional analysis has been carried out to understand the impact of parcels partially mowed on the 23% of FPs ("Not compliant" parcels erroneously detected as Compliant/mowed within the deadline). In this case, the 40% of parcels incorrectly detected as Compliant, have been subject to partial mowing.

7.4 Agricultural Practices monitoring product

7.4.1 Harvest and EFA practices

The validation activities in 2020 have been rather limited due to the non-availability of proper reference datasets.

Only two countries have provided farmer's reports or in-situ data: Lithuania and Czech Republic.

The farmer's reports from Lithuania did not include any information that may be used for validation of L4C products.

The Czech PA provided in-situ data collected during the field campaign run in 2020. Unfortunately, most of the visited arable land parcels were not subject of greening applications (L4C analysis was not done on these parcels) or they were visited after the end of relevant practice periods (the compliancy cannot be checked). The only exception was 11 parcels with fallow land declarations. The parcel status reported by the field visit (mature vegetation, harvested, ploughed) was compared with the results of harvest detection analysis and two relevant rules were constructed:

- harvest shall be detected after the date of field visit for parcels reported as mature vegetation
- harvest shall be detected before the date of field visit for parcels reported as harvested or ploughed

Except one single parcel, no disagreement has been found and the detected harvest week was compliant with the above rules.

7.4.2 Tillage detection

Tillage detection has been introduced as the new functionality in the Sen4CAP system. The tillage detection processor does not differentiate between the tillage & ploughing, it is implemented in a way that it detects all farming activities that cover all the physical and temporal variability of tilling & ploughing practices.

The processor is based on the following concept:

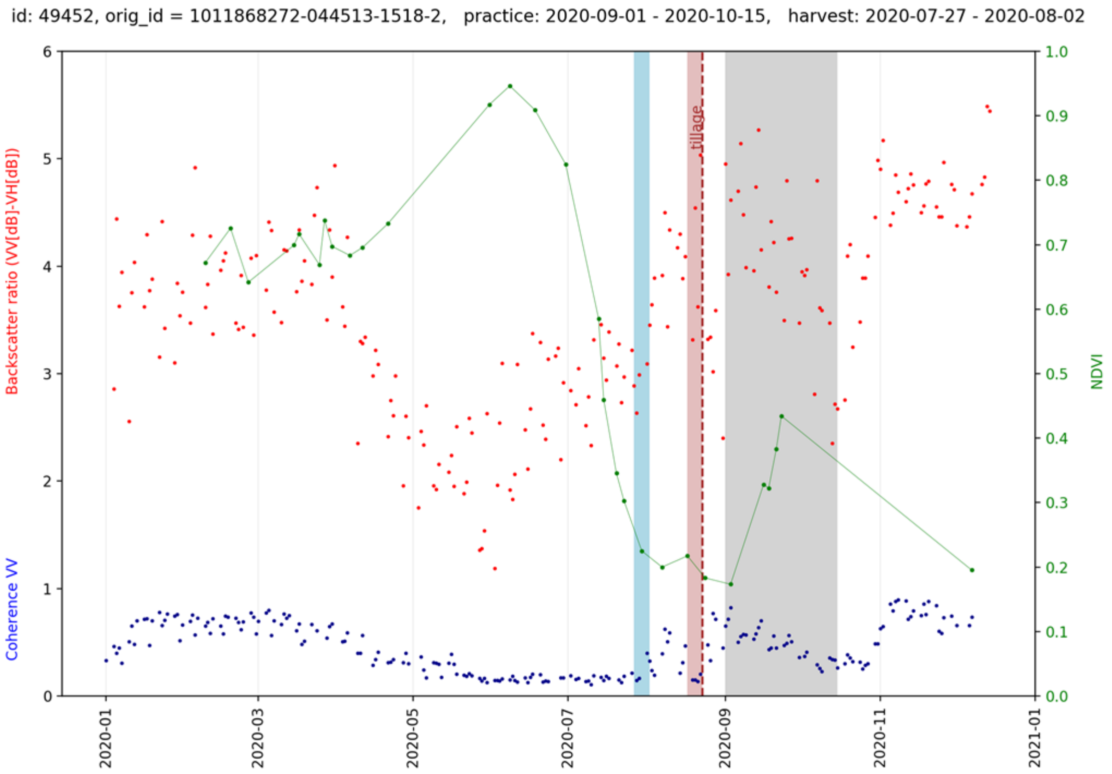
- Same approach as agricultural practices monitoring (automated analysis of EO-based temporal profiles through "harvest" markers);
- Focus on tillage applied after the harvest of the main crop;
- The implementation follows continuous monitoring concept (similarly as harvest detection: weekly evaluation);
- It provides generic solution that could be applied in any EU country (no country specific tailoring).

The implementation method involves two basic rules:

- Detection of harvest is used as the pre-condition to start the tillage detection;
- Tillage evaluation is based on analysis of coherence drops identified in the temporal profile (coherence should increase during/after of harvest and decrease after ploughing/tilling).

The process of tillage detection can be described in Figure 7-12. The start of increase of coherence provides indication of harvest (detected harvest week is represented by blue strip), the subsequent coherence drop indicates the application of tillage (detected tillage week is represented by red strip). This is confirmed by the date of tillage as reported by the farmer (red dotted line).

Figure 7-12. Tillage detection and NDVI, backscatter and coherence temporal profiles



7.4.2.1 Lithuania

Reference datasets

The PA has provided the geotagged photographs acquired by farmers to document parcel status at the date of acquisition of the photograph for more than 600 parcels (examples shown in Figure 7-13). All photographs were interpreted to record the parcel status and to categorize the parcels to select the subset that documents the ploughed parcels.

Also, the PA has provided the list of parcels that were not subject of tillage in 2020.

Figure 7-13. Example of photos provided by the farmer

Validation

The validation has been based on the application of the obvious rule - if the parcel was interpreted as ploughed, it means the tillage had to be applied before the acquisition date of the photograph.

The acquisition date of the photograph has been compared with the week in which the tillage was detected by the system. The difference has been calculated only if the tillage has been detected after the acquisition date of the photograph. All the other cases (tillage detected before the photo is taken) are considered ok and are reported in the first category (see Table 7-13).

Table 7-13. Accuracy of tillage detection based of geotagged photos – LTU 2020

Difference	Photos	Accuracy	
[weeks]	No. of parcels	Category	Cumulative
Before & 0-1	251	72%	
2	50	14%	86%
3	12	3%	89%
> 3	14	4%	93%
Not detected	23	7%	100%
Total	**350**	**100%**	

The resulting accuracy figures are rather high but it has to be taken into account that the real detection accuracy is probably lower due to the fact that the validation was not done against real tillage dates but only using the more „relaxed" procedure in comparison to parcel status information.

Dedicated accuracy analysis has been done for parcels reported under no tillage regime (Table 7-14).

Table 7-14. Assessment of parcels under no tillage regime – LTU 2020

Parcels under tillage regime		
Category	No of parcels	Share
Tillage not detected	1662	32%
Tillage detected	3529	68%
Total	**5191**	**100,0%**

The results show high rate of false positives, i.e. detection of tillage for parcels where any tillage has not been reported. There are two aspects to consider when interpreting the results:

- The tillage detection is based on the analysis of coherence marker and the first significant drop after the harvest is interpreted as tillage. It means that if other activities occur after the harvest (e.g. harvest residuals management) the detector likely detects this activity as tillage application;
- The quality of reference has not been assessed. The data are based on farmers' reports and it is our experience from past validation exercises that these datasets are not fully consistent and may include errors or wrong declarations.

Figure 7-14 and Figure 7-15 below show examples of analysed parcels.

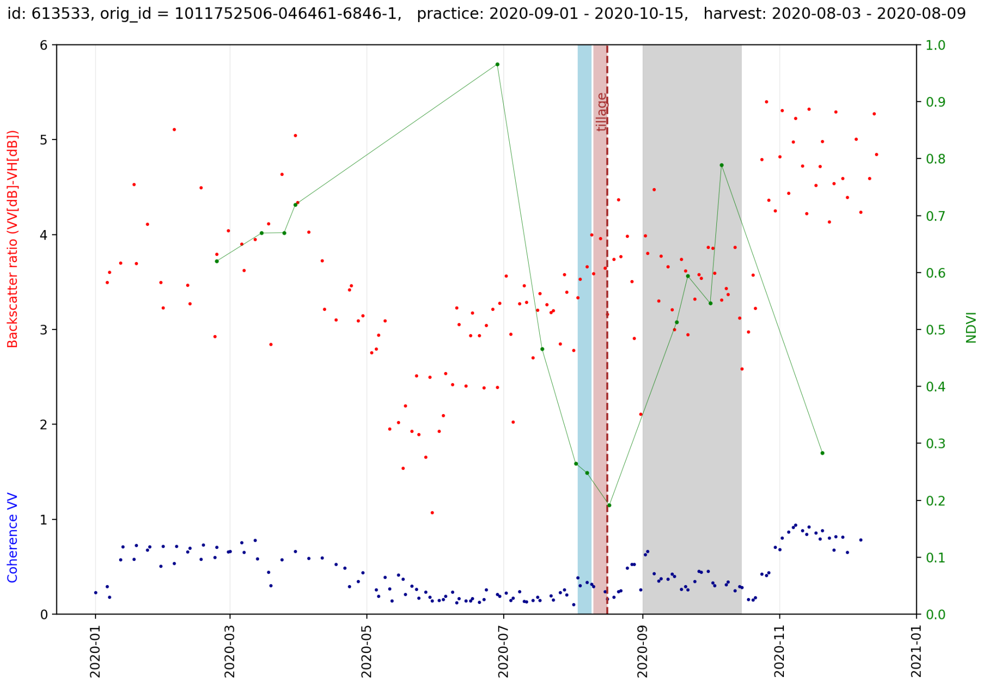


Figure 7-14. Example of parcel with tillage detected just after the harvest – LTU 2020

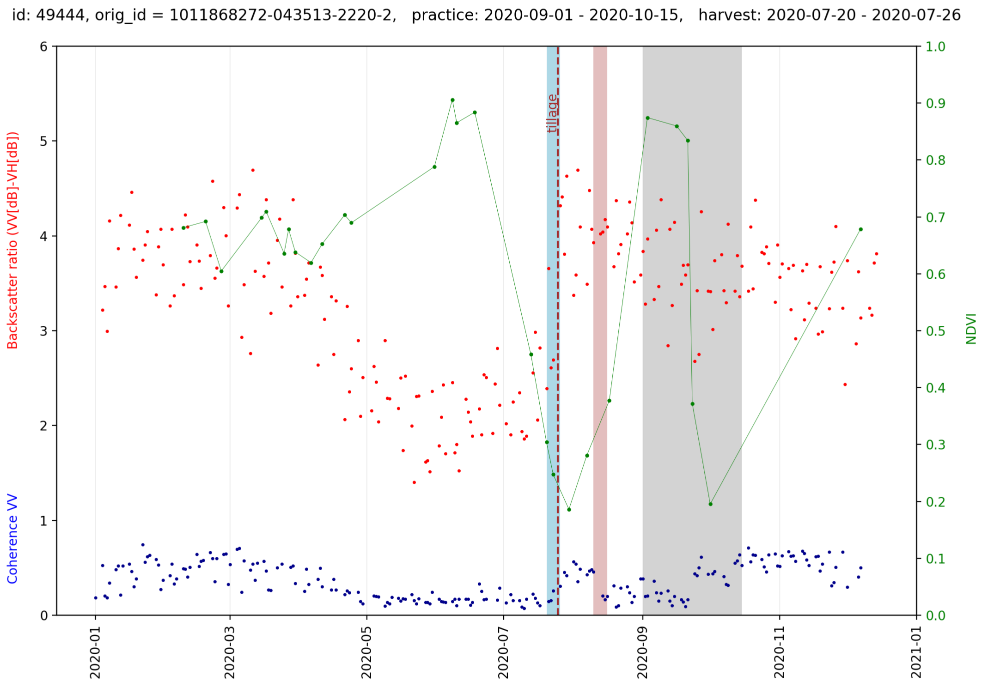


Figure 7-15. Example of parcel with late tillage detection (no clear coherence drop is detected just after the harvest) – LTU 2020

7.4.2.2 Spain - Castilla y Leon

Reference datasets

The PA has provided the farmers' reports from 2018 about the dates of applied practices - harvest/tillage/sowing (for less than 100 parcels). Before using this dataset for validation, only relevant parcels have been selected. Also, visual interpretation of Planet imagery was done to exclude parcels with obvious errors in dates reported by farmers.

The second dataset was represented by the data from GPS tracking of agro machinery in the period of 25.-30.9.2020 (> 1000 parcels). Based on this dataset, we can select parcels on which some farming activities occurred during the week of 25.9. Unfortunately, no information is available concerning the type of activity (harvest/tillage/sowing/other management).

Validation

The validation based on 2018 dataset has been done using the standard approach, the reported tillage date was compared with the week in which the tillage was detected by the system (Table 7-15).

Table 7-15. Accuracy of tillage detection based of farmers' reports – ESP 2020

Difference	Farmers	Accuracy	
[weeks]	No. of parcels	Category	Cumulative
0 – 1	11	33%	
2	8	24%	57%
3	2	6%	63%
> 3	12	37%	100%
Not detected	0	0%	
Total	**33**	**100,0%**	

The tillage has been detected for all reference parcels. Higher rate of more than 3 weeks differences may be caused by the fact that in case multiple drops for coherence marker are detected the detector detects the first one as tillage application (see examples below in Figure 7-16 and Figure 7-17). Such situation occurs when multiple practices are applied after the harvest (e.g. harvest residuals management).

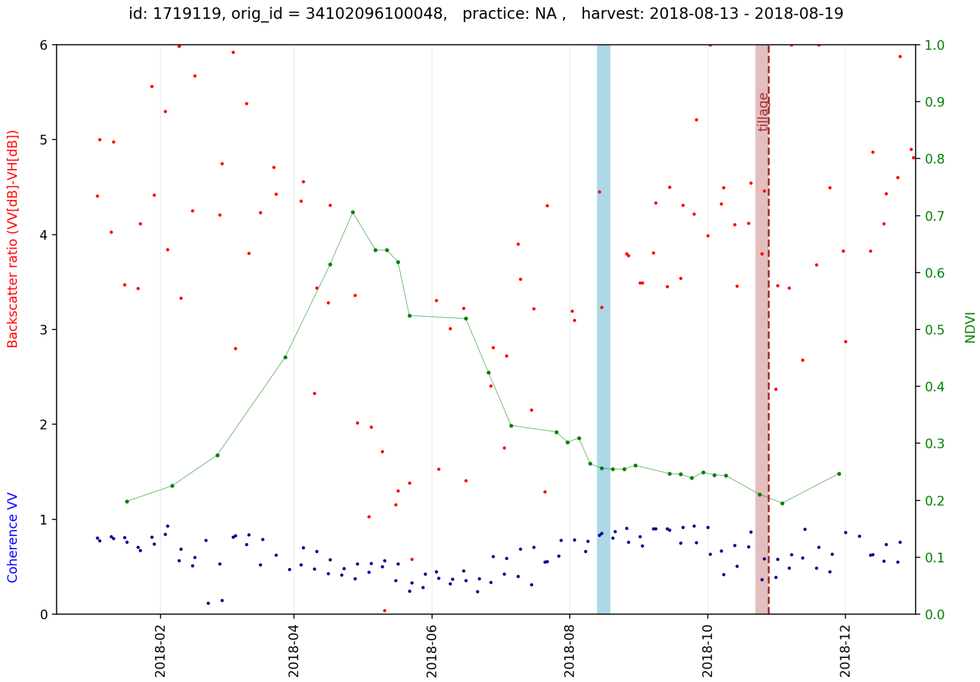
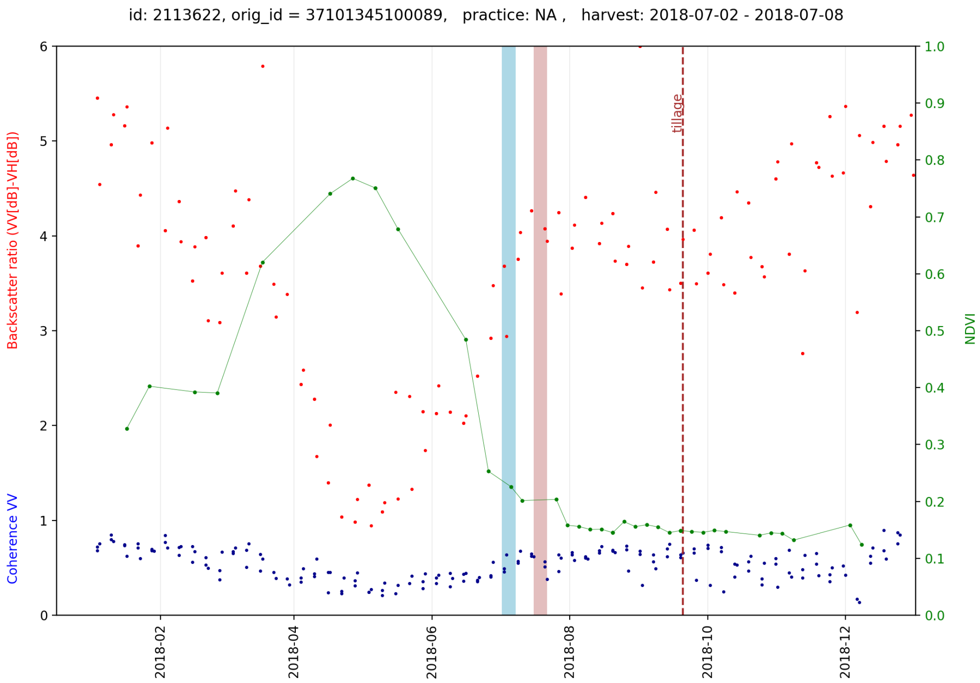
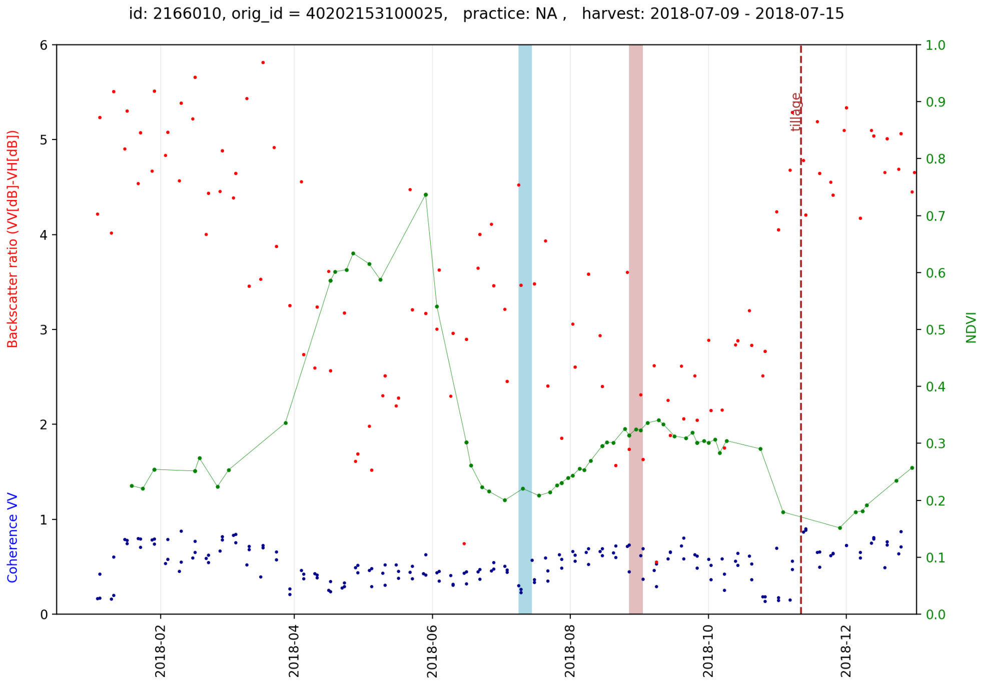


Figure 7-16. Example of parcel with correct tillage detection – ESP 2020





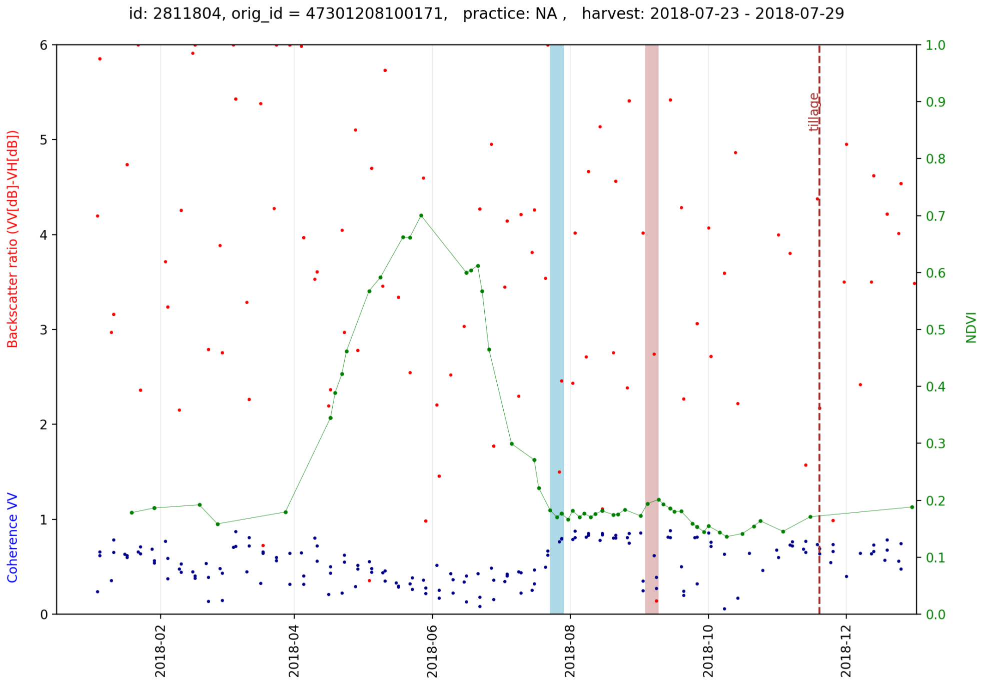


Figure 7-17. Three examples of parcel with earlier tillage detection (clear coherence drop is probably caused by an activity other than ploughing) – ESP 2020

The dataset of 2020 (GPS tracking data) has been processed to select relevant parcels, i.e. the parcels for which the harvest or tillage detection was still active in the period of 25 - 30.9.2020. All parcels with tillage detected before 25.9 were therefore excluded. The differences between the "GPS" week and the week in which harvest or tillage was detected has been computed and accuracy figures derived (Table 7-16).

Table 7-16. Accuracy of tillage detection based of farmers' reports – ESP 2020

Difference	GPS tracking	Accuracy	
[weeks]	No. of parcels	Category	Cumulative
0 – 1	193	38%	
2	76	15%	53%
> 2	16	3%	56%
Harvest or tillage not detected	223	44%	100%
Total	**508**	**100%**	

The accuracy figures in Table 7-16 are rather indicative as we do not have any additional information what type of farmer's activity occurred in the monitored week. Even the parcel in the last row (Harvest or tillage not detected) may be considered correct as both harvest and tillage could have been applied before.

7.4.2.3 Summary

The validation of tillage detection processor has been successfully run for the two pilot countries that provided reference datasets. It has been confirmed that the tool can be run operationally to analyse the parcel status after the harvest of the main crop and to detect application of tillage.

Due to the requirement to develop generic tool not tailored to the specific conditions of particular country, the decision making implemented in the tool is relatively simple and fully transparent. It gives the opportunity to use the tool in different conditions to see how varying parcel status is reflected in the coherence temporal profile. The user has the option to adjust two coherence thresholds introduced in the system to reflect local conditions and increase/decrease the sensitivity to coherence drops. Also, it is possible to export the coherence marker and construct own analytical rules outside the system.

The results of validation confirm high rate of overall tillage detection and 60-80% accuracy when assessing 2 weeks difference towards the reference dates. Lower accuracy is found for no tillage parcels (false detections). This may be caused by the fact that multiple drops for coherence marker are often detected and the tool is not constructed to distinguish the one that is caused by the tillage. On the contrary the detector likely detects the first one as tillage application.