

Agricultural practices monitoring from Sentinel-1 and Sentinel-2

Concepts and methods - EFA use case

Lubos Kucera, GISAT – Czech Republic
Sen4CAP hands-on training, 22-23 January 2020



sen4cap
common agricultural policy

UCL
Université
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de Louvain

CS
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 **SINERGISE**

 **gisat**

DATA:

- The temporal profile of EO derived biophysical indices can indicate vegetation status and a change in vegetation status over time

APPROACH:

- Analysing the temporal profiles and comparing these to agricultural practices rules

OUTCOME:

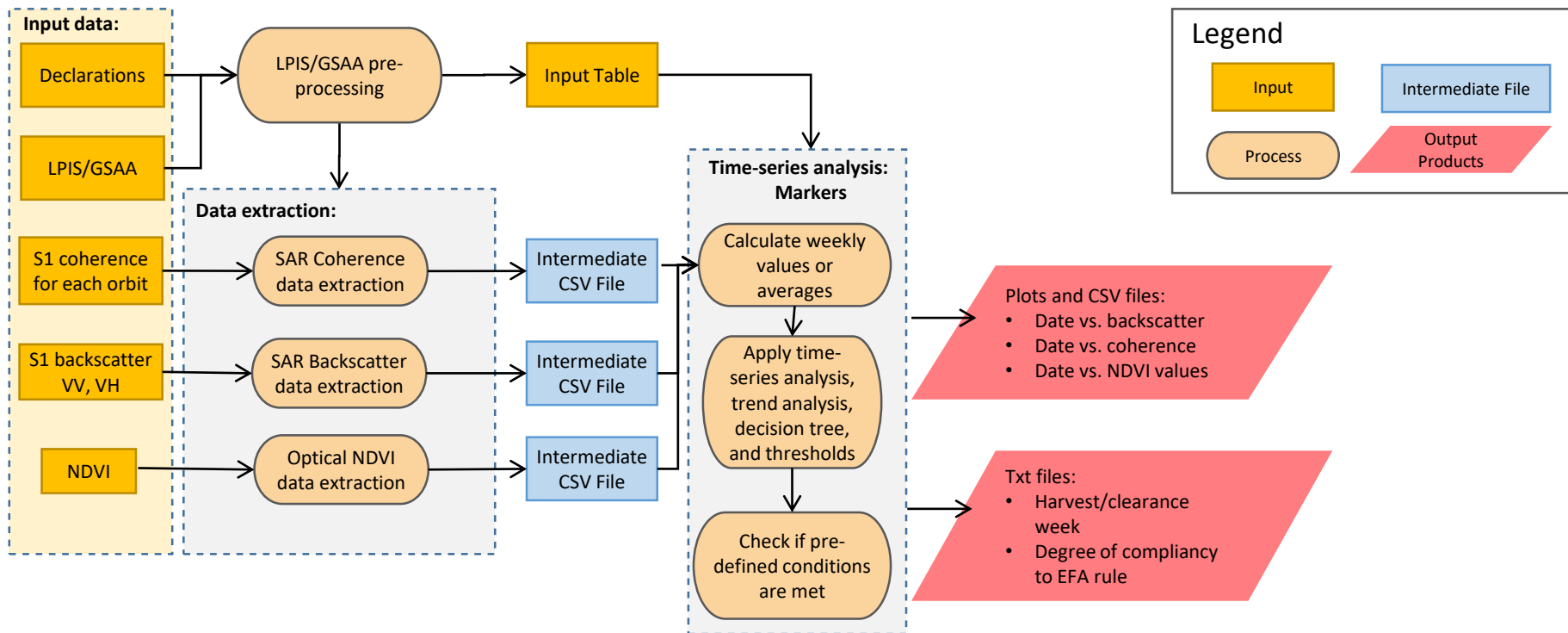
- Provide information on the occurrence of crop harvest or clearance events
- Provide an indication of compliancy, of:
 - Catch crops
 - Nitrogen fixing crops
 - Land lying fallow

Specifications for L4C product



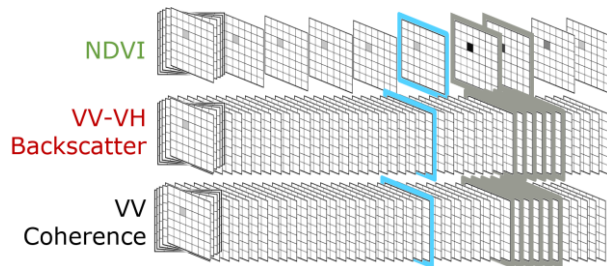
Properties	Product specification
Spatial coverage	National
Time period	Year (required observation period)
Temporal frequency	Week / required observation period
Delivery time	Weekly
Spatial resolution	Parcel-level
Legend	depending on the practice
Format	.csv Table and SHP
Projection	UTM-WGS84
Metadata	XML file
Products distribution	FTP; visualization tool

Workflow of processing chain



Monitoring approach

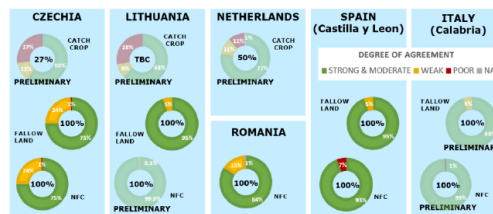
- Analysing the dense S1 and S2/L8 time series per parcel



- Evaluating relevant markers derived from the time series analyses

MARKERS FOR HARVEST	
Presence of vegetation cycle	Threshold of NDVI/FCOVER
Loss of vegetation	Break in NDVI/FCOVER (decrease)
Loss of vegetation	Break in VV/VH ratio (increase)
Presence of vegetation cycle	Threshold of VV/VH ratio
Stable low/no vegetation condition	Break in VV Coherence (increase)
MARKERS FOR AGRICULTURAL PRACTICES	
Presence of vegetation	Threshold of NDVI/FCOVER
Growth of vegetation	Break in NDVI/FCOVER (increase)
No loss of vegetation	No break in NDVI/FCOVER (decrease)
No loss of vegetation	No Significant Positive Trend in VV/VH ratio
Dynamic/high vegetation condition	No Large Break in VV Coherence (increase)

- Applying decision trees to determine the degree of compliancy of the declared agricultural practice



Parcel temporal profiles interpretation

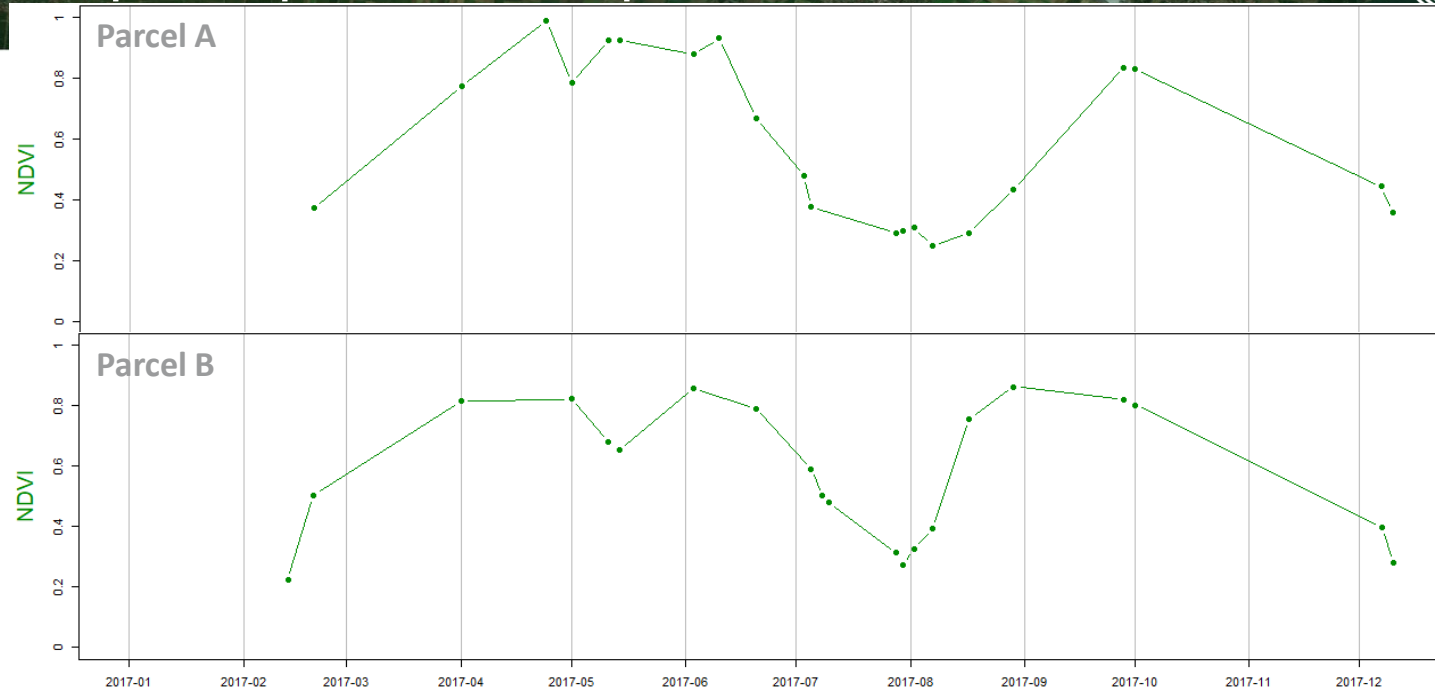


- Parcel A (CZ)
 - 2017: Winter wheat
 - 18.5 ha



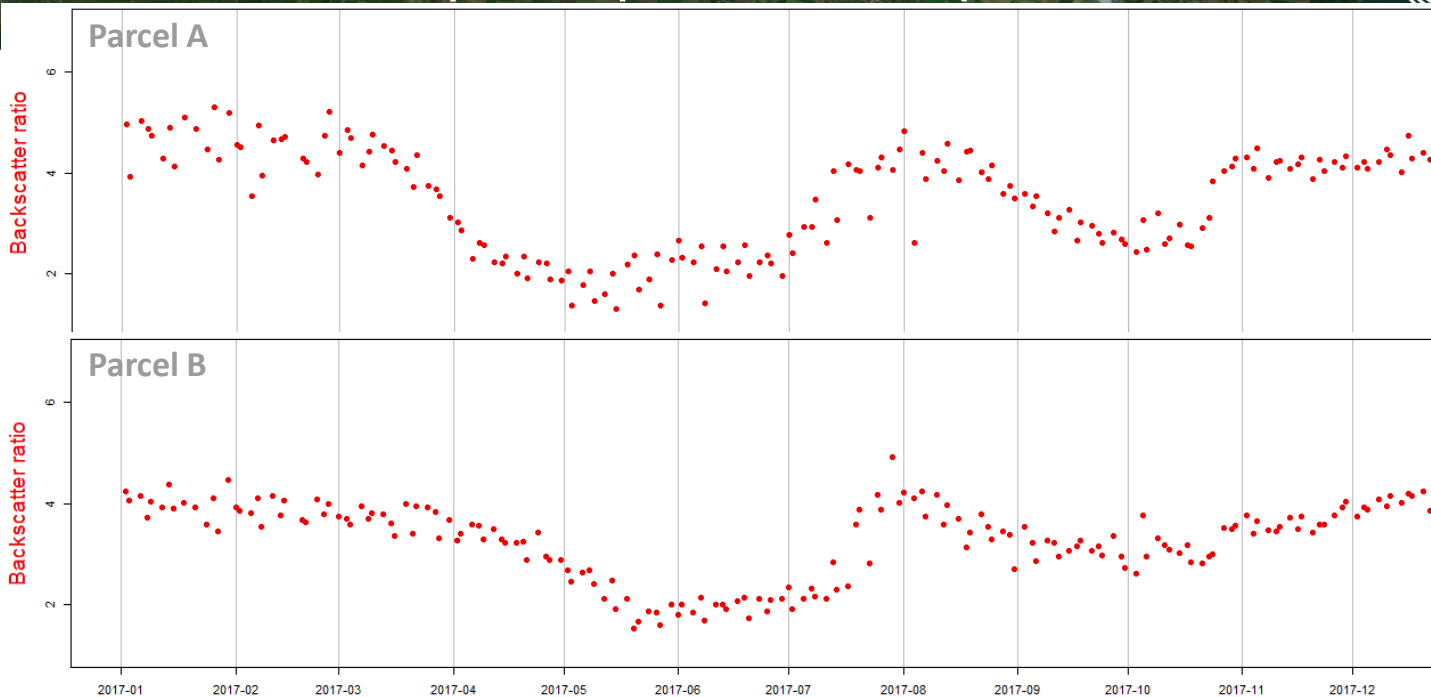
- Parcel B (CZ)
 - 2017: Rapeseed
 - 13.6 ha

NDVI temporal profile interpretation



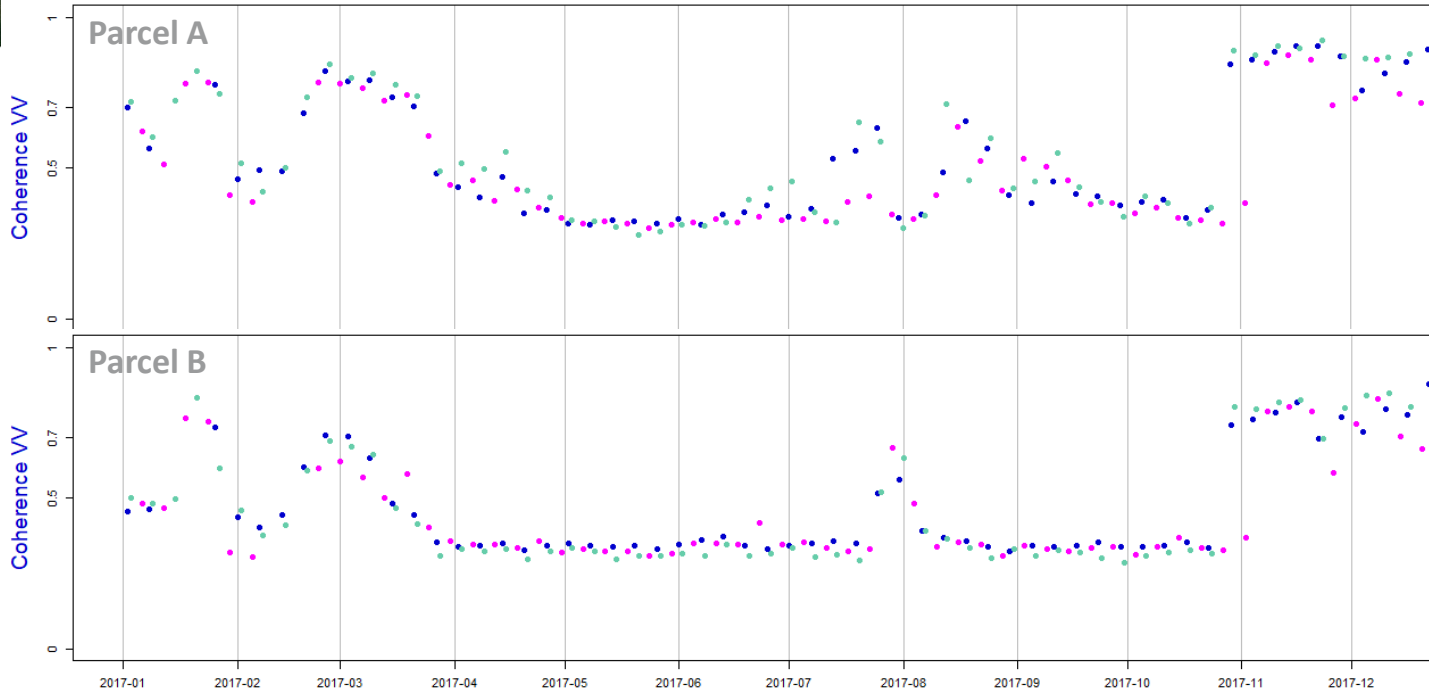
- High values of NDVI -> presence of green vegetation on the parcel
- Decrease of NDVI -> loss of vegetation on the parcel
- Increase of NDVI -> growth of vegetation on the parcel

Backscatter ratio temporal profile interpretation



- Low values -> presence of agricultural crop on the parcel
- High values -> absence of agricultural crop on the parcel
- Increase of backscatter ratio -> loss of agricultural crop vegetation

6 day VV coherence temporal profile interpretation



- Low values -> dynamic conditions on a parcel (change, vegetation)
- High values OR increase of the coherence -> stable conditions on a parcel (low/no vegetation)

- Related to vegetation state or vegetation change on a parcel

MARKERS FOR HARVEST		
M1	M1: Presence of vegetation in the main vegetation season (pre-requisite)	High values of NDVI
M2	M2: Loss of vegetation	Break in NDVI (decrease)
M3	Loss of vegetation	Break in backscatter ratio (increase)
M4	Low/no vegetation	High values of backscatter ratio
M5	Low/no vegetation (stable conditions)	Break in VV Coherence (increase) or high values of VV Coherence
MARKERS FOR DECLARED PRATICES		
M6	Presence of vegetation	High values of NDVI
M7	Growth of vegetation	Break in NDVI (increase)
M8	No loss of vegetation	No break in NDVI (decrease)
M9	No loss of vegetation	No increase of the backscatter ratio
M10	Presence of vegetation (dynamic conditions)	No Break in VV Coherence (increase) and no high values of VV Coherence

- Selection of the relevant markers for each agricultural practice
- Evaluation of the selected markers (TRUE/FALSE) for each week
 - Statistical analyses, trend analyses, 'break-point' detection and decision-tree thresholds
- Tailored logical combination of the markers to interpret the agricultural practice based on the provided temporal rules of each country
 - Integration of information from optical and SAR-based conditions
 - Harvest is considered a marker itself for the decision making on the EFA practices
- Decision
 - **Week of crop harvest/clearance (H_WEEK)**
 - **Degree of compliancy (C_INDEX)** with the declared EFA practice (growing of catch-crop, growing of nitrogen fixing crop, land lying fallow)

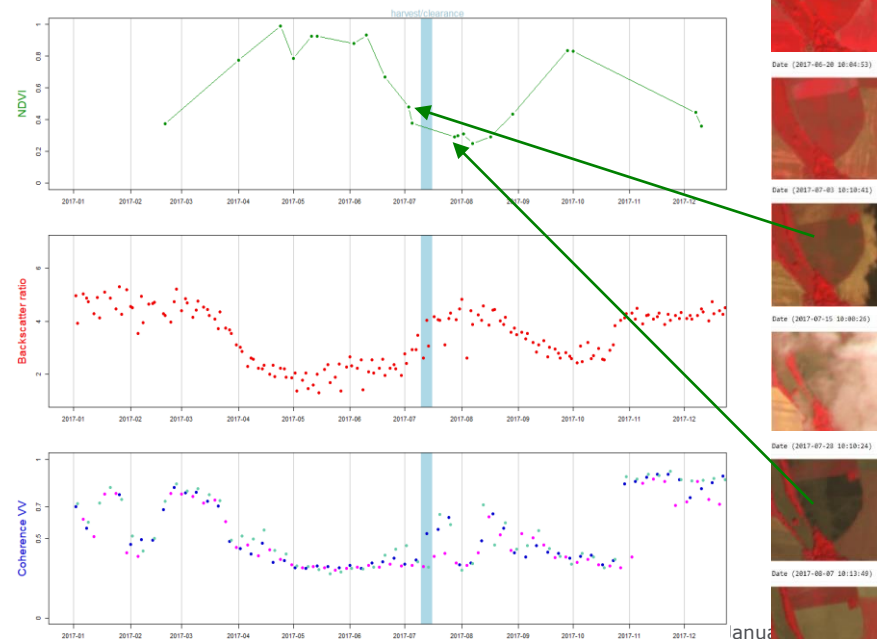
Monitoring of crop harvest/clearance

CROP HARVEST/CLEARANCE: Control approach

Monitoring of **vegetation presence** and **loss**

- Weekly monitoring – evaluation of markers
- Harvest detection – all markers (M1 – M5) are TRUE
- Preliminary detection – only S1 based markers (M3 – M5)

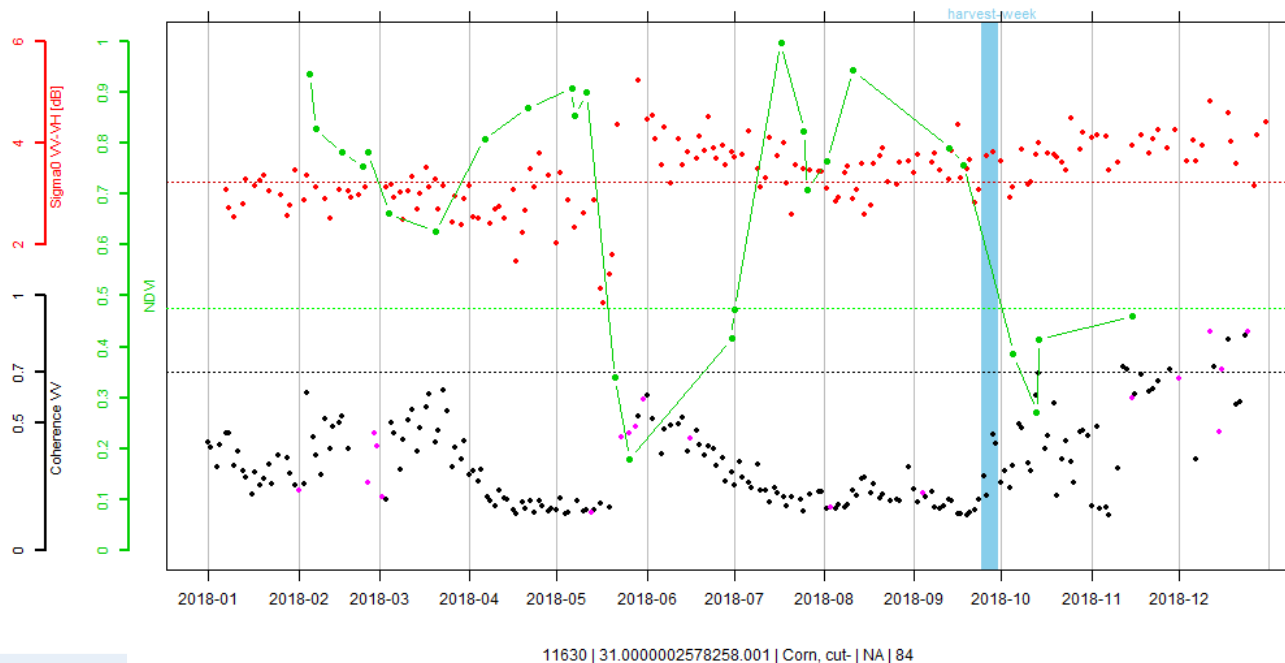
MARKERS FOR HARVEST		
M1	M1: Presence of vegetation in the main vegetation season (pre-requisite)	High values of NDVI
M2	M2: Loss of vegetation	Break in NDVI (decrease)
M3	Loss of vegetation	Break in backscatter ratio (increase)
M4	Low/no vegetation	High values of backscatter ratio
M5	Low/no vegetation (stable conditions)	Break in VV Coherence (increase) or high values of VV Coherence



CROP HARVEST/CLEARANCE: Results (example 1)



- M1 – TRUE
- M2 – TRUE
- M3 – TRUE
- M4 – TRUE
- M5 – TRUE



Planet:

Declared crop	Harvest from	Harvest to
Corn	20.9.2018	25.9.2018

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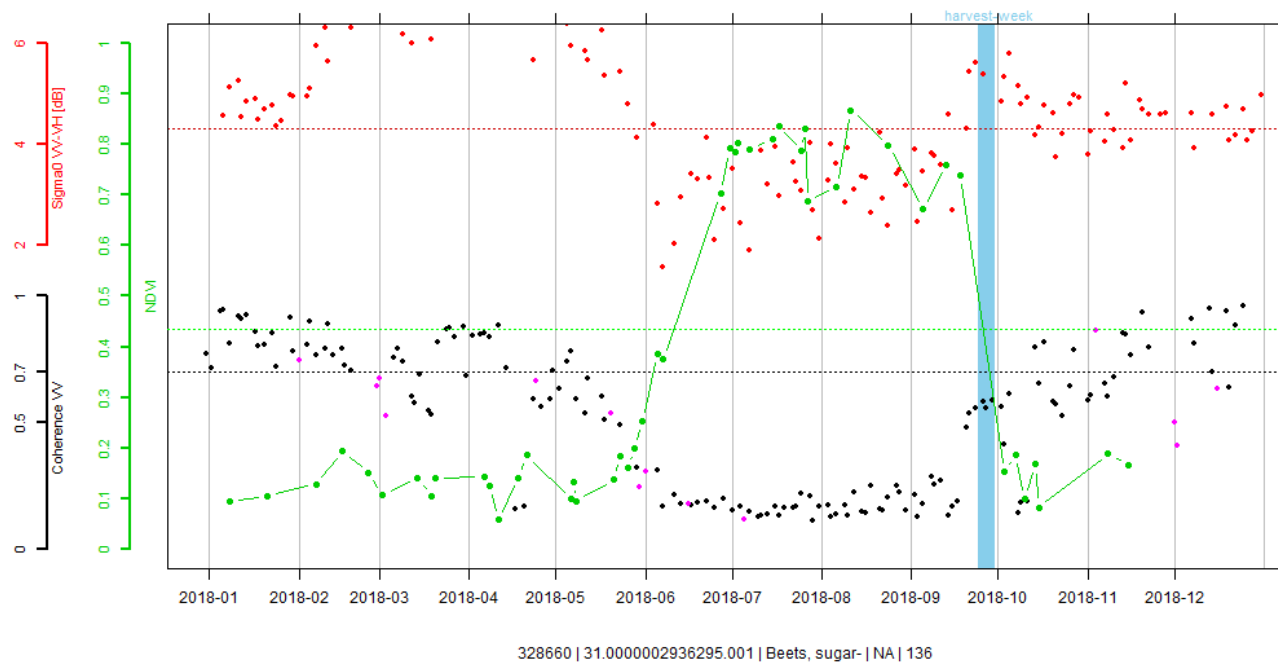


European Space Agency

CROP HARVEST/CLEARANCE: Results (example 2)



- M1 – TRUE
- M2 – TRUE
- M3 – TRUE
- M4 – TRUE
- M5 – TRUE



Farmer interview:

Declared crop	Harvest
Sugar Beets	19.9.2018

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Monitoring of catch crop

CATCH CROP: Rules for Netherlands in 2018



- Parcel selection: based on values of the shapefile attributes
 - Catch Crop as Main Crop ("IND_EA" = 'J')
 - Catch Crop after Main Crop ("GRONDBED_2")
- Temporal rules:
 - Catch Crop as Main Crop - Must be growing in the field between **15 May** and **15 July**.
 - The earliest sowing date for catch crop after main crop is July 15
 - Catch Crop after Main Crop Category 1/2 - Shall be growing in the field for **8 weeks**. Ultimate date of sowing catch crop is **15th of October**.
 - Catch Crop after Main Crop Category 3 - **Sowing of grass in (under) the main crop**. Shall be growing in the field for **8 weeks**. Ultimate date of harvest of main crop is **15th of October**.

CATCH CROP: Control approach

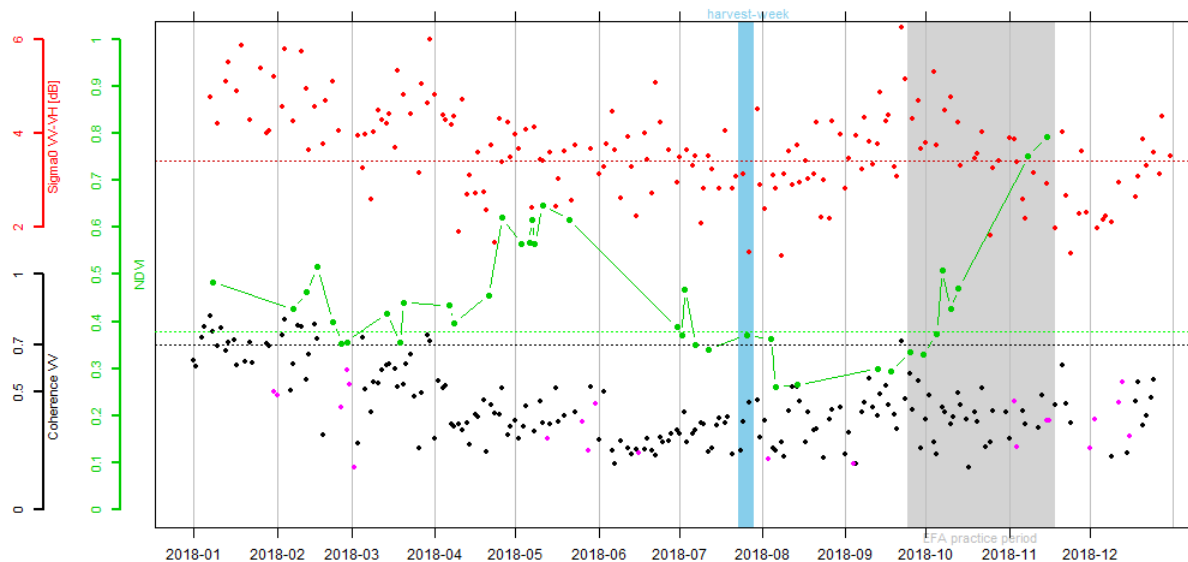
- The vegetation shall be growing and undisturbed during the practice period
- Selected markers:
 - M6 – M10: Evaluated for the practice period
 - Harvest/clearance
- Harvest shall be detected before the practice period
- If All M6-M10 TRUE >>> strong indication of compliancy
- If 1 FALSE >>> moderate indication of compliancy
- If 2 FALSE >>> weak indication of compliancy
- If 3 FALSE >>> poor indication of compliancy
- If M6-M8 are NA
 - M9 & M10 TRUE >>> moderate
 - M9 or M10 FALSE >>> weak

MARKERS FOR DECLARED PRATICES		
M6	Presence of vegetation	High values of NDVI
M7	Growth of vegetation	Break in NDVI (increase)
M8	No loss of vegetation	No break in NDVI (decrease)
M9	No loss of vegetation	No increase of the backscatter ratio
M10	Presence of vegetation (dynamic conditions)	No Break in VV Coherence (increase) and no high values of VV Coherence

CATCH CROP: Results (example 1)

Catch Crop after Main Crop Category 1

- Harvest of main crop detected
- M6 – TRUE
- M7 – TRUE
- M8 – TRUE
- M9 – TRUE
- M10 – TRUE
- C_INDEX – STRONG



663969 | 31.0000003273059.001 | Barley winter | CatchCrop_1 | 20

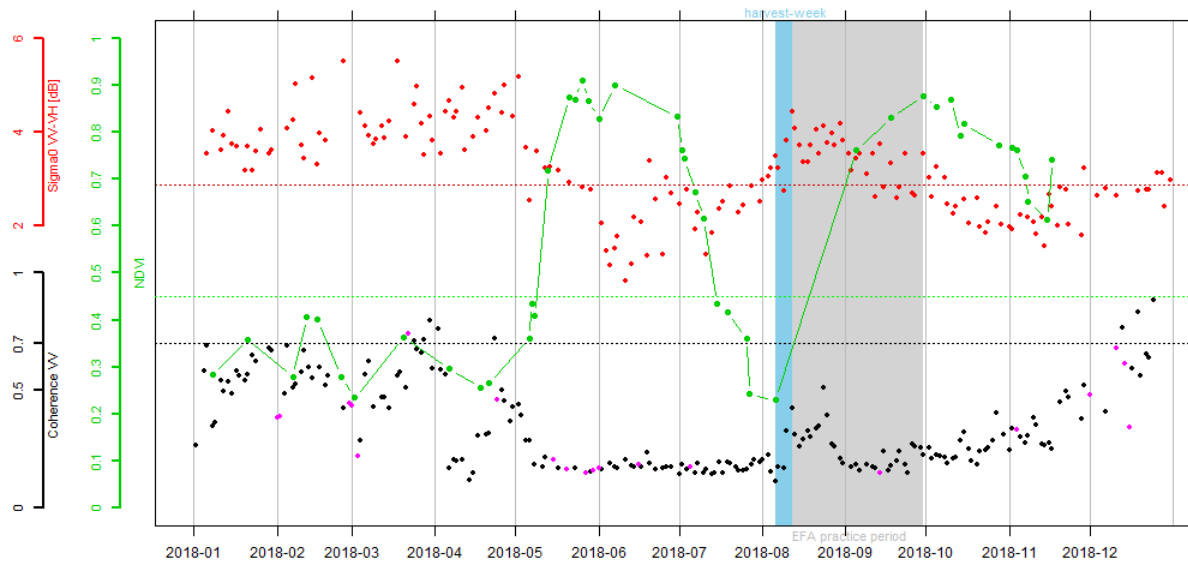
Farmer interview:

Declared crop	Sow crop	Harvest crop	Sow catch-crop
Barley winter	31.10.2017	24.7.2018	5.8.2018

CATCH CROP: Results (example 2)

Catch Crop after Main Crop Category 1

- Harvest of main crop detected
- M6 – TRUE
- M7 – TRUE
- M8 – TRUE
- M9 – TRUE
- M10 – TRUE
- C_INDEX – STRONG



Farmer interview:

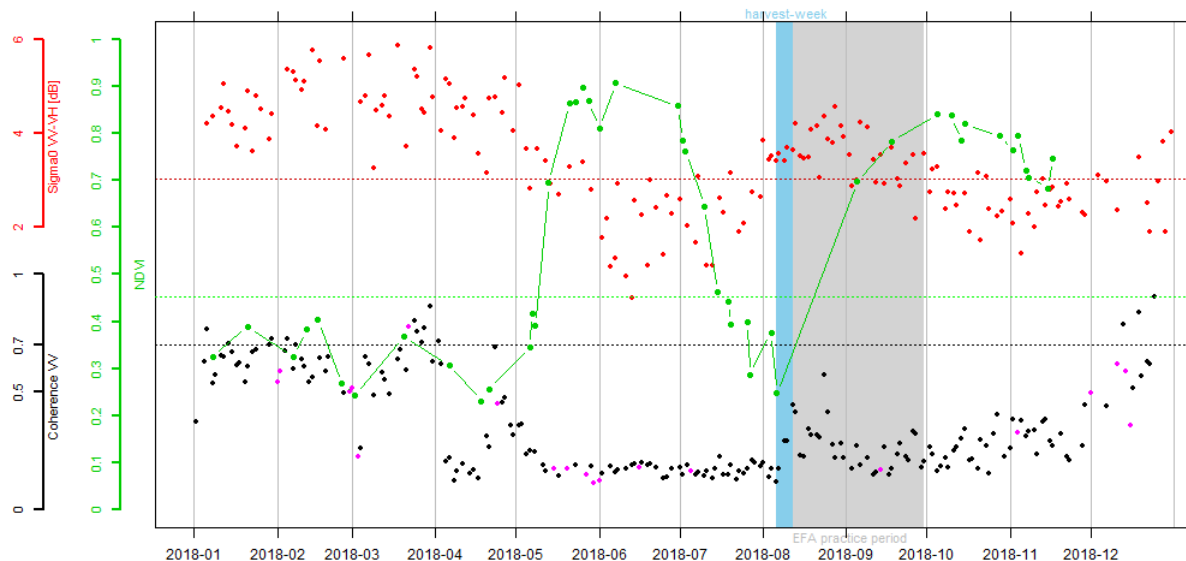
Declared crop	Sow crop	Harvest crop	Sow catch-crop
Barley, summer-	17.4.2018	27.7.2018	20.8.2018

118005 | 31.0000002670293.001 | Barley, summer- | CatchCrop_1 | 225

CATCH CROP: Results (example 3)

Catch Crop after Main Crop Category 1

- Harvest of main crop detected
- M6 – TRUE
- M7 – TRUE
- M8 – TRUE
- M9 – TRUE
- M10 – FALSE
- C_INDEX – MODERATE



118000 | 31.0000002670288.001 | Barley, summer- | CatchCrop_1 | 107

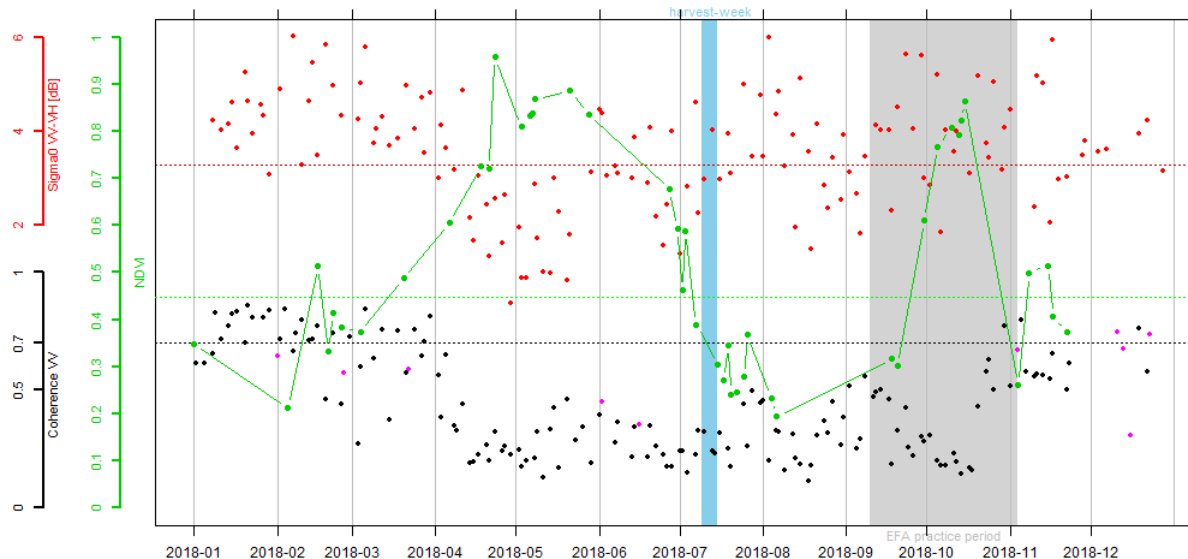
Farmer interview:

Declared crop	Sow crop	Harvest crop	Sow catch-crop
Barley, summer-	16.4.2018	28.7.2018	20.8.2018

CATCH CROP: Results (example 4)

Catch Crop after Main Crop Category 1

- Harvest of main crop detected
- M6 – TRUE
- M7 – FALSE
- M8 – FALSE
- M9 – TRUE
- M10 – FALSE
- C_INDEX – POOR



592074 | 31.0000003188256.001 | Wheat, winter- | CatchCrop_1 | 14

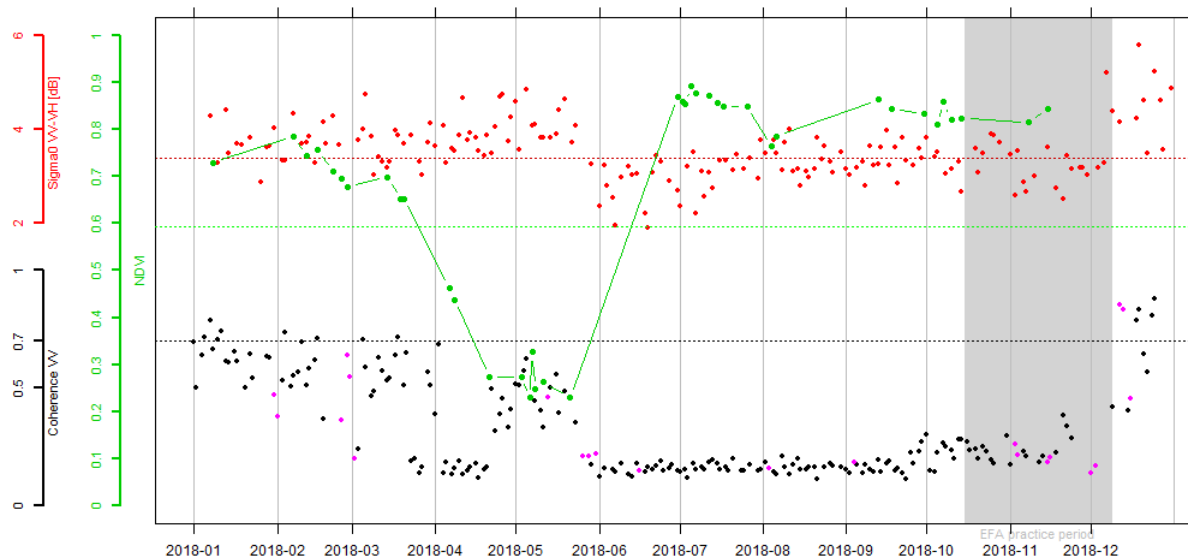
Farmer interview:

Declared crop	Sow crop	Harvest crop	Sow catch-crop
Wheat, winter-	28.10.2017	17.7.2018	23.8.2018

CATCH CROP: Results (example 5)

Catch Crop after Main Crop Category 1

- Harvest of main crop not detected
- M6 – NR
- M7 – NR
- M8 – NR
- M9 – NR
- M10 – NR
- C_INDEX – POOR



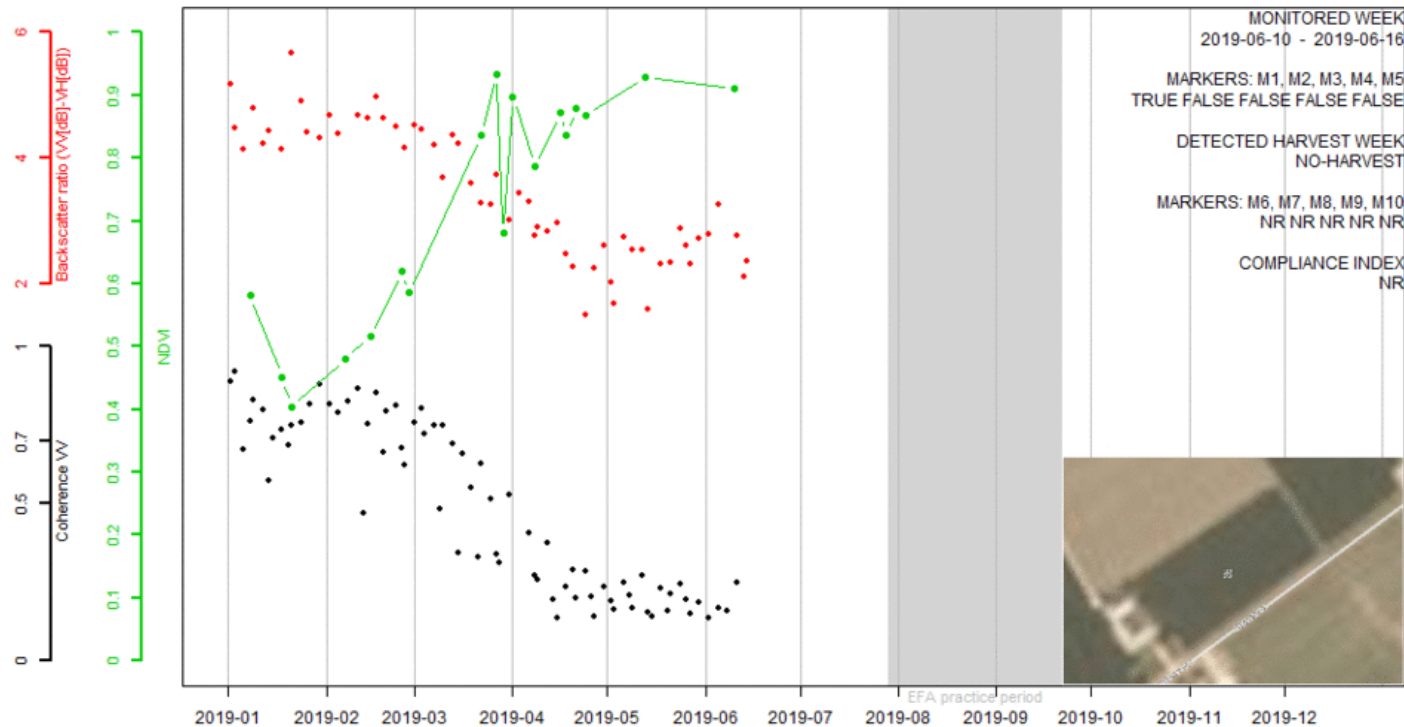
Farmer interview:

Declared crop	Sow crop	Harvest crop	Sow catch-crop
Beets, sugar-	21.4.2018	27.8.2018	5.9.2018

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Continuous monitoring



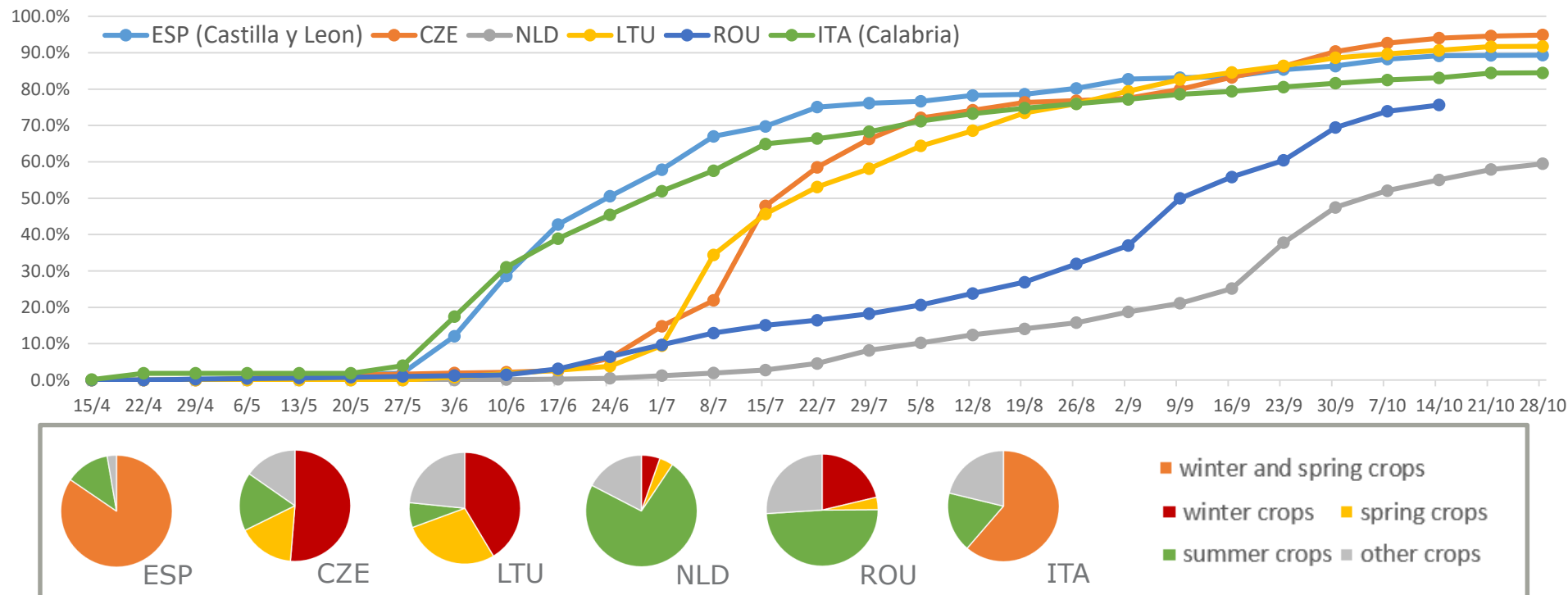
Example: Monitoring of harvest/clearance of a parcel with winter wheat, monitoring of catch crop in the period from 29.7.2019 to 29.9.2019 (NLD, 2.5 ha)

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Evolution of harvest detection in 2019

Evolution of the percentage of the harvested parcels (confirmed harvest week) in 2019



- Sources of reference data
 - Information obtained from farmers (provided by the PAs)
 - Information obtained from Planet imagery (visual interpretation)
- Validation
 - Detected harvest/clearance week is compared with the real date/period of the harvest
 - Markers used for the EFA evaluation are compared with information obtained from the reference datasets

Planet imagery



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European Space Agency

Parcel no. 604104501/7 (CZ) - Winter wheat



Harvest of main crop

Farmer:
25.7.18 (Week 30)

Sentinel 2:
between 20.7.-30.7.18

Planet:
between 25.7.-26.7.18



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Parcel no. 604104501/7 (CZ) - Winter wheat



100618

050718

150718

200718

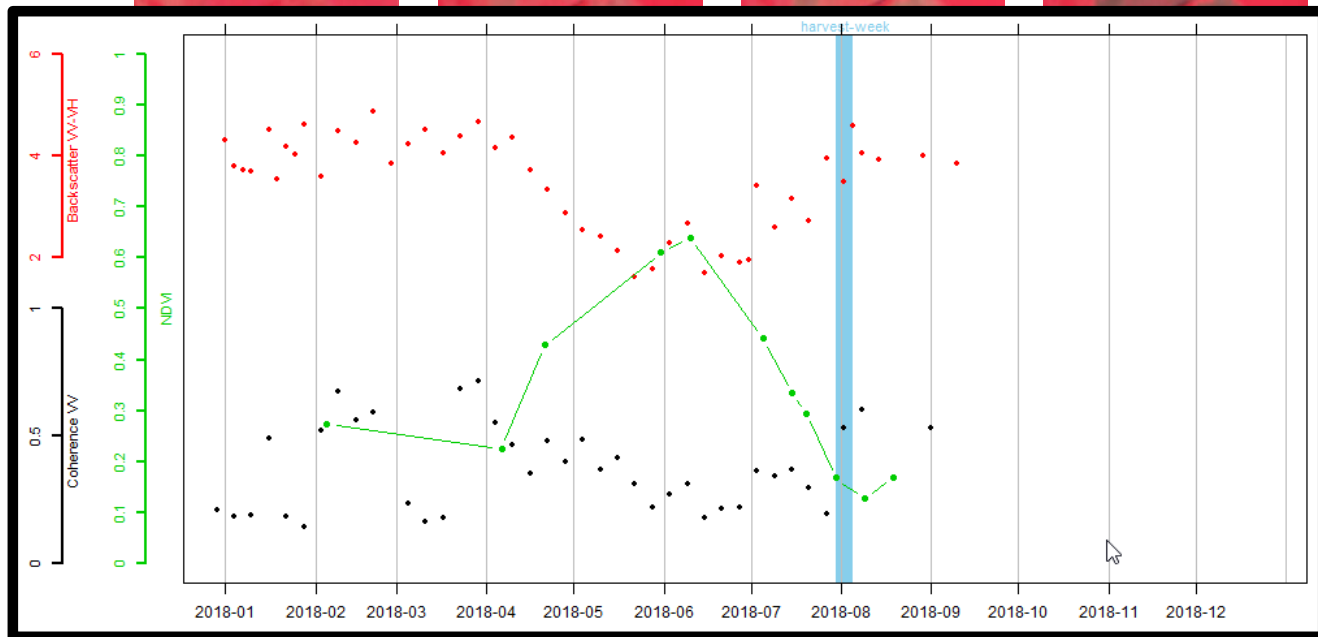
Harvest of main crop

Farmer:
25.7.18 (Week 30)

Sentinel 2:
between 20.7.-30.7.18

Planet:
between 25.7.-26.7.18

Time series analysis:
30.7.-5.8.18 (Week 31)

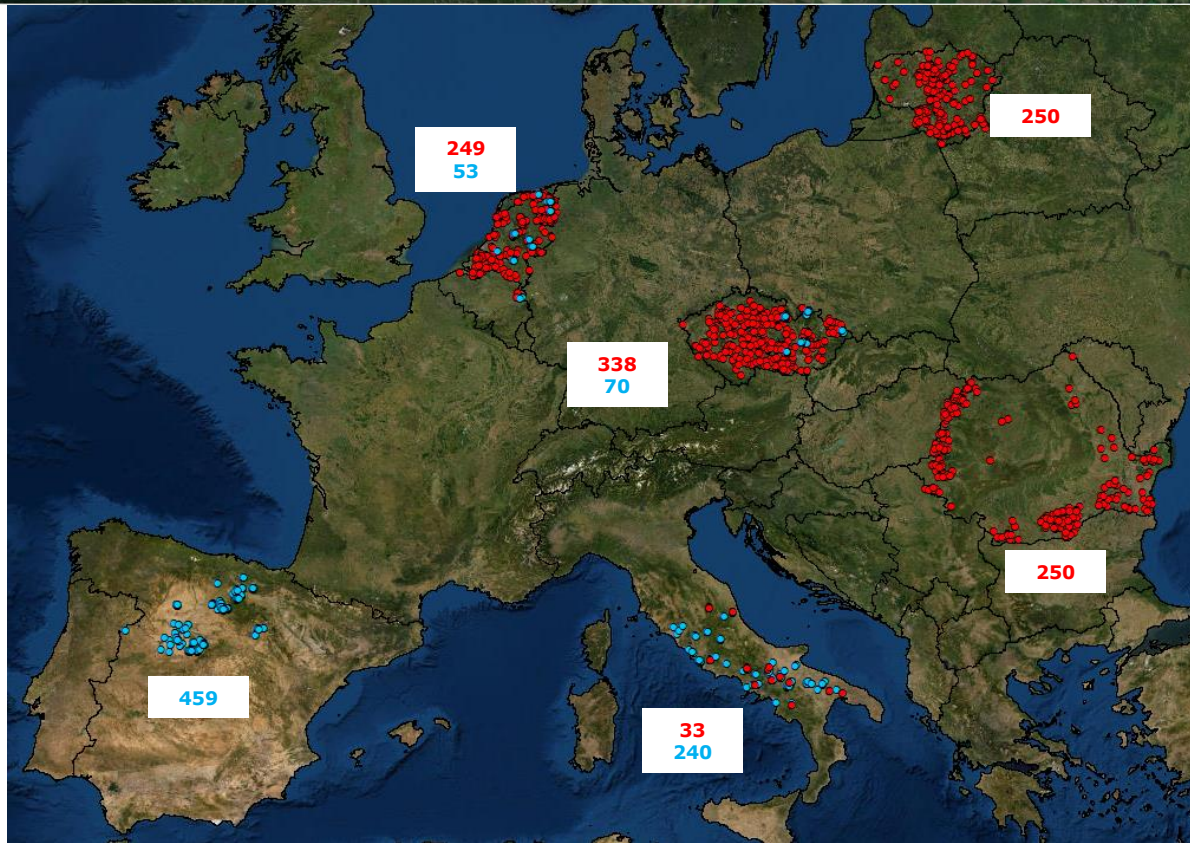


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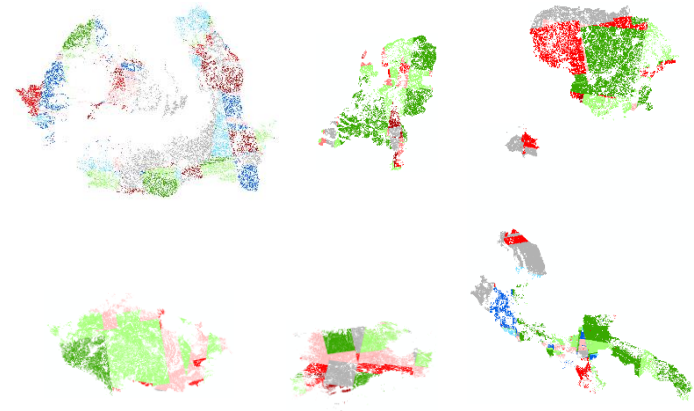
European Space Agency

Reference data (2018): Harvest of the main crop



- ~ 250 parcels
- random selection (Planet)

- red – Planet
- blue – farmers



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Validation: harvest/clearance week (2018, 2019)



Harvest detection accuracy 2018 [%]

Difference [weeks]	Czechia	Italy	Lithuania	Netherlands	Romania	Spain (farmers)
<=1	72.2	75.8	74.4	83.1	69.6	52.9
= 2	14.5	12.1	14.8	7.6	14	15.9
= 3	6.2	6.1	3.6	2.8	6.0	12.4
> 3	5.9	6.1	4.0	0.8	9.6	13.5
Not detected	1.2	0.0	3.2	5.6	0.8	5.2
Total	100	100	100	100	100	100

Harvest detection accuracy 2019 [%] PRELIMINARY (mid October)

Difference [weeks]	Czechia	Italy	Lithuania	Netherlands	Romania	Spain
<=1	75.2		75.1	79.2	69.5	53.6
= 2	13.6		11.7	4.8	7.2	16.0
= 3	6.0		7.0	0.4	5.4	12.0
> 3	4.0		3.9	0.8	9.6	16.8
Not detected*	1		2.3	14.8	8.4	1.6
Total	100		100	100	100	100

Validation: EFA markers (Planet, 2018)



Catch crop [%]				
Markers	Czechia	Lithuania	Netherlands	Romania
Presence of vegetation (NDVI)	91.2	96.8	90.8	89.8
Growth of vegetation (NDVI)	76.2	73.0	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	43.0
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“ or „MOD“ / NO – C_INDEX „POOR“ or „WEEK“)	79.6	86.8	80.4	88.3

Nitrogen fixing crop [%]					
Markers	Czechia	Italy	Lithuania	Romania	Spain
Presence of vegetation (NDVI)	100.0	100.0	100.0	96.8	98.8
Harvest in the practice period	41.2	79.6	96.0	85.6	80.4
COMPLIANCE (YES – C_INDEX „STRONG“ or „MOD“ / NO – C_INDEX „POOR“ or „WEEK“)	41.2	100.0	100.0	82.8	98.8

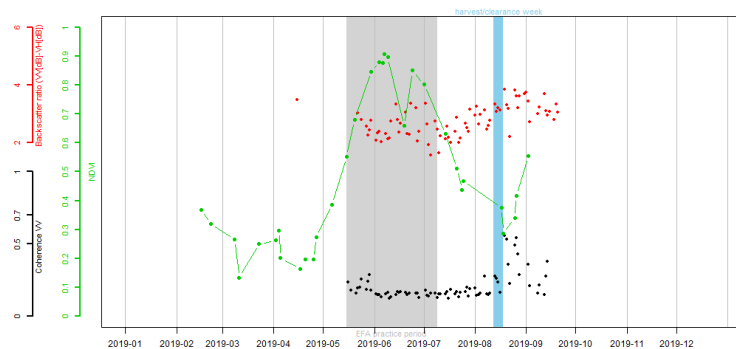
Fallow land [%]				
Markers	Czechia	Italy	Lithuania	Spain
Presence of vegetation (NDVI)	99.5	98.4	100.0	60.0
Harvest in the practice period	66.1	93.6	88.8	47.6
COMPLIANCE (YES – C_INDEX „STRONG“ or „MOD“ / NO – C_INDEX „POOR“ or „WEEK“)	66.6	93.6	88.8	47.6

Reliability of temporal profiles analysis

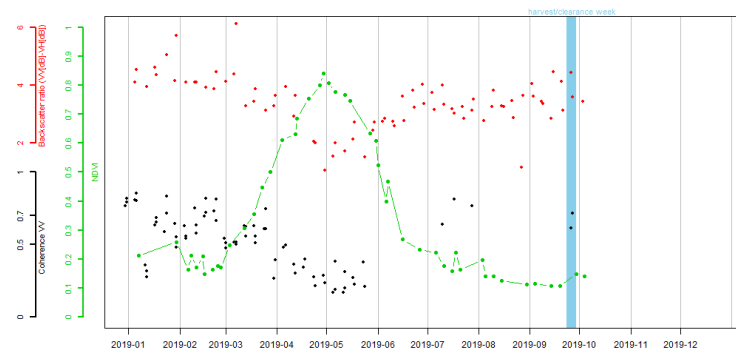


- All the parcels with at least single Sentinel-1 pixel (20m) are monitored in 2019
(pixel centroid falls inside 10 meters buffer)
- Impact on reliability of temporal profile analysis
 - Gaps (missing data) in the EO data time series
 - Size & shape of the parcel
 - Parcel uniformity (in term of cover & activities carried out)
 - Optical vs. SAR based markers
 - Targetted time period (summer vs. autumn)
 - Crop senescence (southern countries, cereals+maize+potatoes) - additional optical index needed
- New „reliability“ marker to be introduced
 - Evaluation of S1 gaps before harvest and within the period
 - Categorisation of parcel size & shape
 - Parcel statistics?

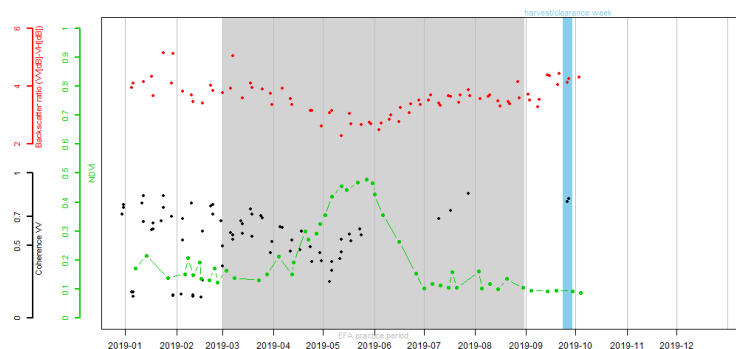
Gaps (missing data) in the EO data time series



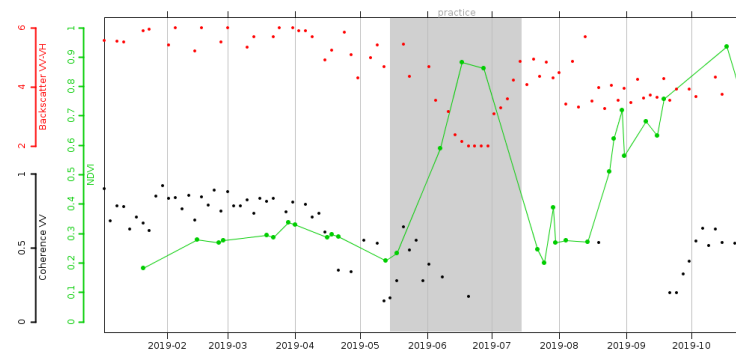
264272 | 1005465869-238547-9549-2 | Spring triticale | 217



249 | 428675 | BARLEY | 33



473 | 428701 | PEAS | 188

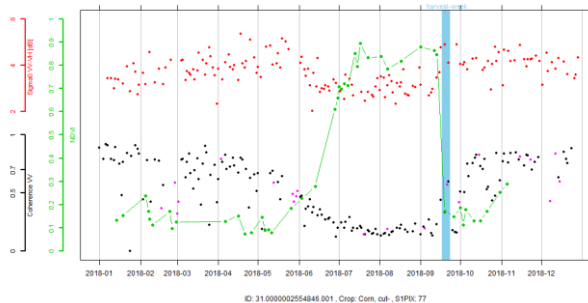


151830 | 31.0000004188220.001 | Japanese oats | 294

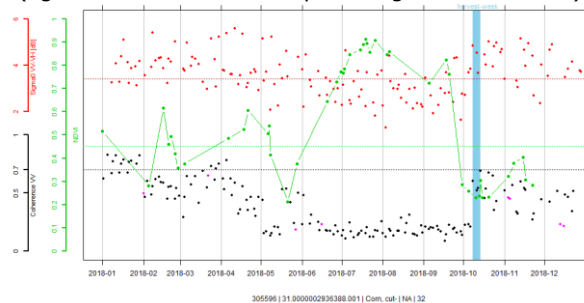
Temporal profiles vs. parcel size



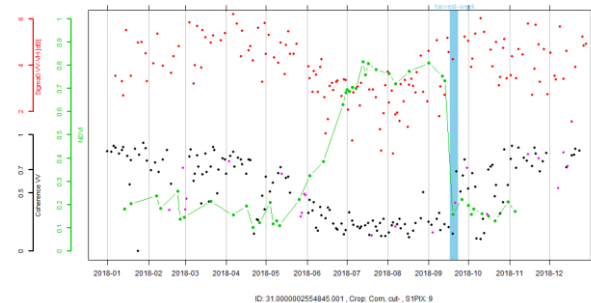
77 Sentinel-1 pixels **Harvest**
Planet: 13-19.9. vs S4C: 17-23.9.



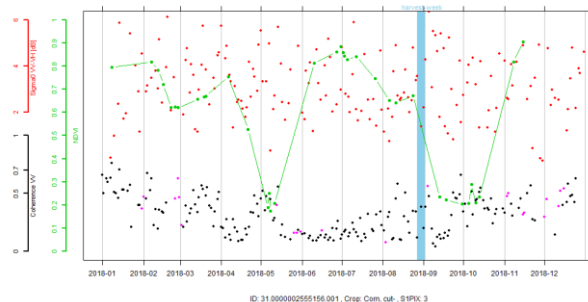
32 Sentinel-1 pixels **Harvest**
Planet: 26-27.9. vs S4C: 8-14.10.
(agricultural works on the parcel right after harvest)



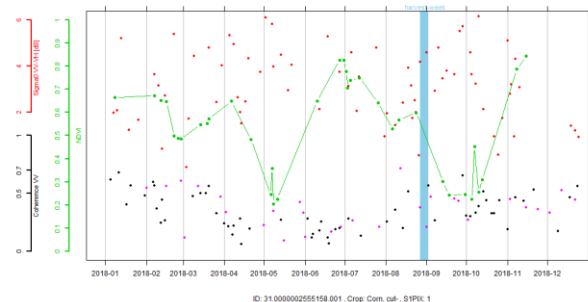
9 Sentinel-1 pixels **Harvest**
Planet: 13-19.9. vs S4C: 17-23.9.



3 Sentinel-1 pixels **Harvest**
Planet: 11-13.9. vs S4C: 27.8.-2.9.



1 Sentinel-1 pixel **Harvest**
Planet: 11-13.9. vs S4C: 27.8.-2.9.



Thank you for your attention

Any questions?