Geospatial Intelligence for Environment Protection against illegal activities

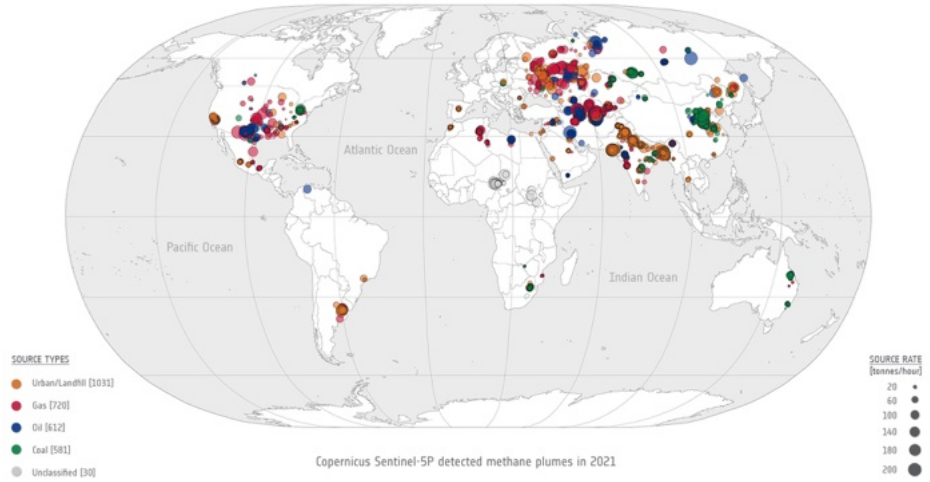
This work is supported by the European Union's Caroline Herschel Framework Partnership Agreement on Copernicus User Uptake under grant agreement No FPA 275/G/GRO/COPE/17/10042, project FPCUP (Framework Partnership Agreement on Copernicus User Uptake), Action No 2021-3-19, Geospatial Intelligence for Environment Protection Against Illegal Activities, SGA grant no. 18

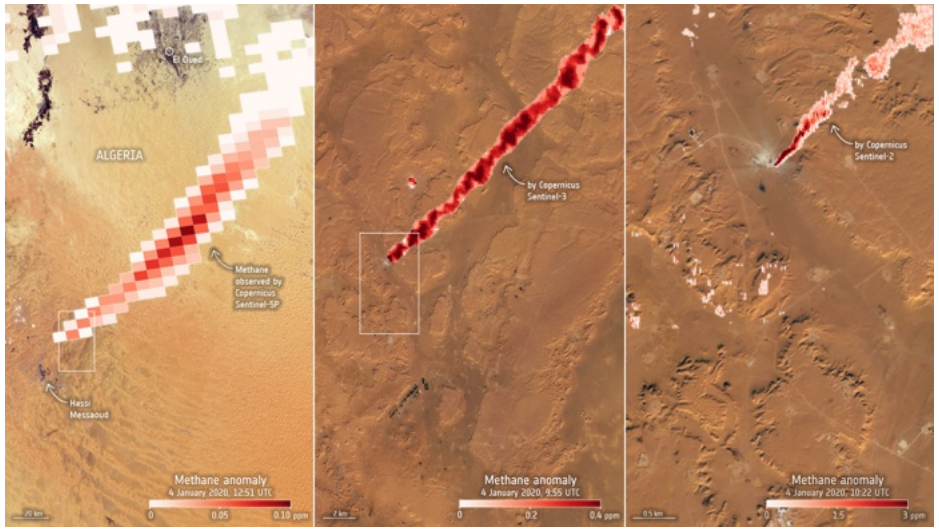
Sentinel satellites map methane emmissions

Recent results from SRON Netherlands Institute for Space Research:

- Sentinel-5P, with daily global coverage, can detect methane leaks anywhere on Earth
- Sentinel-2 satellites are equipped with multi-band instruments and can identify precise locations of detected methane leaks
- Sentinel-3 satellites, are equipped with multi-band radiometers that can observe shortwave infrared bands which are sensitive to methane concentrations

Source:
https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Trio_of_Sentinel_satellites_map_methane_super-emitters (20/09/2023)





Environmental Injustice Mapped with CLMS

CLMS (Copernicus Land Monitoring Service) provides free, high-resolution land data and services to users and citizens around the globe.

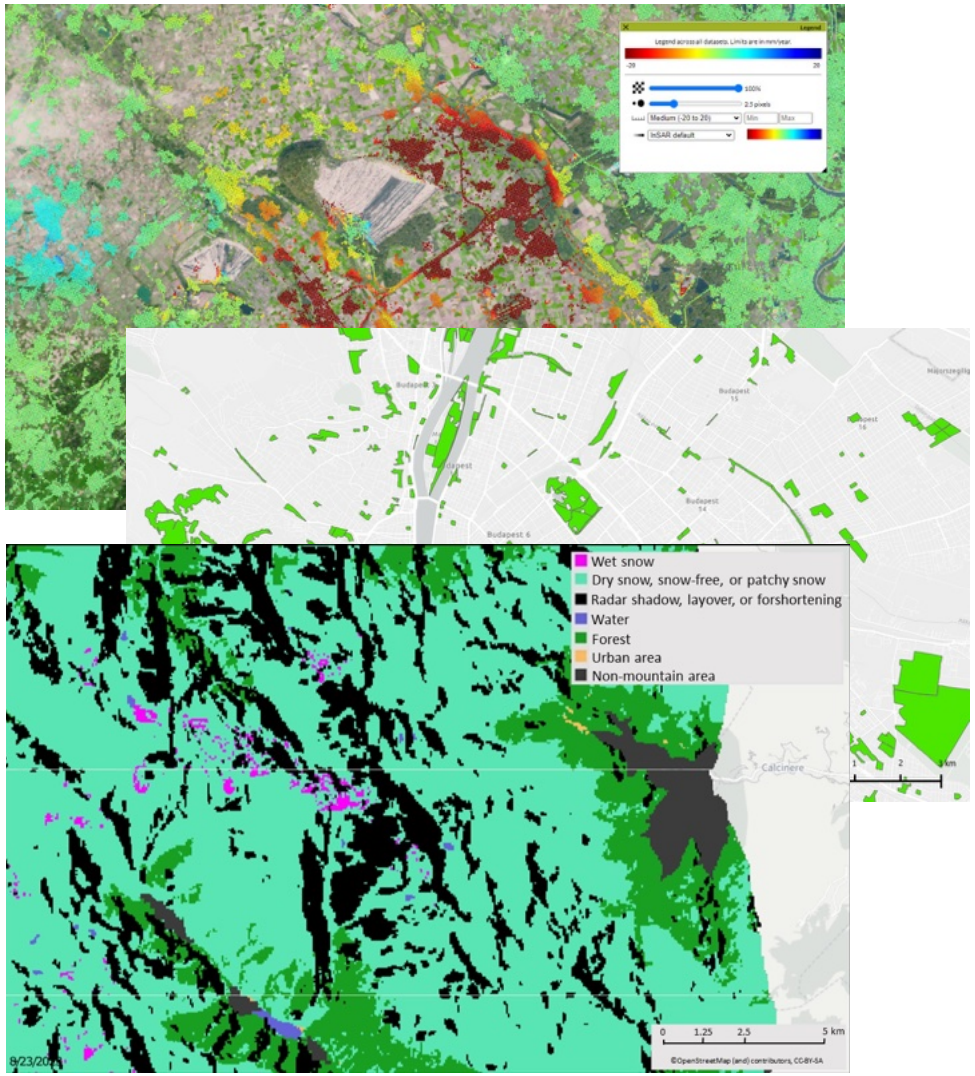
Environmental Injustice: underprivileged and marginalised communities are the most vulnerable to environmental degradation and advocates for a more equitable distribution of environmental risks

EGMS can detect and measure ground movements across Europe with millimetre accuracy and it helps assessing human activity such as mining, tunnelling and over-exploitation of aquifers

Urban Atlas can provide information on green spaces or tree cover.

Snow and Ice: can be used to identify areas at risk of snowmelt-related flooding; avalanche prediction and hydroelectric power management.

Source: Copernicus Observer: https://www.copernicus.eu/en/news/news/observer-mapping-environmental-injustice-copernicus-land-monitoring-service (21/09/2023)



Geospatial Intelligence

"GEOINT encompasses all aspects of imagery and geospatial information and services. It includes, but is not limited to the analysis of literal imagery; geospatial data; and information technically derived from the processing, exploitation, literal, and non-literal analysis of spectral, spatial, and temporal fused products. These types of data can be collected on stationary and moving targets by electro-optical, synthetic aperture radar, related sensor programs, and non-technical means (to include geospatial information acquired by personnel in the field)." Retired Air Force Lt. Gen. James R. Clapper, October 2005

Activity and objectives

GEOINT4ENV is a FPCUP action supporting the **investigation** of both public authorities and private entities information needs related to
-illegal activities affecting the environment such as waste, water, air pollution and forestry as well as
-the performance of remote sensing and geospatial intelligence (GEOINT) methods to answer those information needs (where, when, what, why, who),

Activities are performed by **Taking into account** the EU context and actions to improve environmental compliance and governance and aim at **Designing appropriate workflows** allowing to collect and process EO space and in-situ data, as needed to produce actionable intelligence to be used in Environmental Compliance Assurance (ECA)

The partners planned a number of activities aiming to perform the needed data processing and analysis in order to answer the where, when, what, why, who questions and allowing them to **formulate recommendations supporting the uptake** of the services by the relevant users

GEOINT4ENV is a top-down activity supported by DG ENV as part of the FPCUP WP 2021

Context

-Relevant regulatory frameworks: Commission Communication on "**EU actions to improve environmental compliance and governance**" and related green deal acts;
-Activities developed by the **Environmental Compliance and Governance Forum; Non-compliance events** reported by governmental and EU organisations on waste crime, forest crime, illegal building, air quality, illegal fertilisation, water pollution**;**
-Better, open and free geospatial data and **advance in processing and analysis** technology supporting production of actionable intelligence – the GEOINT framework
-In *Combating environmental crimes and related infringements : environmental compliance assurance : guidance document** the geo-spatial intelligence is mentioned in combination with Earth observation and tracking capabilities contributing to the general surveillance, with 6 roles: Early alerts based on land use changes; Risk assessment; Real-time information in combination with site visits; Forensic evidence of past misconduct - based on archive data; Visual evidence at criminal trials; Deterrence when the method is publicly known.

*European Commission, Directorate-General for Environment, Office of the European Union, 2021, https://data.europa.eu/doi/10.2779/035969

General approach

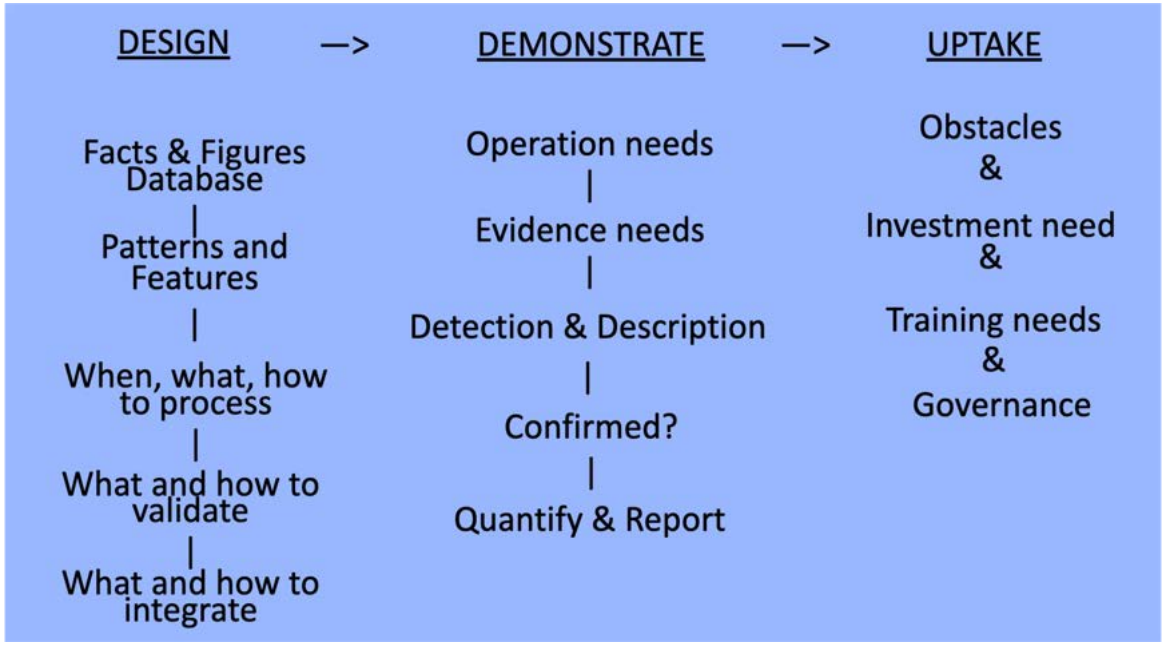
Need analysis (types of non compliant events, current knowledge on patterns and features, types of actionable intelligence required)

Investigate **methods and resources** (needed to detect / raise warning, validate, measure / quantify, evaluate / assess in order to produce evidence / actionable intelligence)

Prepare and run **demonstrations** (identify relevant sites / cases, collect data, apply methods using web platforms, other means)

Validate findings (based on dialog with user organisations and relevant parties and relevant OSINT)

Disseminate and report (design and implement the ***Knowledge–Sharing Platform*** based on selected cases addressed in demonstration activities gathering information on requirements, methods and data, intelligence produced)



Interraction with possible users

Cyprus: agencies (9) and Municipalities (3): Department of Environment, Department of Fisheries and Marine Research, Water Development Department, Department of Land and Surveys, Public Works Department, Cyprus Quarries Association, Nicosia Municipality, Limassol Municipality

Germany: Federal Ministry for the Environment (BMUV – 16), Environmental Agency Germany (UBA - 16), Federal Criminal Police Office (BKA – 16 local offices), public order offices and prosecutors, Environmental NGOs, foundations & activists

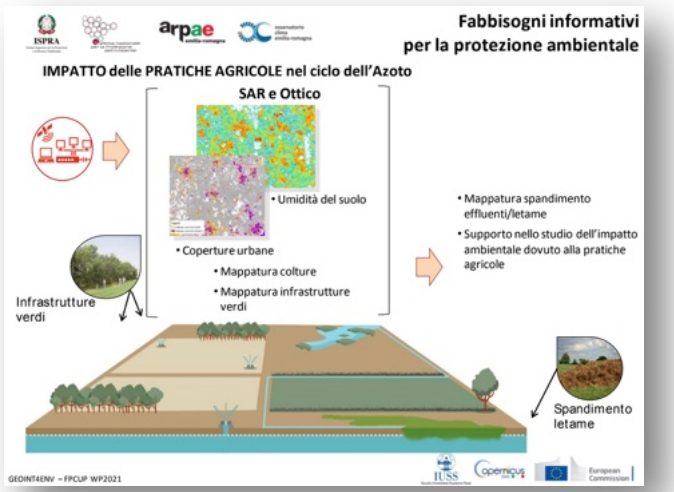
Italy: National Park, Administrative Region, Environmental Protection Agency (forestry & illegal logging), Environment protection agencies and regional administrative authorities in Veneto, Latium, Lombardia, Emilia Romagna, Basilicata, Valle D'Aosta, Umbria, Campania (manure spreading), local administrations and authorities involved in land planning and monitoring (illegal construction)

Poland: Ministry of Climate and Environment (Ministerstwo Klimatu i Środowiska) - Department of Waste Management, Department of Nature Conservation, Department of Environmental Instruments, Department of Forestry and Hunting, Main Inspector of Environmental Protection (Główny Inspektor Ochrony Środowiska), General Directorate for Environmental Protection (Główna Dyrekcja Ochrony Środowiska), State Forest, National Parks (23), National Water Management (11 regional boards), Construction Supervision Inspectorates (1 central, 16 regional, 314 province)

Romania: Ministry of Environment, Water and Forest - MMAP (Ministerul Mediului, Apelor si Pădurilor) as central authority, National Environmental Protection Agency - ANPM (Agenția Națională pentru Protecția Mediului) as executive agency, with 42 subordinated county agencies; the National Environmental Guard - GNM (Garda Națională de Mediu), in charge of enforcement, with 42 subordinated county commissariats, and 2 additional commissariats for Bucharest and the Danube Delta; and the National Agency for Natural Protected Areas - ANANP (Agenția Națională pentru Arii Naturale Protejate) with 5 territorial areas. Construction State Inspectorate (One central 0ffice, 42 regional offices at county level)

Interraction with possible users

Workshops and seminars organized by the partners allowed identification of operational requirements as well as sharing information on current findings and way forward



Către: Garda Națională de Mediu

În atenția: Doamnei Comisar General Marioara-Artemis GĂTEJ

București, 22 Februarie 2022

Stimată doamnă comisar general,

Începând cu luna ianuarie 2021, Agenția Spațială Română, Meteo Romania, împreuna cu parteneri din Cipru, Germania, Italia și Polonia (CBK PAN Polonia, Cyprus University of Technology, German Research Centre for Geosciences (GFZ) Potsdam, ISPRA Ambiente Italia) derulează proiectul *Geospatial Intelligence for Environmental Protection Against Illegal Activities* (GEOINT4ENV), proiect finanțat de Comisia Europeană în cadrul parteneriatului *Copernicus User Uptake Programme* (FPCUP).

Principalul obiectiv al proiectului este evaluarea metodelor de analiză și intelligence geospatial (GEOINT) în raport cu detecția, identificarea și cuantificarea fenomenelor ce reprezintă încălcări ale legislației privind protecția mediului sau abateri de la reguli. Metodele evaluate se bazează pe date geospațiale în general și pe date satelitare în principal pentru a încerca să răspundă la întrebări esențiale - unde, când, cum, ce, cât, cine, de ce - în legătură cu fenomenele menționate și să producă probe ce pot fi utilizate ulterior în cadrul unor acțiuni corective sau de eliminare a efectelor. Conceptele și analizele menționate urmează să fie aplicate în raport cu următoarele teme:

Current Planning & Future Activities

Calendar

Activities / Time	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Requirements analysis	--	--	--	--	--	W1	--	R1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methods selection	--	--	--	--	--	--	--	–	--	W2	--	R2	--	--	--	--	--	--	--	--	--	--	--	--
Case studies	--	--	--	--	--	--	--	--	--	--	--	R3	--	--	--	--	--	R3	--	R4	--	--	--	--
Uptake planning	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	W3	--	R5	R6	--

Coordination
Overall coordination: ROSA
Coordination per topic:
Air (METEO)
Forestry (CBK PAN)
Waste (GFZ)
Water (CUT)
Illegal Building (ISPRA)
Illegal Manure Spreading (ISPRA)
Dialogue with users: coordination ISPRA, implementation all partners.
Demonstration products: GFZ

Outcomes
W1: Workshop on user need analysis in M06
R1: report on users profiles, needs and regulatory obstacles (M08)
W2: Workshop on GEOINT methods and tools in M10. Deliverables:
R2: report on recommended IT infrastructure, needed data and analysis tools (M12)
R4: portfolio of demonstration products (INTREPs) in pilot test sites (M20)
R3: knowledge sharing platform (KSP) - software and user manual (M18)
W3: Workshop on workflows and technical and legal barriers in M20
R5: report on possible workflows, technical obstacles and needed investment (M22)
R6: summary of recommendations on workflows, training needs and uptake (M23)

*Due to delays in accessing needed data, a project extension of 6 months was requested to European Commission

Manure spreading

Manure spreading: Regulatory references

Europe

European Commission Directive Air Quality 2008/50/CE :

- The aim: to avoid, prevent or reduce harmful effects of air pollutants **(PM2.5, PM10**, SO2, NO2, Pb, Co, Benzene, O3, As, Cd, Ni, Benzo(a)pirene) on human health and the environment
- Proposal for a revision (October 2022): new limits for air pollutants from 2030

Italy

D. Lgs. 155/2010 delegated the AQ competences to the Regions and Autonomous Provinces supported by the regional environmental agencies (ARPA/APPA), organized in the National Environmental Protection System – SNPA

Manure spreading: User requirements

Needs and technical requirements:

- Key requirement: Database platform to collect and homogeneously manage the information on manure spreading activities
- Monitoring activities during the no-spreading period
- Areas identified as prone to manure spreading: Pianura Padana (Po plain)
- Minimum mapping unit: between 10 m^2 and 1 ha
- Monitoring update: weekly or at least monthly threshold
- Delivery time of monitoring results: a few days after the reported event and remote sensing data acquisition

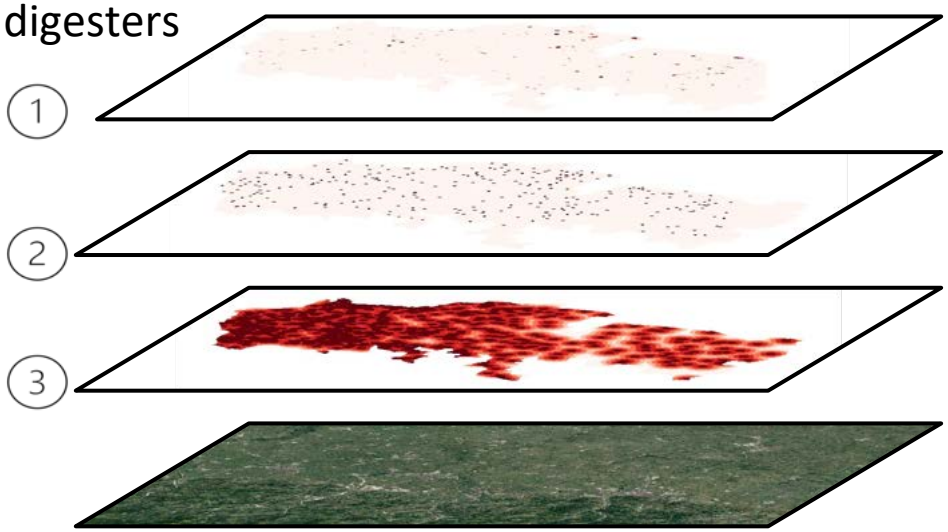
Obstacles

- difficulty in tracing the spreading information (timing and location of the event)
- difficulty in linking the event to measures on the ground and the company responsible for the spreading
- difficulty in monitoring because the spreading is not always reported to the competent authorities
- difficulty in accessing manure spreading authorisation
- lack of up-to-date spatial layers

Manure spreading: evaluation method

The candidate method for monitoring of manure spreading is based on 3 variables integration:

- **Variable 1** - Manure spreading frequency produced by automatic processing of Sentinel-2 time series
- **Variable 2** - Manure spreading identification areas by an experienced operator
- **Variable 3** - Distance from farms and/or bio-digesters

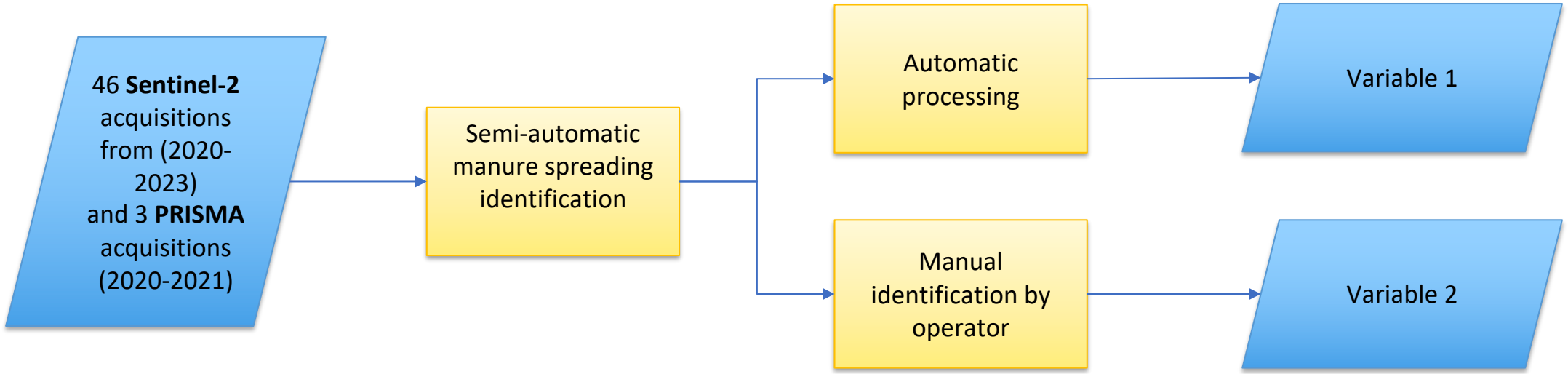


the values of each variable are normalized to the range [0-1] and then variables are combined.

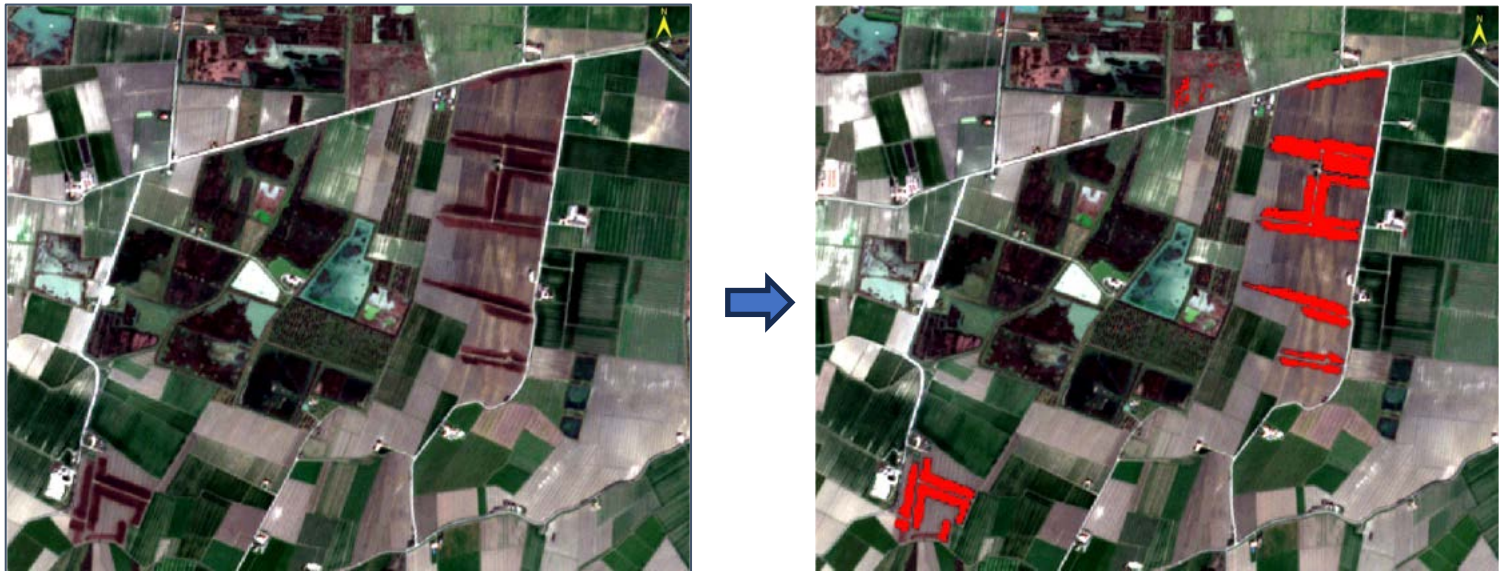
The susceptibility values are converted into 5 different classes to enhance the readability of the maps.

Therefore, very high susceptibility rates are detected uniquely in the areas where the three layers reach a maximum value.

Manure spreading: evaluation results



Examples of the result of the algorithm for the semi-automatic manure spreading identification on 28th February 2023 Sentinel-2 acquisition



Manure spreading: strenghts and limitations

The strenghts of this methodology are:

- semi-automatic procedure
- Sentinel-2 open data
- PRISMA images to deepen manure spectral signature
- analysis of wide areas of agricultural soil
- immediate overview/focus on critical areas
- periodic update possibility
- annual implementation

The limitations of this methodology are:

- Needs of an operator to validate the data
- Difficulties Identifying spreads in vegetated soils
- Need of further field campaign and new soil chemistry analyses

Illeegal logging

Illegal logging - user needs in Italy

- Over 30% of Italian user indicate illegal logging occurring outside concession boundaries of a forest management plan
- Ancillary information are required to identify illegal logging using satellite Earth Observation, to exclude authorized logging sites or areas of forest loss related to natural factors (i.e. wildfires, insect outbreaks, wind disturbance)
- Required minimum mapping unit: 1 to 5 hectares
- Optimal update frequency: from weekly to monthly
- Earth Observation products support planning of local authorities in-situ checks for the cases where there is really a high risk of infringement

Illegall logging - Methods

Identification of changes related to forest disturbances

Characterization of changes
(based on spectral and spatio-temporal variability)

Forest logging identification

Comparison with authorized logging sites

Illegal logging detection

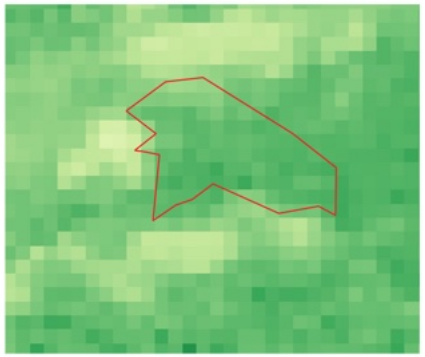
Satellite Earth Observation to identify and characterize illegal logging

- *Data:* Copernicus Sentinel-2 MSI time series
  Copernicus Sentinel-1 time series

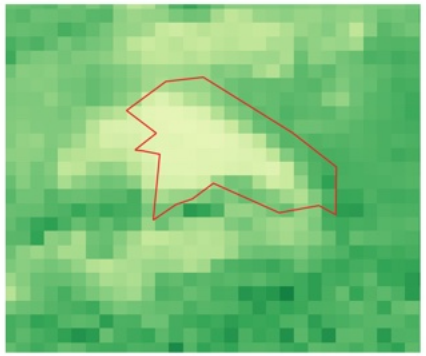
Spatial resolution: 10- 20 m

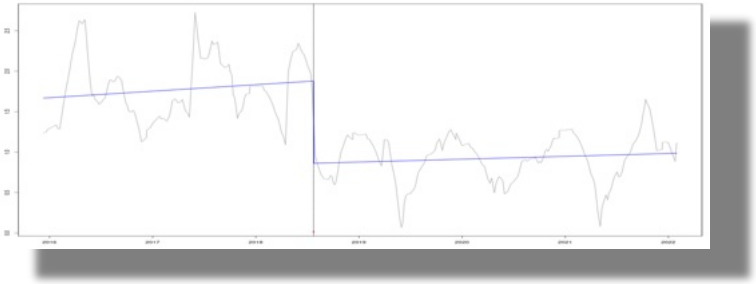
Methodology: time series abrupt changes identification (Bfast), spatio-temporal analysis of changes

Pre-logging (2016)

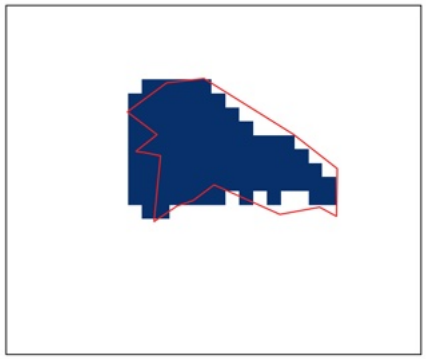


Post-logging (2017)

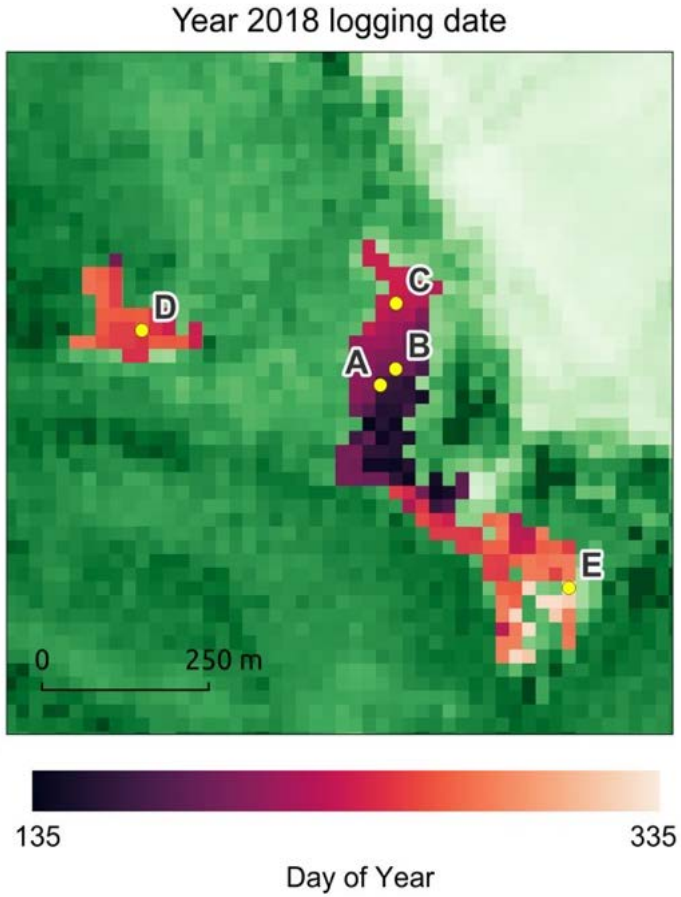


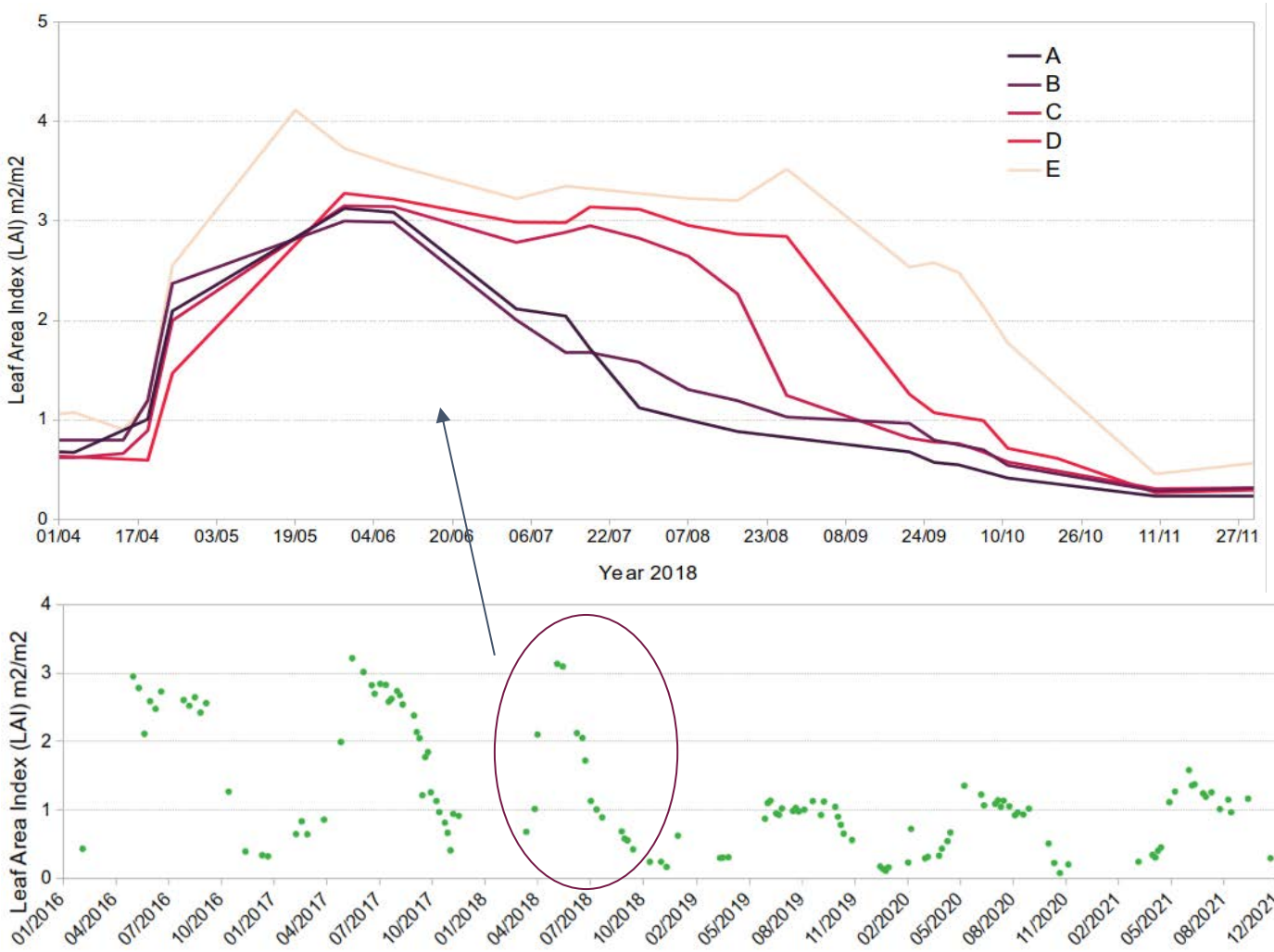


Identified logging area



Illegall logging - Results in Italy

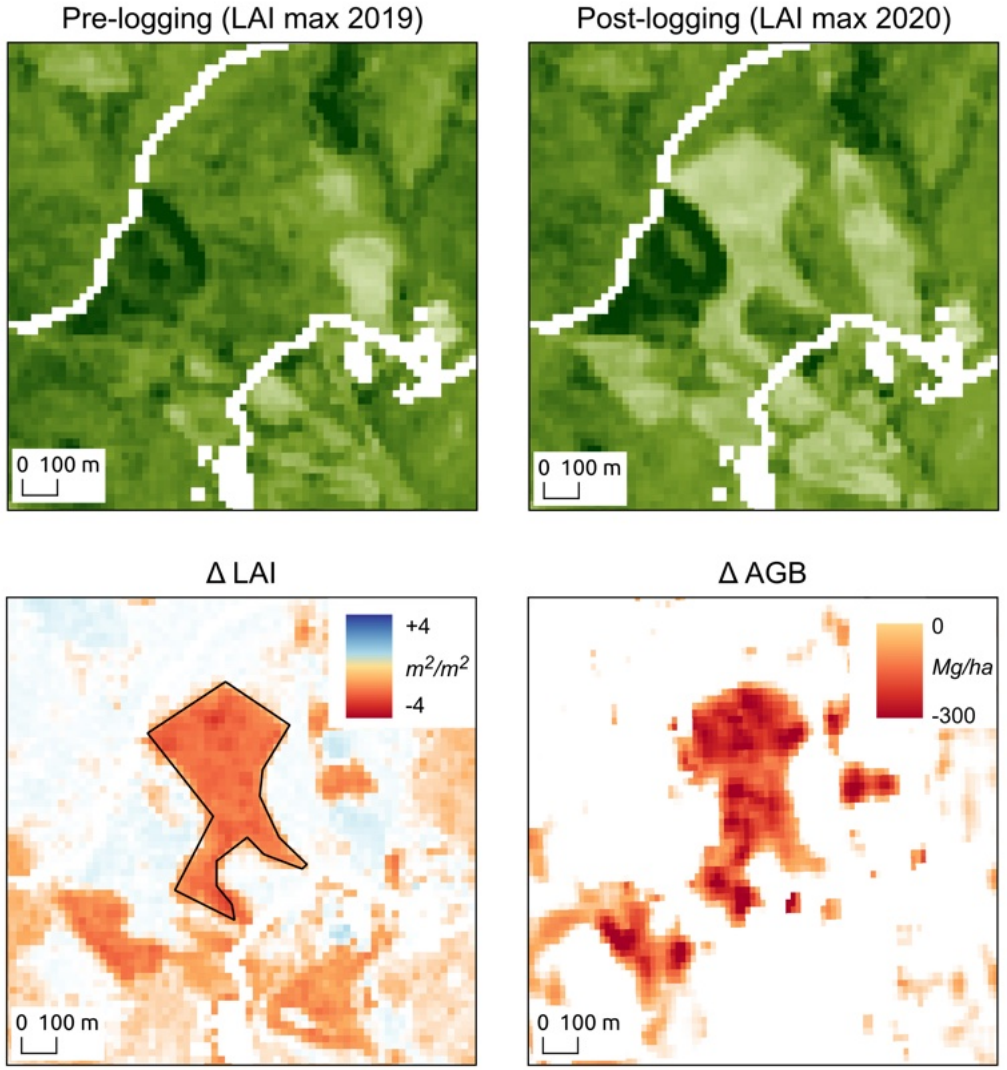




Illegall logging – Results in Italy

Time series analysis allows
to quantify loss within logging sites
in terms of biophysical parameters:

- Leaf Area Index (LAI)
- Above Ground Biomass (AGB)



Illegal logging - User requirements in Poland

- Polish State Forests declared no problems with illegal logging
- Illegal logging occurring on: protected areas, along river banks, municipalities areas
- Required information:
  - Satellite/airborne imagery before and after
  - Time of occurrence
  - Affected area/biomass

Illegal logging - Case studies in Poland

Inter-annual change detection by comparison of yearly updated high resolution LC/LU maps of Poland, generated from Sentinel-2 time series:

- Based on S2GLC approach
- Pixel size: 10 m
- Automatic approach
- Method indicates hot-spots which can be confirmed by local authorities

http://s2glc.cbk.waw.pl

Illegal logging - Case studies in Poland

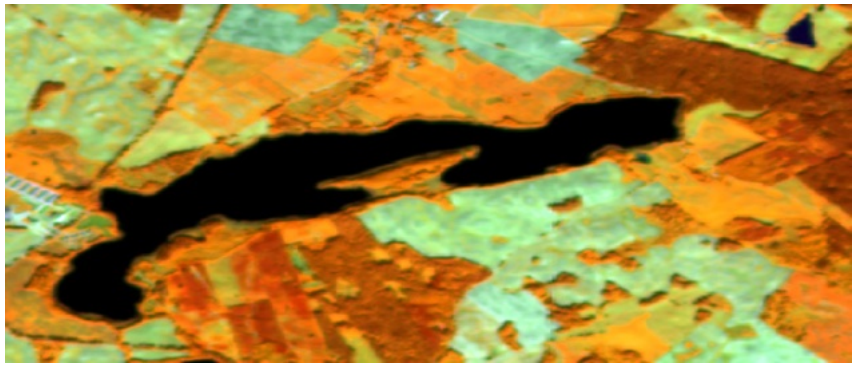
- Illegal trees logged within protected area in Poland
- Sentinel-2 images from 2021 and 2022
- Change detection mask with logged trees

Strengths

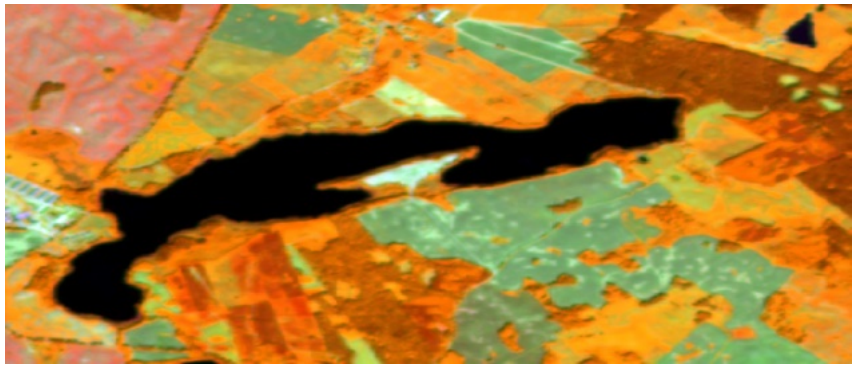
- Fully **automatic** approach
- Based on open access satellite imagery from Copernicus programme

Limitations

- Changes detected year to year – could be modified to detect changes monthly/weekly
- Minimum Mapping Unit 10 m x 10 m



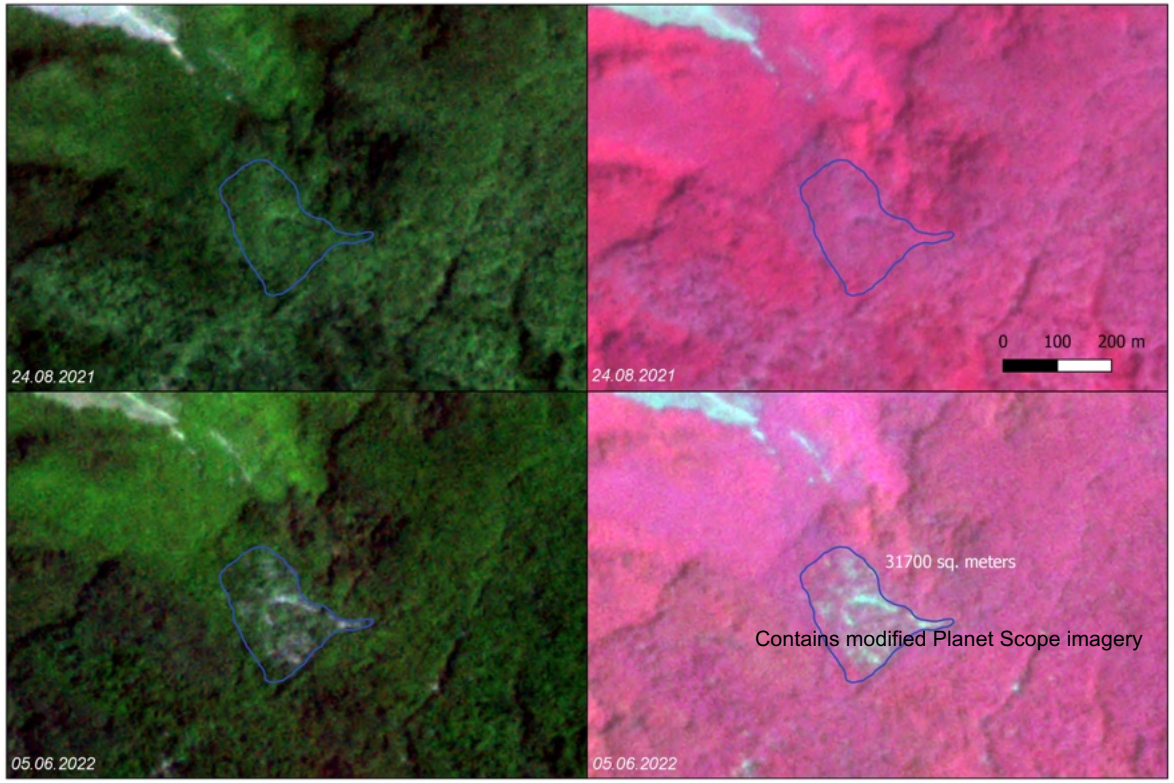
2021

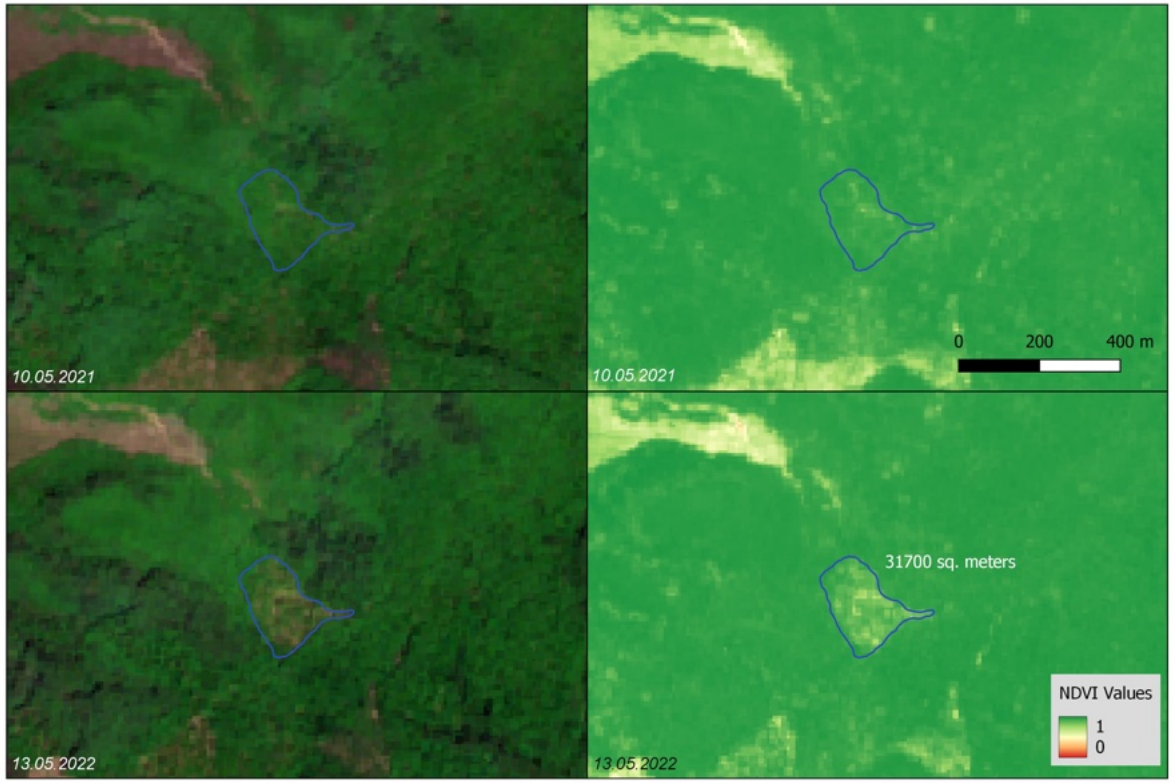


2022

Logged trees

Illegal logging - Case studies in Romania





AOIs selected considering available information, on exploitation permits for assessing performance of satellite EO to detect and measure in sites where TLS is also performed

Illegal construction

Illegal construction monitoring - User requirements Italy

Technical requirements identified from user needs:

- The main output should be **GIS maps** identifying **land cover changes** related to new **construction sites or buildings**
- A sufficient level of detail to **distinguish illegal activities in the frame of local planning and protected areas**; **local authorities and municipalities** can therefore **use the produced change detection maps to verify** (through in situ observations or photointerpretation of updated very high-resolution images) if the detected changes are illegal constructions
- The **minimum spatial resolution** for monitoring illegal buildings is between **10m and 100m** ($100\ m^2 < MMU < 10{,}000\ m^2$)
- The **temporal period** of the monitoring should be **between 1 and 12 months**
- The **delivery time** of the monitoring results should be between **a few days and a month after the monitoring activity**

Illegal construction - Workflow

Input

- Data collection: collection and preprocessing of EO data (Sentinel-1 and Sentinel-2 time series)
- Detection of potential change related to land consumption: developed methodology adapted from Luti et al. (2021)
- Construction of the potential change mask
- Overlay with ancillary data as local plans or official maps of buildings (cadastre)

Output

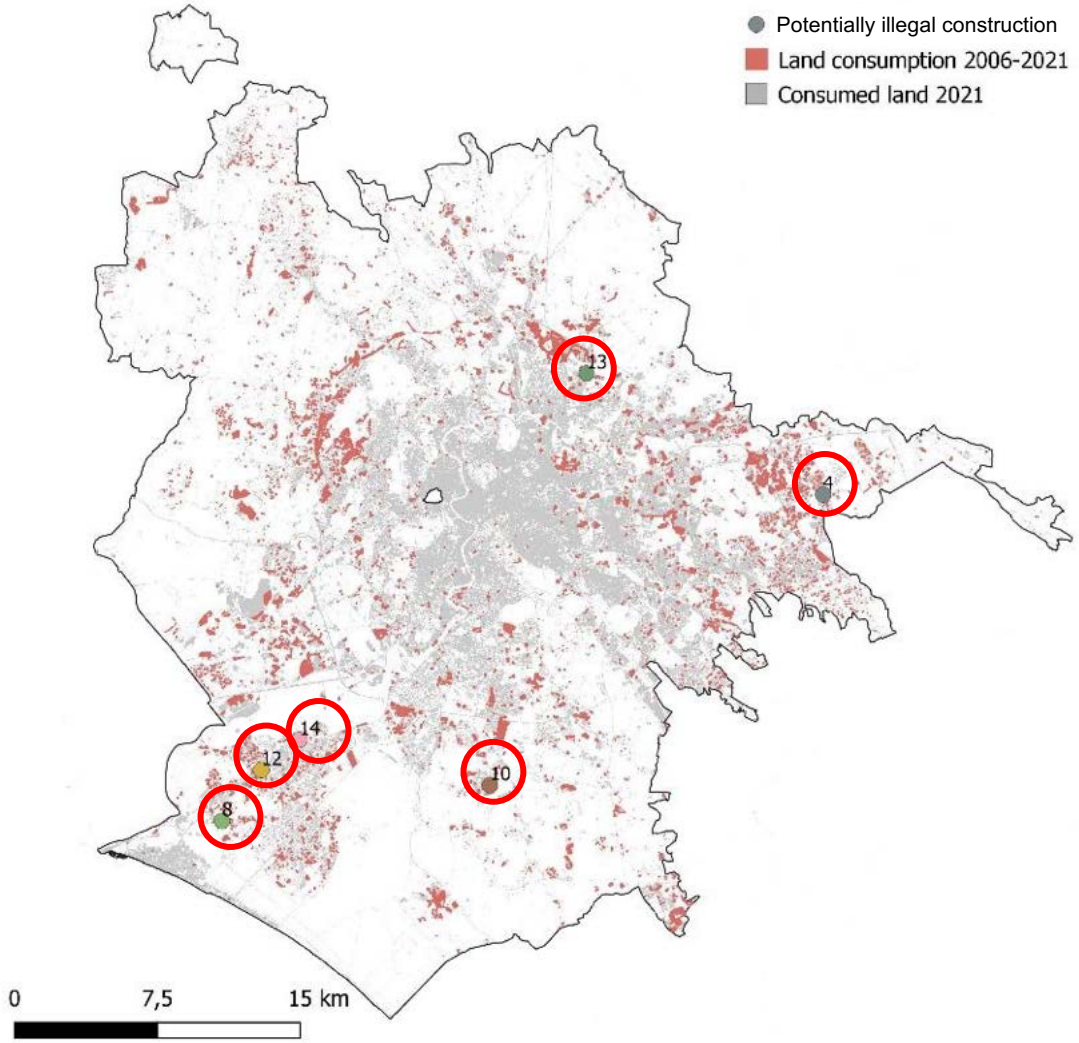
- GIS maps of potentially illegal buildings

Illegal construction - Rome Municipality Example

The method was applied to Rome for the **period 2020-2021**

The maps of possible changes was **photointerpreted** and **overlayed to the cadaster**

Several changes that don't overlap cadaster buildings were identified as possible illegal construction



Illegal construction monitoring - strengths and limitations

Strengths

- The method allows for the **automatic detection of possible changes**
- **Training data is not required**
- **Synergic use of Sentinel-1 and Sentinel-2** data, reducing cost of monitoring
- **Method** that can be adapted to different landscapes

Limitations

- The method doesn't allow for detecting **changes in height of existing buildings**
- The possible changes need to be **photointerpreted** to refine the number of actual changes
- **Ancillary data is required** to define **zones of illegal construction**
- **In situ verification** is **required** to detect constructions that are illegal according to the local legal framework

Waste Crime

Waste Crime - Inspection Cases

- In the context of remote sensing and GEOINT, the temporary or final disposal / deposition of waste under open sky represents the main activity that can be observed and monitored
- Additional specific activity: burning of waste under open sky

Waste crime - User needs

User needs

Main needs of users from Germany,

Poland and Romania

- Detection of illegal waste sites
- Monitoring of legal & illegal waste sites regarding type and quantity of materials, time of occurrence and temporal evolution
- Methane emissions from landfills
- Detection of fires on waste sites

Challenges / Requirements

Challenges

- heterogeneity of waste sites regarding size, materials, spatial layout/structure
- small-scale size and structure of waste sites

User requirements

- Method used in the detection and monitoring of waste dump sites should be scalable and affordable

Waste crimes in Romania

We will use the understanding of environmental problem in the context of induces offence and injury like those identified in a proposal of new European Directive for Environmental Compliance:

c. the collection, transport, recovery or disposal of waste, the supervision of such operations and the after-care of disposal sites, including action taken as a dealer or a broker (waste management), when an unlawful conduct:

i. concerns hazardous waste as defined in Article 3(2) of Directive 2008/98/EC of the European Parliament and of the Council39 and is undertaken in a non-negligible quantity;

ii. concerns other waste than referred to in point (i) and causes or is likely to cause death or serious injury to any person or substantial damage to the quality of air, the quality of soil or the quality of water, or to animals or plants;

Waste crime

- Illegal industrial waste disposal
- Illegal municipal waste disposal
- Waste burning

Image Credit: G4Media

User dialog in participating countries

Challenges / Requirements

Challenges

- heterogeneity of waste sites regarding size, materials, spatial layout/structure
- small-scale size and structure of waste sites

User requirements

- Method used in the detection and monitoring of waste dump sites should be scalable and affordable

Waste crime - evaluated methods

1. Visual interpretation of very high resolution satellite imagery
2. Automated change detection based monitoring of known waste sites
3. Automated world-wide detection of formerly unknown waste sites

Waste crimes in Romania

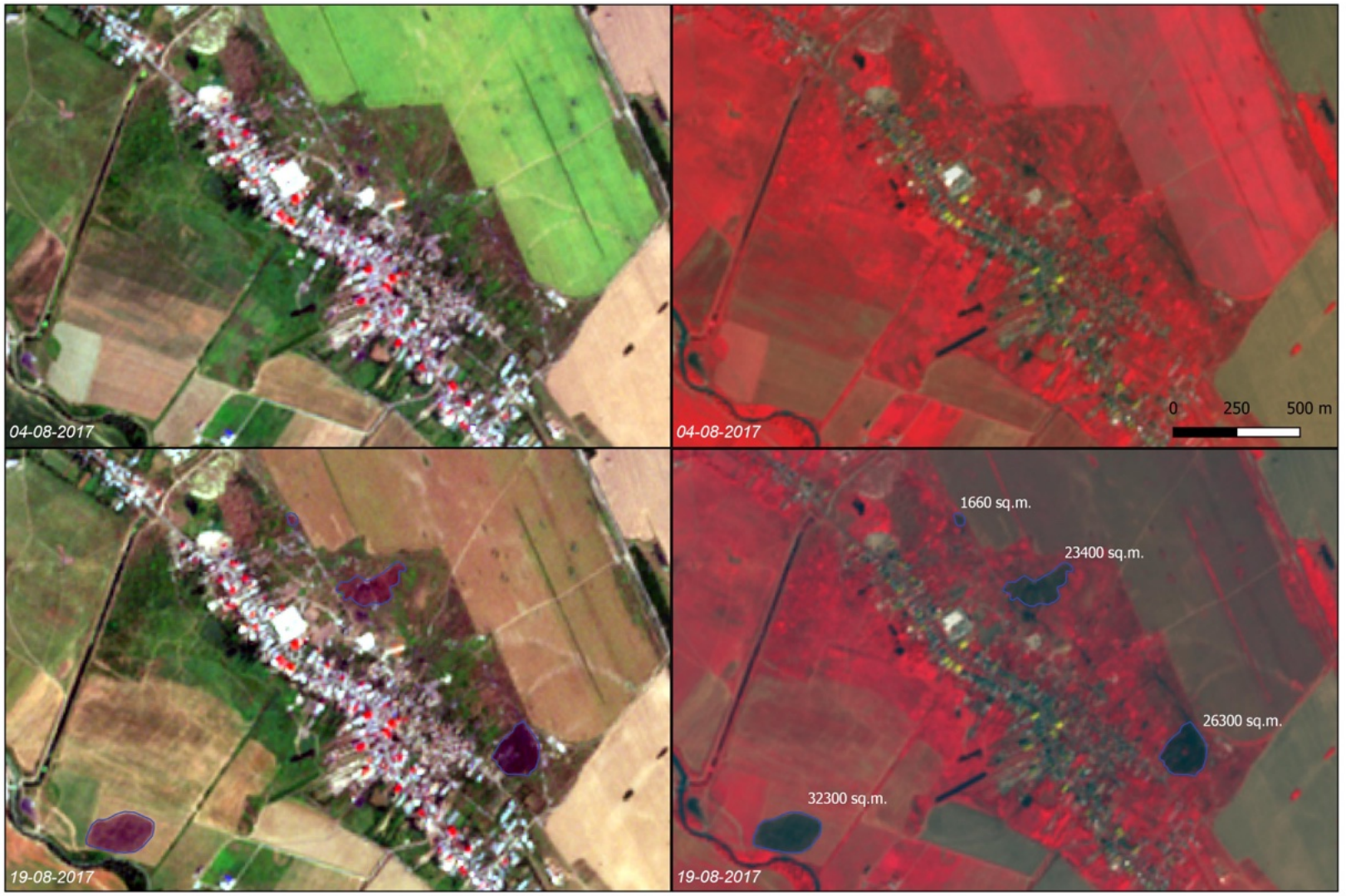
Site detection performed based on Fire events observed on FIRMS (Based on daily satellite images (MODIS, VIIRS)

Source: https://firms.modaps.eosdis.nasa.gov

Waste crimes in Romania

Practical example\Best practices

2017
Waste disposal and burning detection
Surface affected detection



Contains modified Copernicus Sentinel-2 data

Waste crimes in Romania

Practical example\Best practices

2020
Waste disposal and burning detection
Surface affected detection

Contains modified Copernicus Sentinel-2 data

Waste crimes in Romania

Practical example\Best practices

2020
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Waste crimes in Romania

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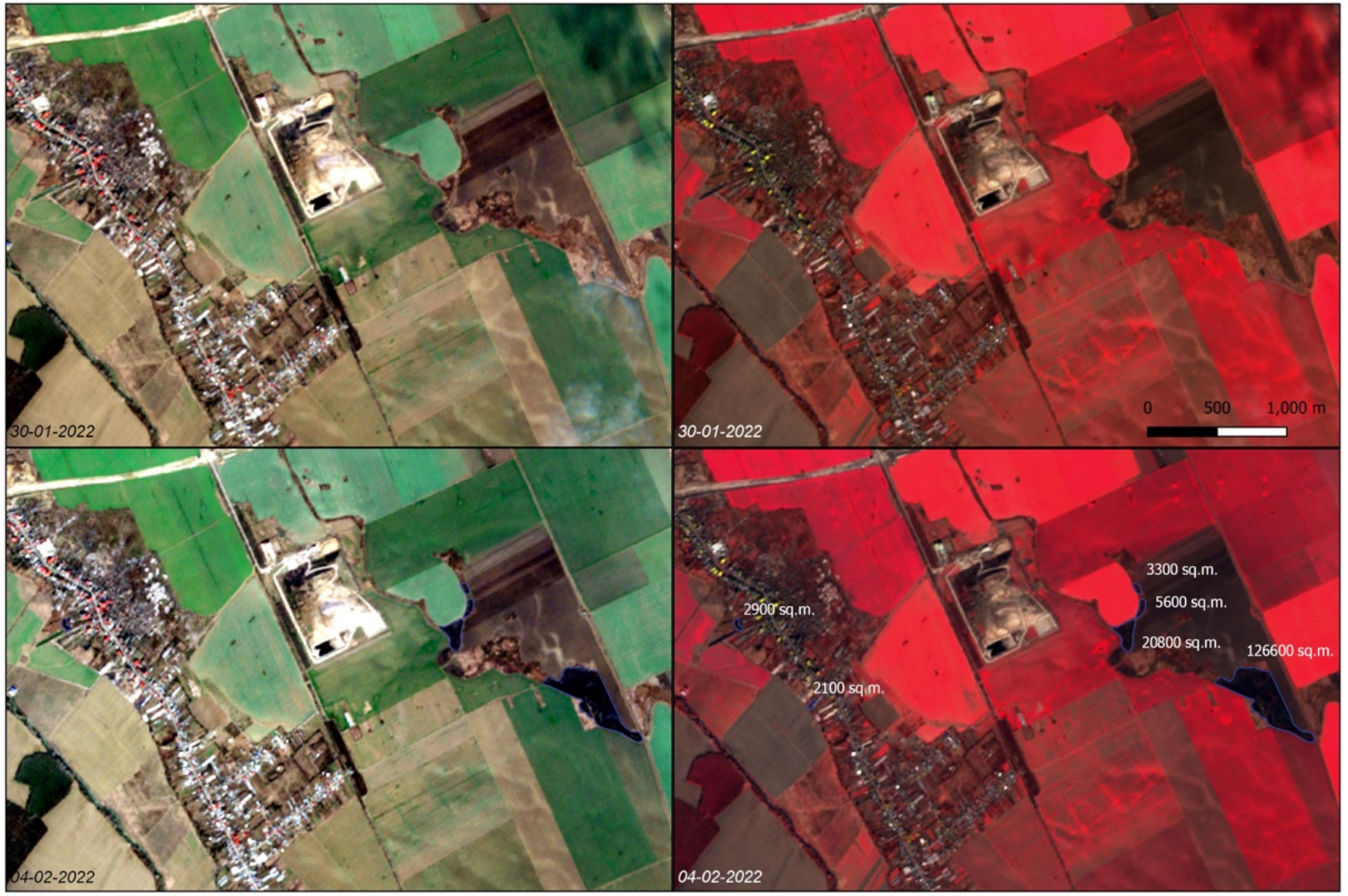
Waste disposal and burning detection
Surface affected detection



Contains modified Copernicus Sentinel-2 data

Waste crimes in Romania

Practical example\Best practices

2022
Waste disposal and burning detection
Surface affected detection

Contains modified Copernicus Sentinel-2 data

Summary for detected AOIs

- 5 out of 7 fire events identified on Sentinel-2 imagery
- burned surfaces mainly in the pasture area of the village (permanently herbaceous)
- Total burned area: ~ 42 ha

Waste crimes in Romania

Examples

2020 – 2023 time series
Evolution of affected area over time

Waste crimes in Romania

Technical strenghts and limitations

Strenghts:

- Detection of illegal landfills, dump sites, and illegal waste storage facilities
- Monitoring of activities at closed landfills and closed storage facilities
- Monitoring of legal landfills with regard to the quantity of waste
- Monitoring and classification of waste types that are spread on a landfill, dump site or facility
- Detection of contaminated sites and deposits
- Monitoring of interim waste storage sites

Limitations:

- Lack of very high-resolution satellite imagery with a high repetition rate at affordable costs
- Eventually conflicts with the General Data Protection Regulations
- Some process cannot be automated

Monitoring of waste sites based on change detection

- Areas of interest: Brandenburg, Germany and Southern Turkey
- Heterogeneous materials and material distributions
- Low/No internal budget and know-how for data & data analysis
- Binary “change / no change” information sufficient → alert when large changes occur

Data

PlanetScope data (3 m) Scenes between 2016-2022 selected to temporally match the site-specific available Google Earth time series

a) SEN-2

b) PlanetScope

c) VHR Data (Google Earth)

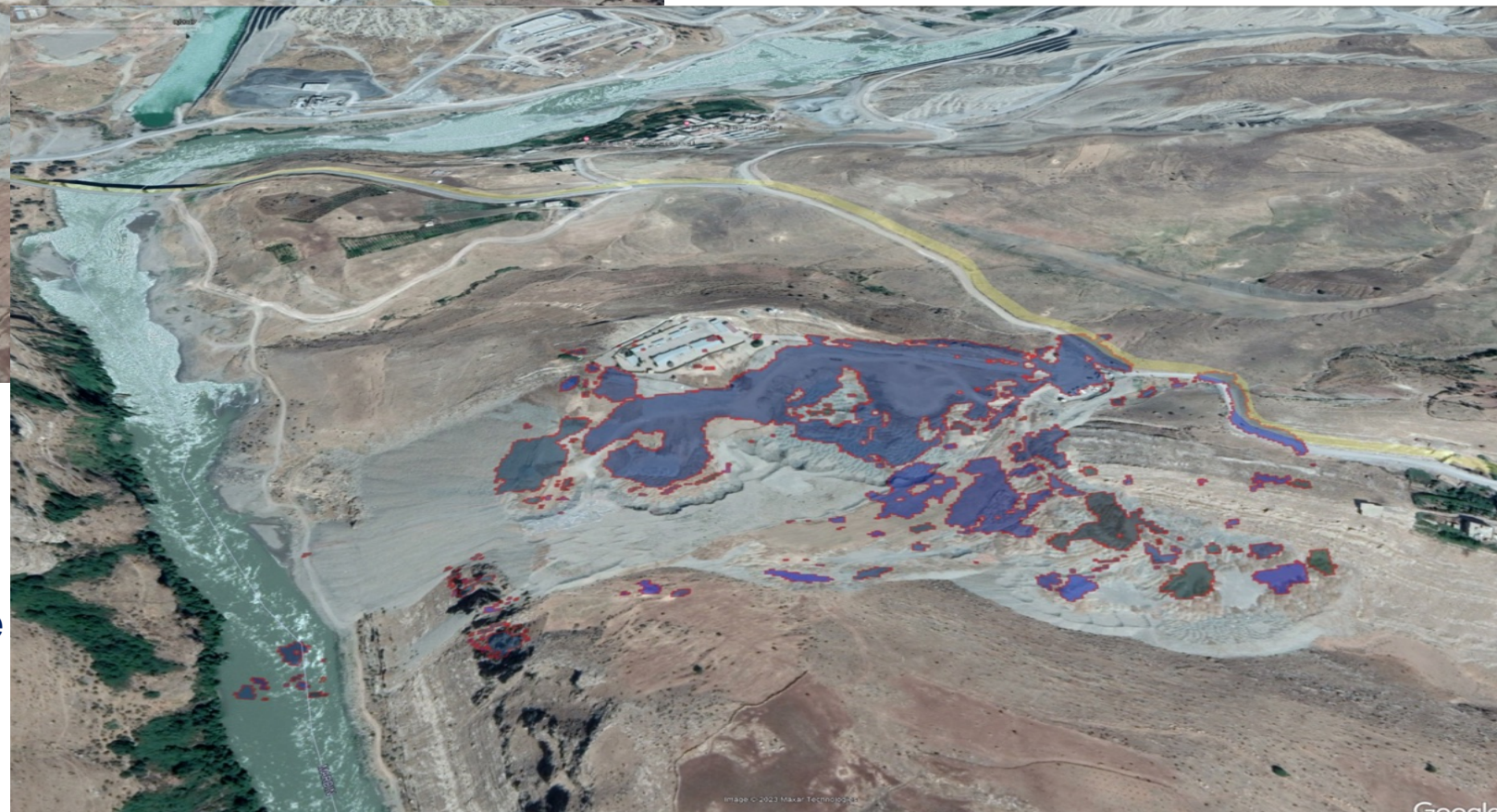
c) Change map 06-09.2022

South Turkey

2016-05-28

South Turkey

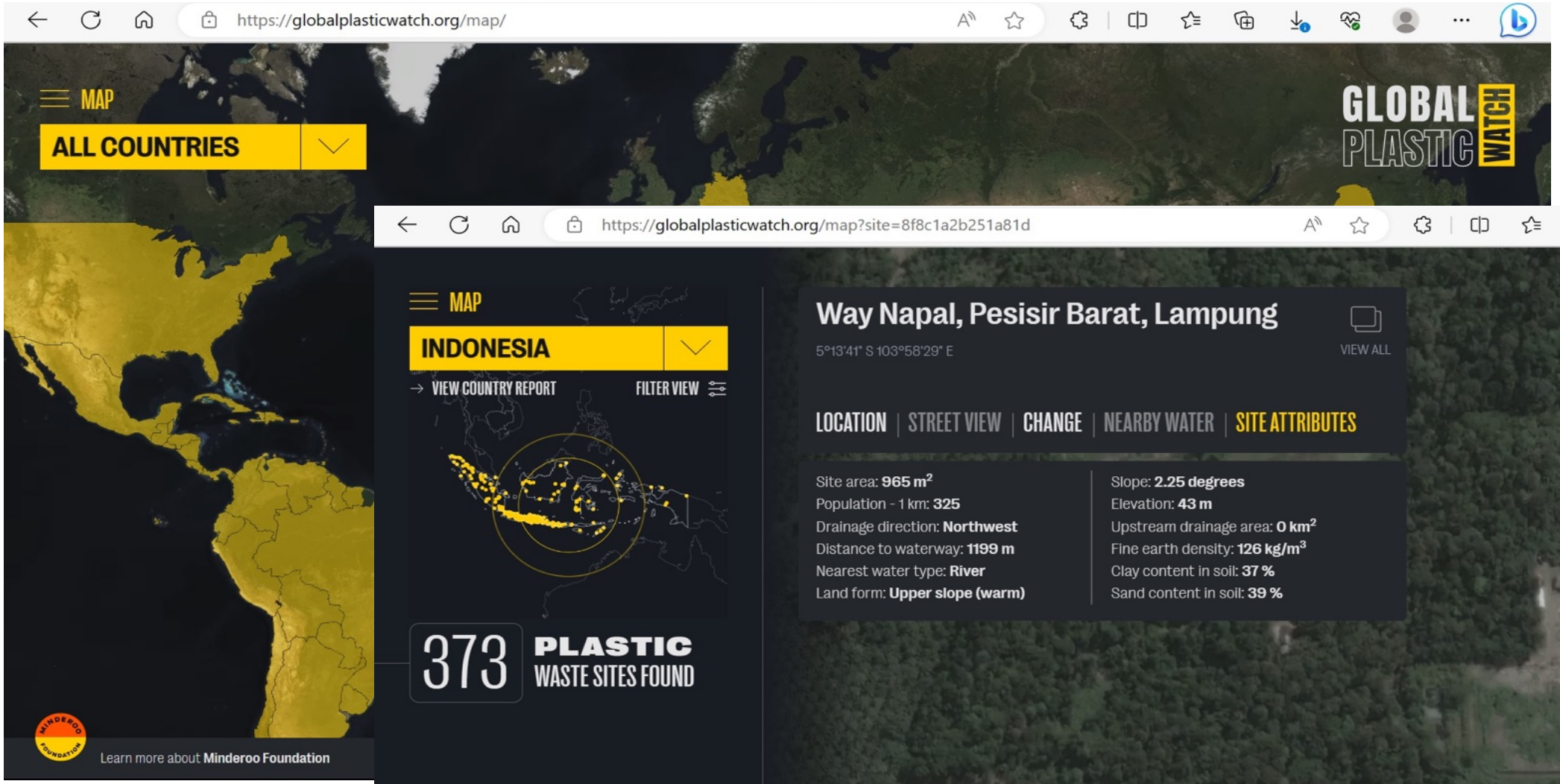
2017-08-13



South Turkey

Areas affected by a change between 2016-05-28 and 2017-08-13 (Method: IR-MAD)

Global Plastic Watch



Contributions

Topics and contributors
Air pollution: CUT, METEO, ROSA
Illegal construction: ISPRA, ROSA, CBK PAN
Illegal forestry: CBK PAN, ROSA, CUT, ISPRA
Illegal manure spreading: ISPRA, ROSA, METEO
Waste crime: GFZ, ROSA, CBK PAN, CUT
Water pollution: CUT, METEO, GFZ

Organisations and scientists
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CUT: Thrasos Stylianou, Christiana Papoutsa, Kyriakos Themistocleous
GFZ: Mathias Bochow, Katrin Koch, Tobias Weiß
ISPRA: Luca Congedo, Ines Marinosci, Antonella Tornato, Nico Bonora, Emiliano Agrillo,Federico Filipponi
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