# An automated end-to-end framework for CAP monitoring

## Lessons learned from the Cypriot use case

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National Observatory of Athens – Beyond Centre of Excellence

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869366.

# Objectives

- **Design** and **develop EO data products** to **address customers' needs**
- Make PAs and CBs' **monitoring task more efficient, accurate** and **cost effective**
- EO based services **to monitor agricultural malpractices** and **their environmental impacts**

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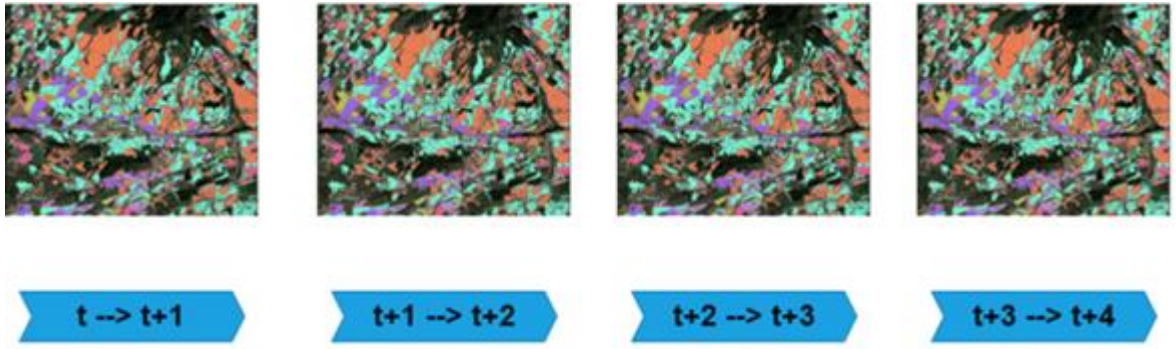
# Cultivated crop type maps

- Well-tested Machine Learning and Deep Learning Models Applied
- Dynamic Crop Type Mapping for every cultivation year
- 2 Pilot cases
  - Cyprus (CAPO) ~ 0.2 hec average parcel size
- National scale results
- Parcel-based or Pixel-based Approaches
- For every evaluated field S1/S2 band and indices time-series were calculated using the LPIS buffered geometries
  - Sentinel-2 L2A Spectral bands (B01-B12)
    - Scene Classification (SCL)
    - Vegetation Indices - VIs (NDVI, NDWI, PSRI)
  - Sentinel-1 GRD
    - Backscattering coefficients (VV-VH)

*Multi temporal Crop type mapping*




*Crops Classification Map based on declaration polygons, describing each crop category with different colors*

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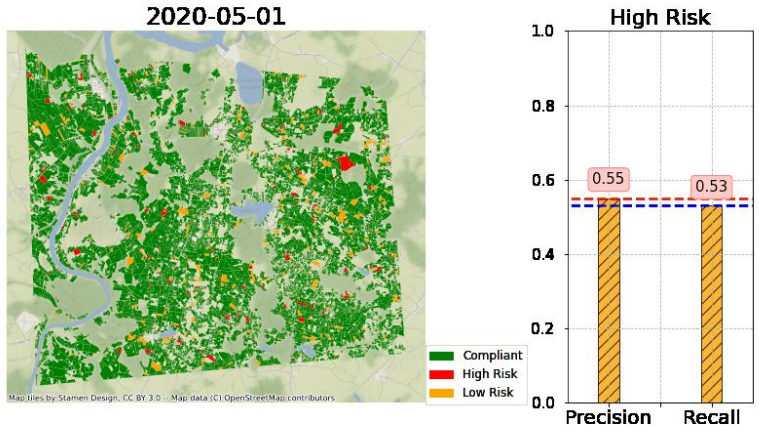
# EO services

- **Alert Mechanism:** Our advanced smart sampling algorithm uses a traffic light system to detect potential instances of false applicant declarations, even in the initial stages of the cultivation period. This helps to reduce fraud and errors in crop reporting, ensuring accurate data for subsidies and other financial programs.

  *[1] M. Rousi et al., "Semantically Enriched Crop Type Classification and Linked Earth Observation Data to Support the Common Agricultural Policy Monitoring," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 14, pp. 529-552, 2021, doi: 10.1109/JSTARS.2020.3038152*




- **Supervision of Cross-Compliance:** The results derived from the Cultivated Crop Type Maps service serve as the foundation for addressing **Greening requirements**, such as Crops Diversification, making it a vital tool for anyone seeking to optimize the monitoring of farming operations. This feature helps to ensure compliance with regulations and promote sustainable agricultural practices.

*Greening I Compliance Map*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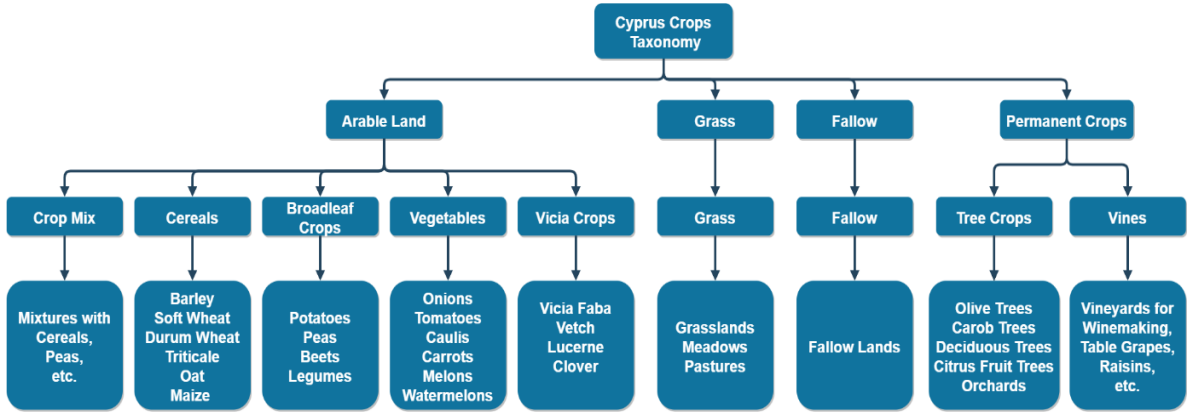
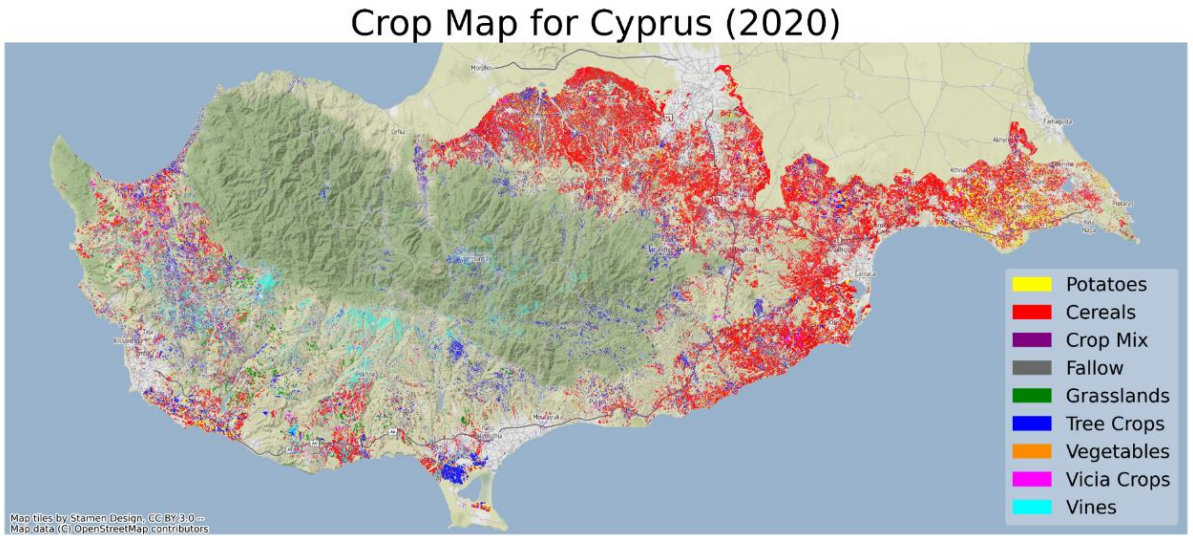
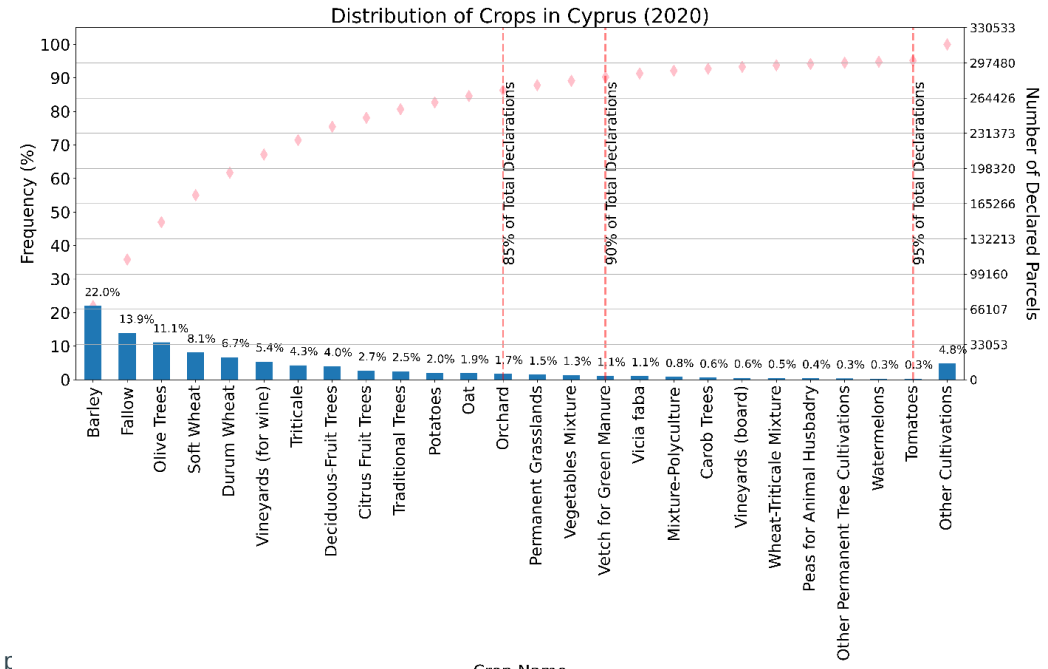
# Case of Cyprus

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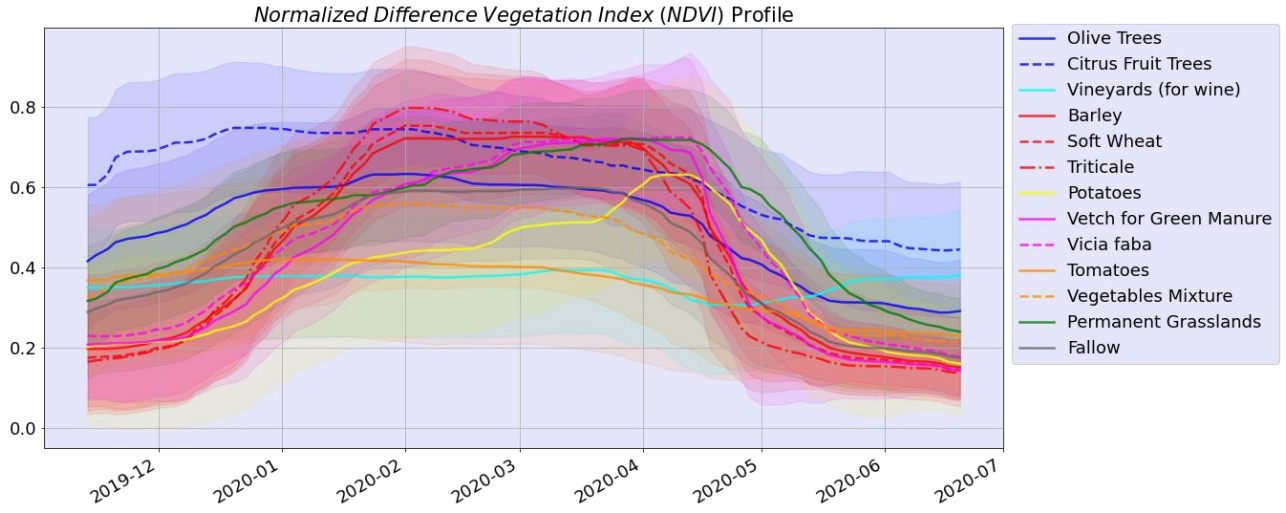
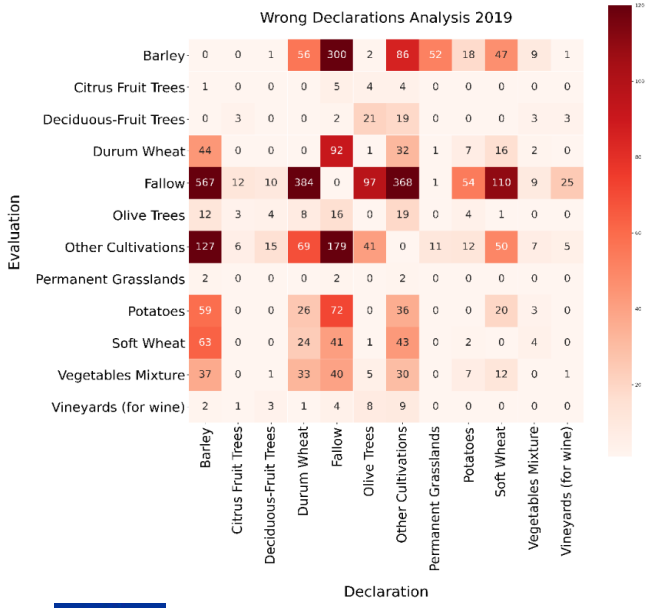
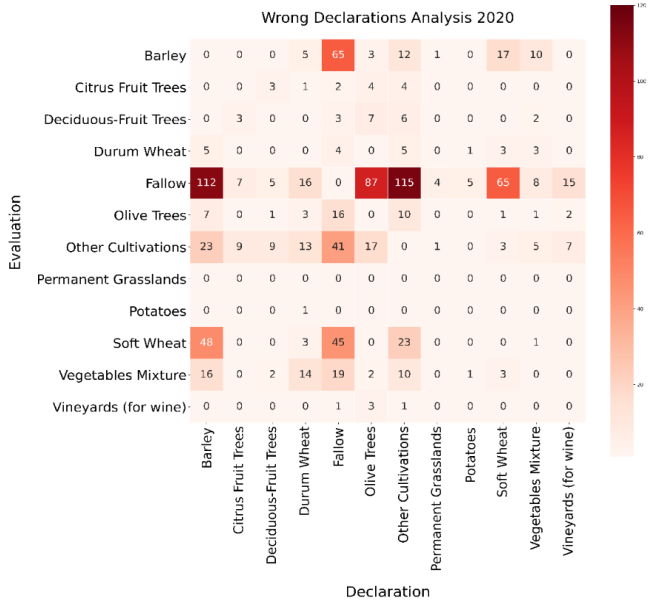
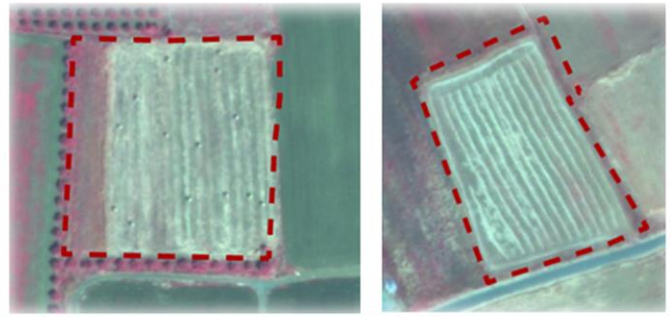
# Case of Cyprus – Current Issues (1)




## Fallow Land Case



*Wrong Declarations Percentage > 10%*

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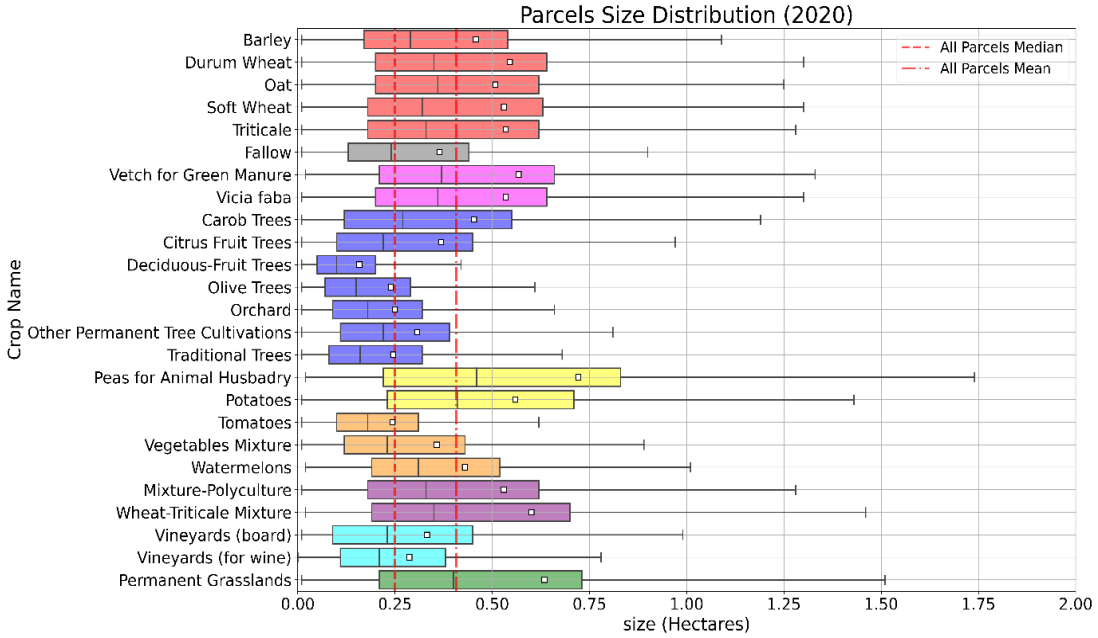
# Case of Cyprus – Current Issues (2)

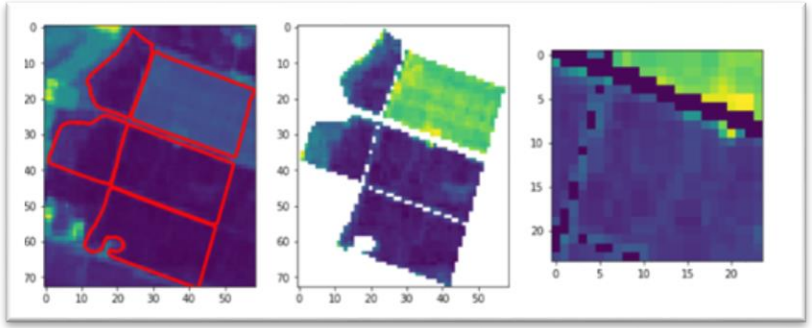



a) Small Parcels Issue → Average size < 0.3 hec (mixels issues)

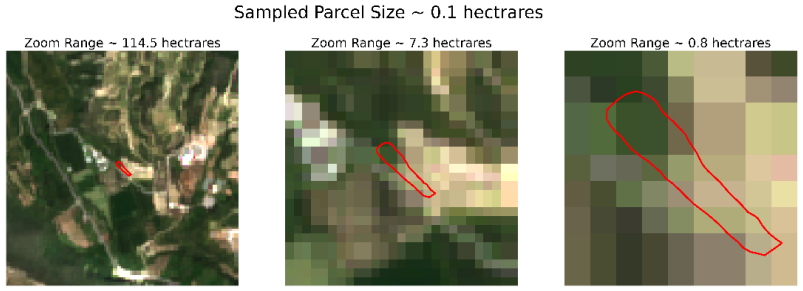
b) Multiple Cultivations – Polycultures

c) Intense ground vegetation on permanent cultivations

b)



a)




c)

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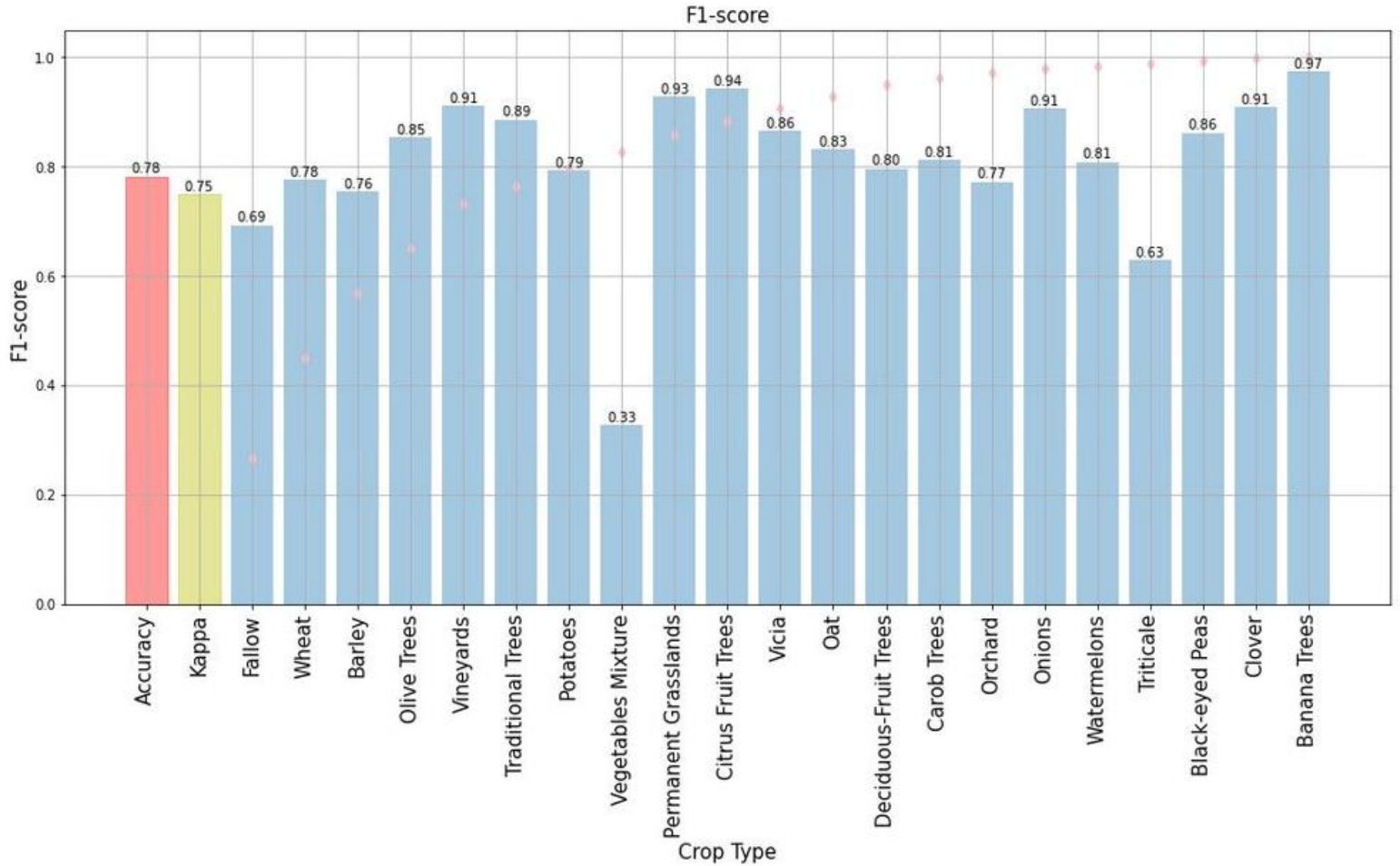
# Product Performance

- **Alpha Error** (False Positive Declared As Compliant) → Significant Improvement
  - Accuracy of Correct Declarations > 90%
- **Beta Error** (False Negative Declared As Compliant) → Improvement
  - Recall of False Declarations ~ 33%
  - Precision of False Declarations ~ 40%
- Declaration Confirmation [0,1,2] (based on confidence of the predictions):
  - 242216 cases confirm (~ 80%)
  - 17459 cases not confirm (~ 6%)
  - 47649 cases not clear decision




*CCTM F1 Score - Results based on RS and OTSC validations*

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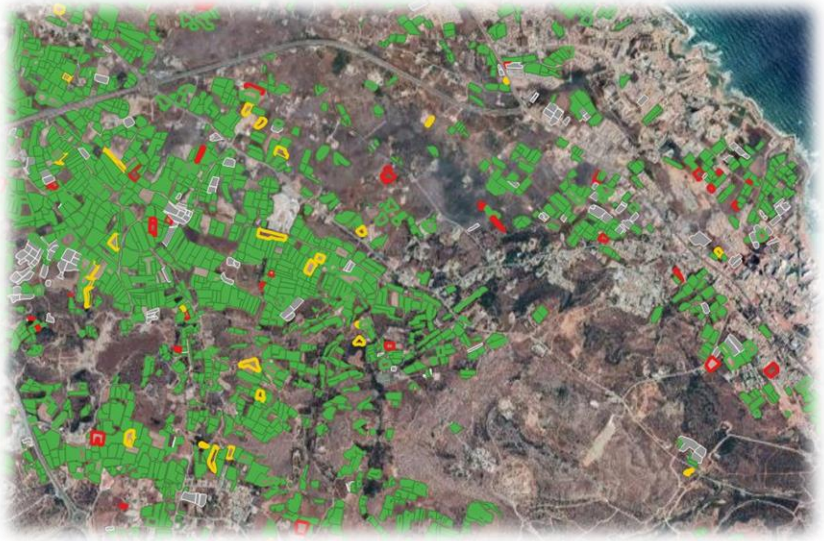
# Other Services – Smart Sampling ALERTS

- Level of ALERT [0,4]:
  - 0: Cases that no reason of ALERT identified
  - 1: Cases with low confidence
  - 2: Cases with average confidence / disagreement of higher hierarchical level
  - 3: Cases with high confidence / strong disagreement of higher hierarchical level
  - -1: NO EVALUATED CASES

- Level of Alert [0,4]:
  - 0 → 255528 cases (~ 78%)
  - 1 → 31903 cases (~ 10%)
  - 2 → 11375 cases (~ 4%)
  - 3 → 8518 cases (~ 3%)
  - -1 → 18349 cases (~ 5%)

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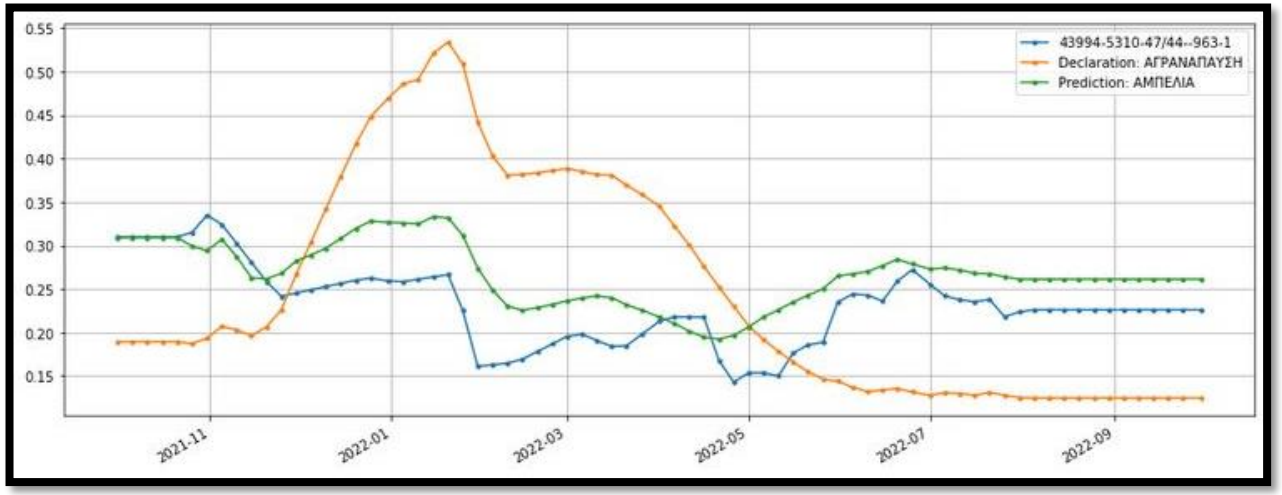
# Alert Detected Case Example




| | |
|---|---|
| UNIQUE_ID | 43994-5310-47/44--963-1 |
| APPL_ID | 43994 |
| D_AREA | 0.083 |
| C_AREA | 0.082 |
| N_PIXELS | 10 |
| DECL_C | 75 |
| DECL_N | ΑΓΡΑΝΑΠΑΥΣΗ |
| DECL_F | ΑΓΡΑΝΑΠΑΥΣΗ |
| PRED_C1 | 70 |
| PRED_N1 | ΑΜΠΕΛΙΑ |
| CONF_1 | 0.721 |
| PRED_C2 | 75 |
| PRED_N2 | ΑΓΡΑΝΑΠΑΥΣΗ |
| CONF_2 | 0.206 |
| PRED_C3 | 42 |
| PRED_N3 | ΕΛΙΕΣ |
| CONF_3 | 0.023 |
| PRED_F | ΑΜΠΕΛΙΑ |
| CONFIRM | 1 |
| ALERT | 3 |
| CD_DECL | E1 |
| CD_PRED | E1 |
| CD | 0 |

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# Other Services – Crops Diversification

| Category | Description | Crop diversification rules |
|---|---|---|
| Category1 | TAL between 10 and 30 ha | • At least 2 different crop types<br>• Main crop ≤ 75% of TAL |
| Category2 | TAL greater than 30 ha | • At least 3 different crop types<br>• Main crop ≤ 75% of TAL<br>• 2 main crops ≤ 95% of TAL |
| Category3 | TGrass and Fallow greater than 75% of TAL | Main crop ≤ 75% of remaining AL |
| Exemption1 | TAL less than 10 ha | No crop diversification required |
| Exemption2 | TGrass and Fallow greater than 75% of TAL and remaining AL less than 30 ha | No crop diversification required |
| Exemption3 | PGrass, TGrass and Cwater greater than 75% of EAA and remaining AL less than 30 ha | No crop diversification required |
| Exemption4 | Cwater = TAL | No crop diversification required |

TAL = Total Arable Land; AL = Arable Land; EAA = Eligible Agriculture Area; TGrass = Temporary Grassland; PGrass = Permanent Grassland; Fallow = Land Lying Fallow; Cwater = Crop Under Water

- CD_DECL: Crop Diversification based on applicant declaration
- CD_PRED: Crop Diversification based on model prediction
- CD: Combined decision based on the above → CD: [1,4]
  - 4: Both Compliant (~ 39%)
  - 3: One of them Compliant
  - 2: One of them Incompliant
  - 1: Both Incompliant (~ 4%)
  - 0: One of them is Exemption (~ 57%)
  - -1: Cases not processed

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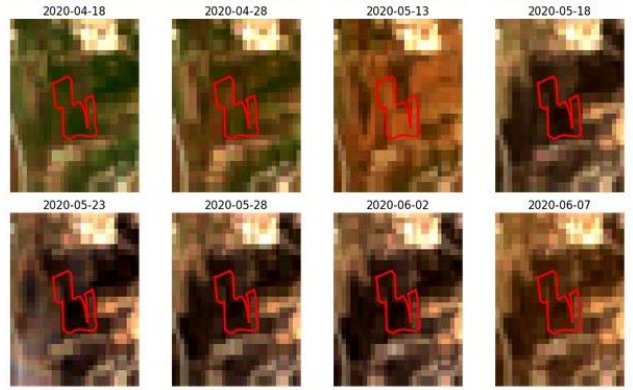
# Analytics on Vegetation and Soil Index Time-series

## EO Products provided

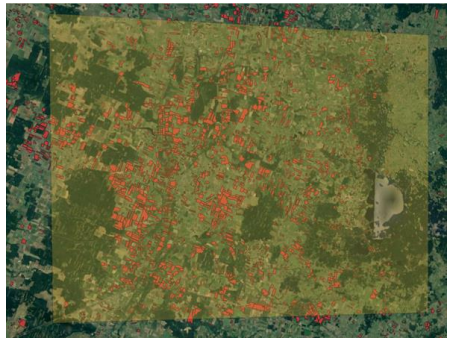
- Monitoring of **GAECs** and **SMRs** requirements through Incompliance Maps
  - Proximity to water-ways / Runoff Risk assessment for NVAs water pollution (**GAEC1/SMR1**)
  - Minimum soil cover for Soil Erosion (**GAEC 4**)
  - Stubble Burning Identification and Burnt Scar Mapping (**GAEC 6**)
- Detection of illegal activity on **Natura2000** regions
- Comprehensive GIS and Analytics Tools:
  - Advanced Visualization of Vegetation Indices
  - Robust Temporal and Zonal Statistics
  - Dynamic Animations of Area Evolution over Time
  - Smart Multi-Faceted Geospatial Queries
  - Accurate Detection of Index Anomalies and Trends

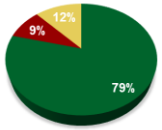
*RUSLE estimation for Runoff Risk Assessment*

*Stubble Burning Identification*




*Analytics and Aggregated Statistics over custom Areas using specific GIS querying functionalities*






*Illegal Activity detection on Natura2000 regions*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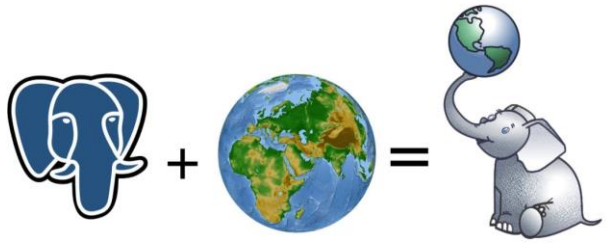
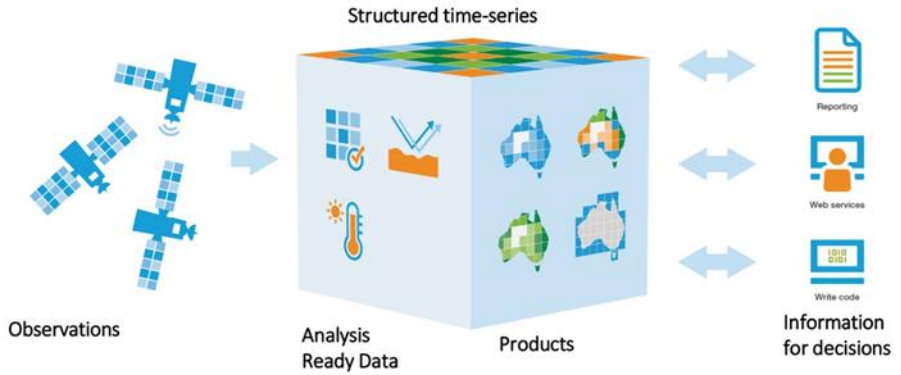
# Complex Queries and Scalable country-specific knowledge

- The **results** of the downstream services that Data Cube supports are used to update a PostgreSQL/PostGIS database.
- The database contains **aggregated results per parcel**, which can then be easily accessed, enabling a **back-and-forth communication with the Data Cube**.
- Thus, we have a Data Cube that includes and keep on being **dynamically populated** by Sentinel-1 and Sentinel-2 products.
- The Cube also hosts **auxiliary geospatial data** (e.g., LPIS) that are used to enable the provision high level data products (e.g., crop classification) that in turn populate the cubes.
- This way, we end up with **country specific knowledge bases for CAP monitoring**



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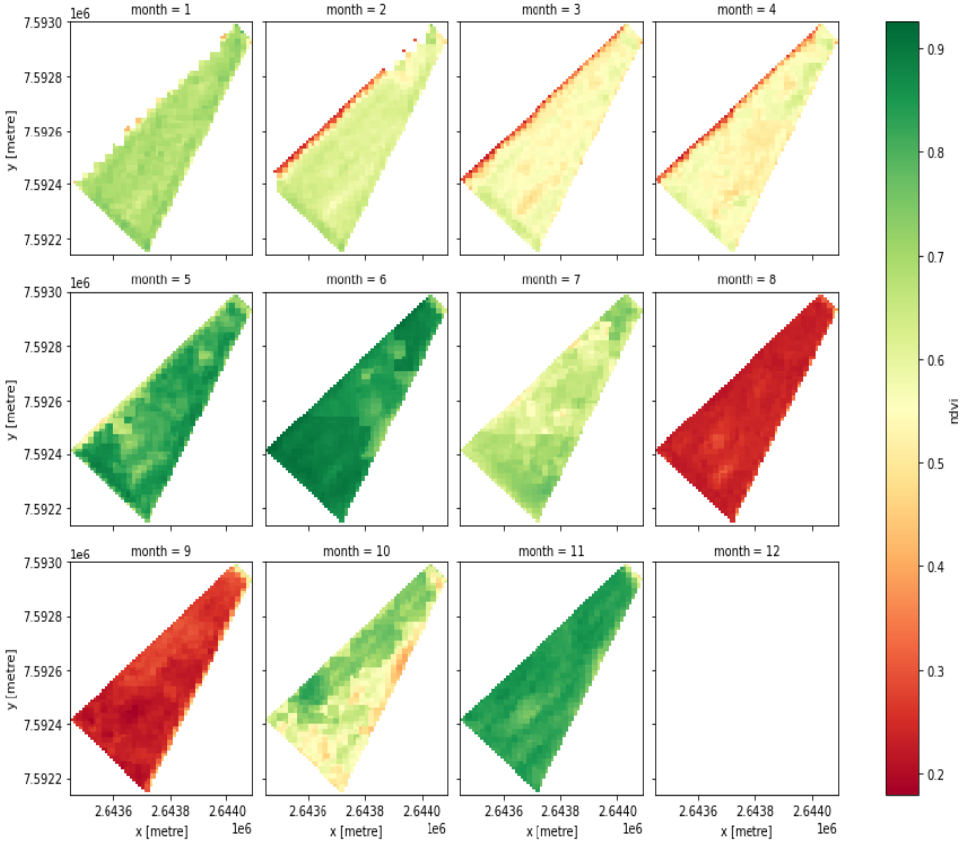
# Analytics Functionalities

Visualizations can be extracted for **any s1/s2 product, any aggregated statistic measurement, either on the pixel or on the parcel level and for a specific parcel, a crop type or a crop family**.

## Temporal Statistics over an area

- All the necessary raw data or indices are calculated within a specific time window.
- The statistics for the chosen bands can be presented as either aggregated values for a particular parcel or as a plot covering a larger area.




**It plays a crucial role to the validation of results generated by the rest of back- end processes**

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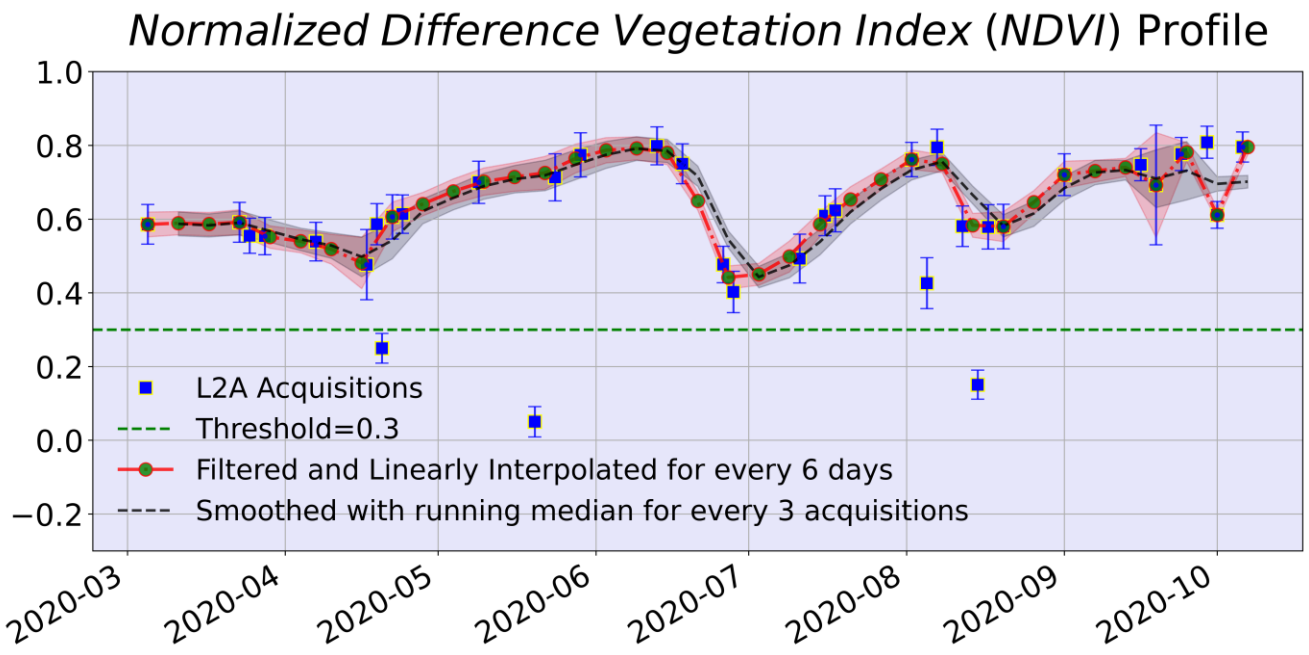
# Analytics Functionalities




## Satellite Image Time-Series processing techniques

- The ENVISION Data Cube solution includes various SITS processing techniques to enhance pixel or parcel time-series for optimal analysis.
  - Filtering
  - Interpolating
  - Resampling
  - Smoothing
- The interpolated SITS can be sampled at any desired temporal resolution to extract meaningful insights.
- Our solution also offers smoothing functionalities, such as rolling median, to reduce noise from temporal fluctuations. This feature results in clearer patterns and better visualization of long-term trends.
- Possible anomalies detection to any chosen index

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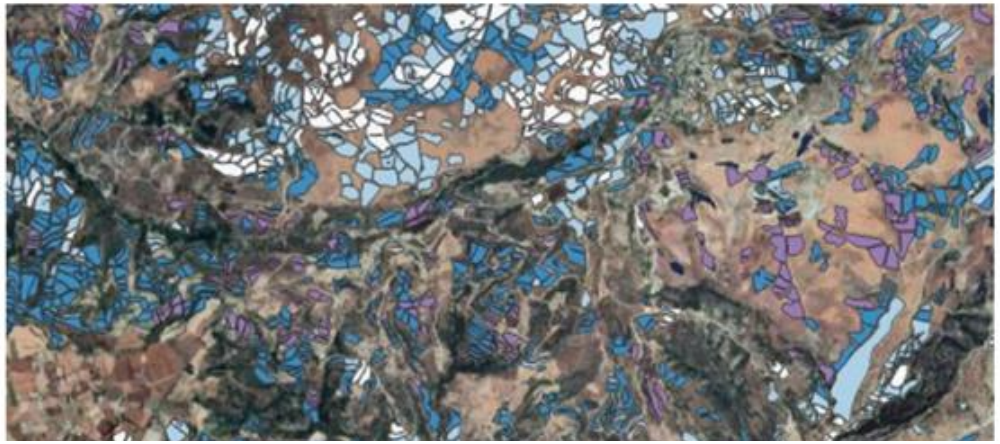
# Soil Index Time-series

## Minimum Soil Cover

- Current CAP demands the identification of soil coverage during specific months throughout the year.
- Initially, the average slope for each parcel has been calculated based on a 20m raster Digital Elevation Model.
- This slope refers to the full polygon, without using any buffer zone.
- The algorithm of Geospatial Soil Sensing System (GEOS3) has been utilized for creating soil masking rules.

## Runoff Risk Assessment

- GAEC 1 aims at the reduction of water pollution in nitrate vulnerable areas has been developed, taking into account the proximity into the closest water areas
- It relies on long-standing concept of **soil erosion** by water, modelled through **RUSLE**.
- In addition, it utilizes also the orientation of each parcel



| | | Water Proximity (meters) | | | |
|---|---|---|---|---|---|
| | | <=10 | <=50 | >50 | >100 |
| RUSLE | <=4 | High | Low | Low | Very Low |
| | >4 and <=8 | High | Moderate | Low | Very Low |
| | >8 and <=15 | High | High | Moderate | Very Low |
| | >15 | Very High | Very High | Moderate | Very Low |

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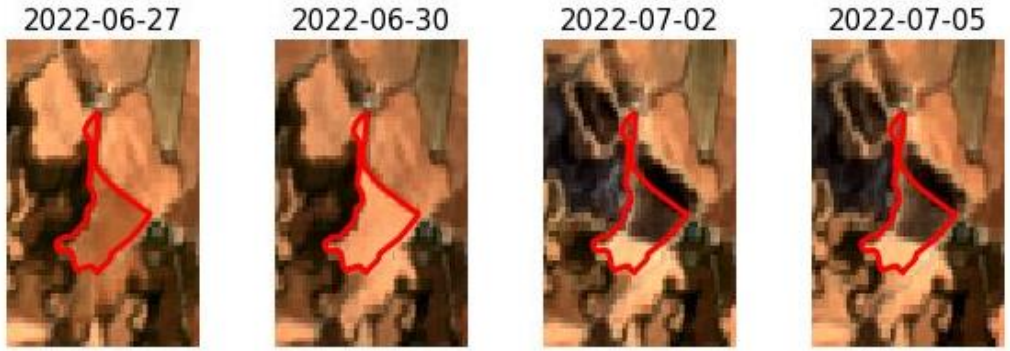
# Stubble Burning Identification

- Farmers rarely declare when they burn their crop parcels
- Paying agencies can easily **monitor GAEC 6 compliance** for each crop parcel by identifying burnt crop parcels and the date they were burnt
- A pixel-based approach is used for national-scale coverage to identify burnt areas
- The approach exploits a combination of indices, such as NBR or NDWI, along with sliding windows to improve accuracy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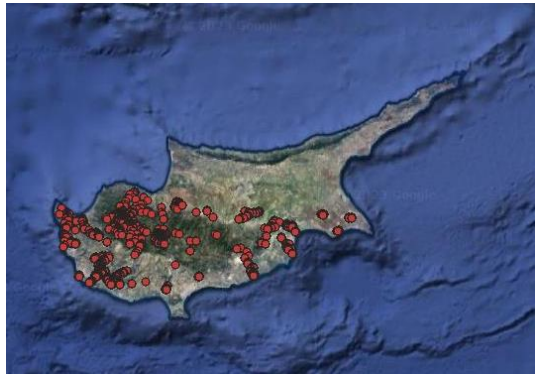
# Natura 2000 Hotspot Detection

- The Natura 2000 is a protected area network in the European Union that aims to ensure the survival of the region's most valuable and threatened species and habitats.
- Similar methodology used in the Stubble Burning approach can be applied using the **NDVI** and **BSI**.
- By marking pixels that fall within the Natura regions but are **not associated with declared parcels from an LPIS**, it is possible to detect and identify potential illegal activity.
- Results are presented as point geometry too, enhancing the validation process

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# Remarks

- **Enhanced Monitoring**: Continuous monitoring of vegetation and soil over time.
- **Scalability**: Our system is designed to provide accurate crop classification results at any scale, from a small Area of Interest to an entire country.
- **Generalization Performance**: Our service provides reliable crop classification information across different regions, helping Paying Agencies to make informed decisions about agriculture management strategies. Paying Agencies can manage diverse regions with varying crops and cultivation practices.
- **Cost Reduction**: Inspections can be carried out more efficiently, reducing the need for costly manual field visits. Paying Agencies can save time and resources, and focus on other critical tasks related to agriculture management.
- **Early Detection**: The time-series analysis provides an early warning system for any potential problems.
- **Customizable Analysis**: The service offers a variety of customizable analysis tools to meet specific needs and requirements.

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# Thank you for your attention!

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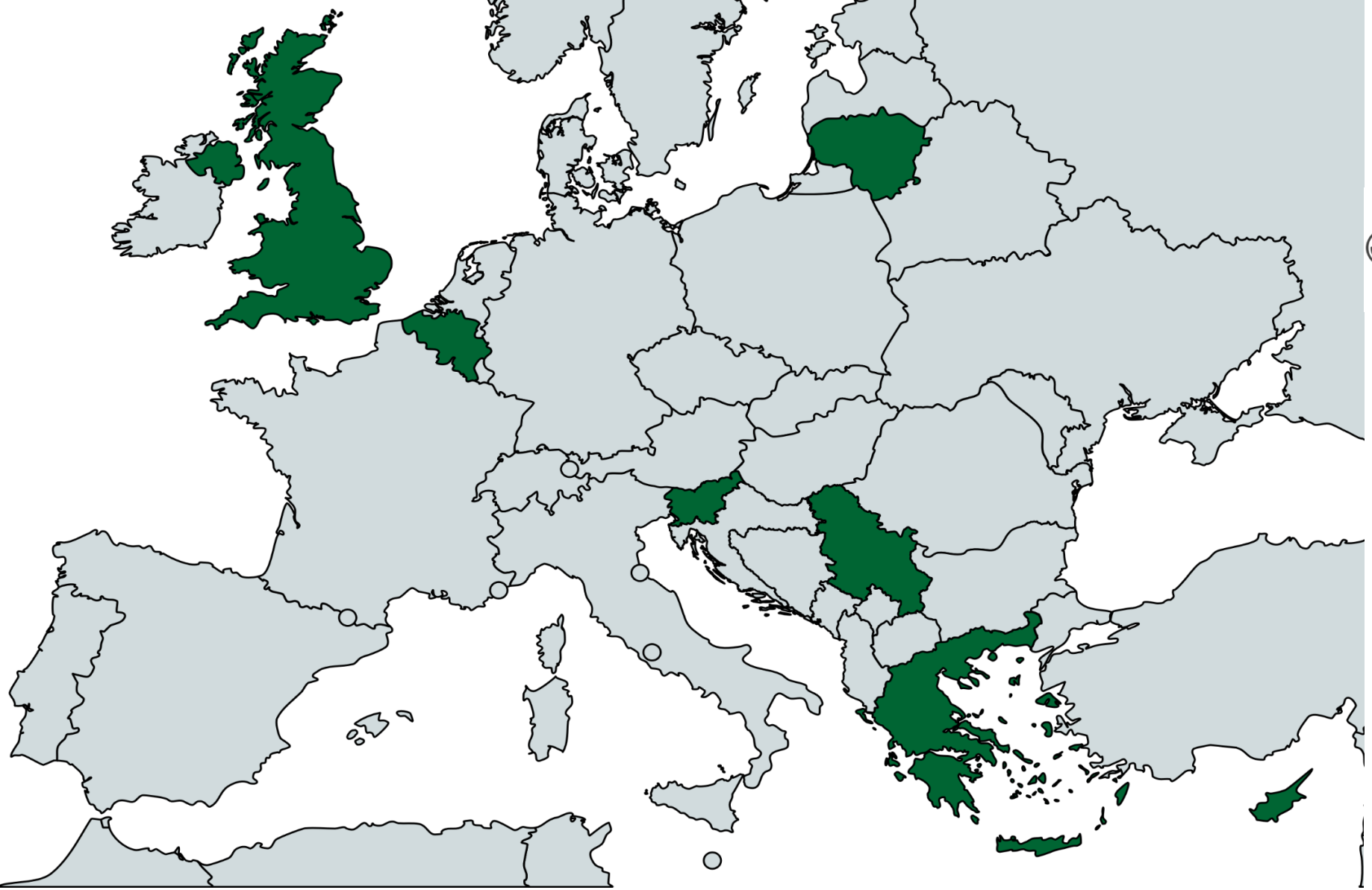

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