Copernicus Assisted Inland Water Quality Emergency Monitoring Service

by

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This project has received funding from the European Union’s Horizon 2020 Research and Innovation Action programme under Grant Agreement No 101004157

Expectations

- Support to SDGs 3, 6, 13, 15
- Become an evolution service element of the Copernicus Emergency Management Service (CEMS)
- Couple with EUROGEO activities
- Facilitate monitoring operation of water utilities & governmental agencies

WQeMS
framework
enablers
services
EO research

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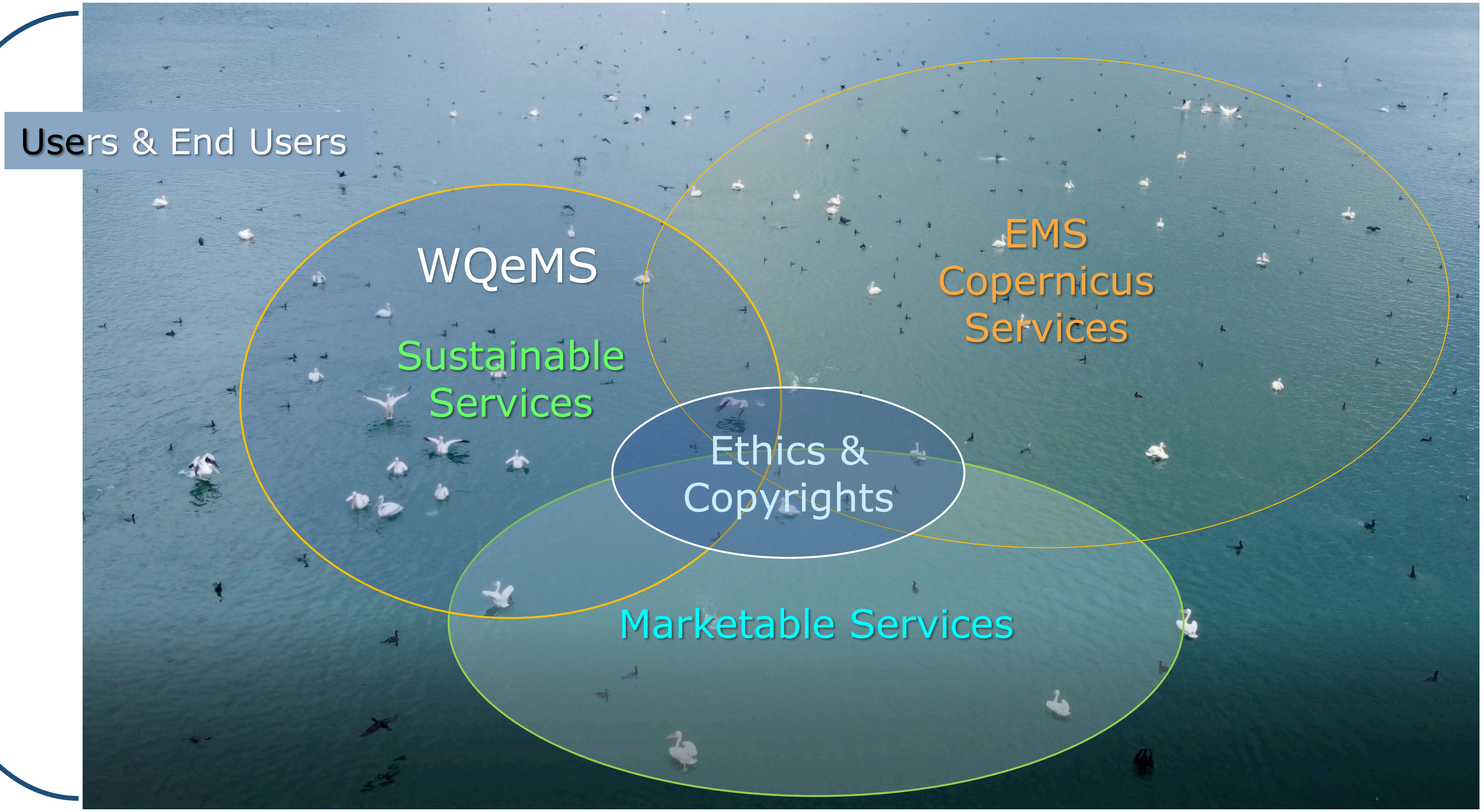
Finding the right niche – Keeping the balance

Water we drink...



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Expected service features

RS product reliability and adaptability for the non-RS society users (experts and simple users)

Cross-scale	Uncertainty	Copyrights
Proven processes	Validation	User griendly interface
Framework conditions	Metadata quality	Easy to access products
Standardization	Analysis and reporting	Delivery maintenance

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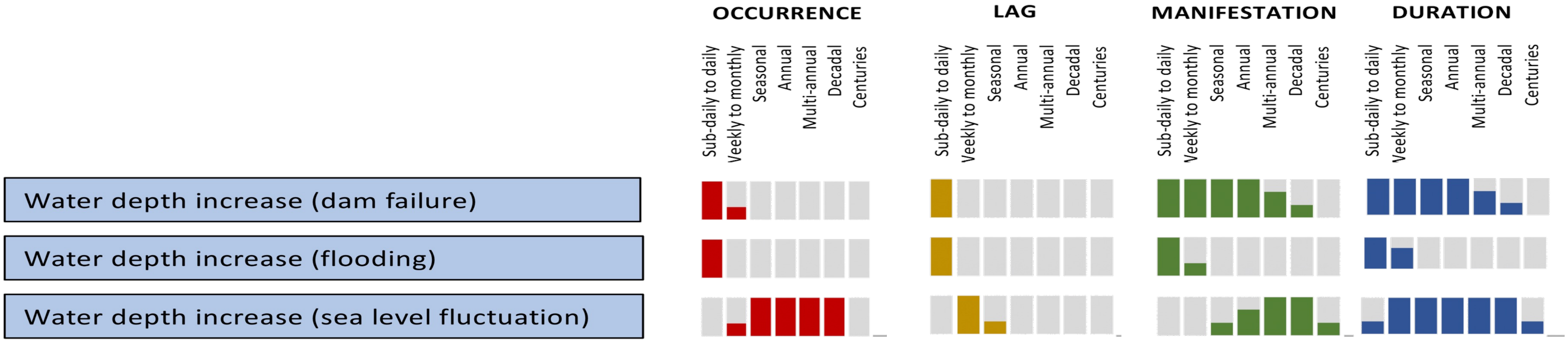
EO detectability of changes/ incidents



Term	Definition and associated information
Occurrence	The time span of the actual natural event or process or human activity
Lag	The time between commencement and detection
Manifestation	The time period of detectability
Duration	The time from commencement to completion of a natural event or process or human activity.

Global Change Biology

RESEARCH ARTICLE | Open Access

A globally relevant change taxonomy and evidence-based change framework for land monitoring

Richard M. Lucas, Sophia German, Graciela Metternicht, Rebecca K. Schmidt, Christopher J. Owers, Suzanne M. Prober, Anna E. Richards, Sally Tetreault-Campbell, Kristen J. Williams, Norman Mueller, Belle Tissott, Sean M. T. Chua, Alison Cowood, Terry Hills, Dayani Gunawardana, Alexis McIntyre, Sebastien Chognard, Clive Hurford, Carole Planque, Suvarna Punalekar, Daniel Clewley, Ruth Sonnenschein, Nicholas J. Murray, Ioannis Manakos, Palma Blonda, Kate Owers, Stephen Roxburgh, Heather Kay, Peter Bunting, Claire Horton ... See fewer authors

First published: 01 September 2022 | https://doi.org/10.1111/gcb.16346

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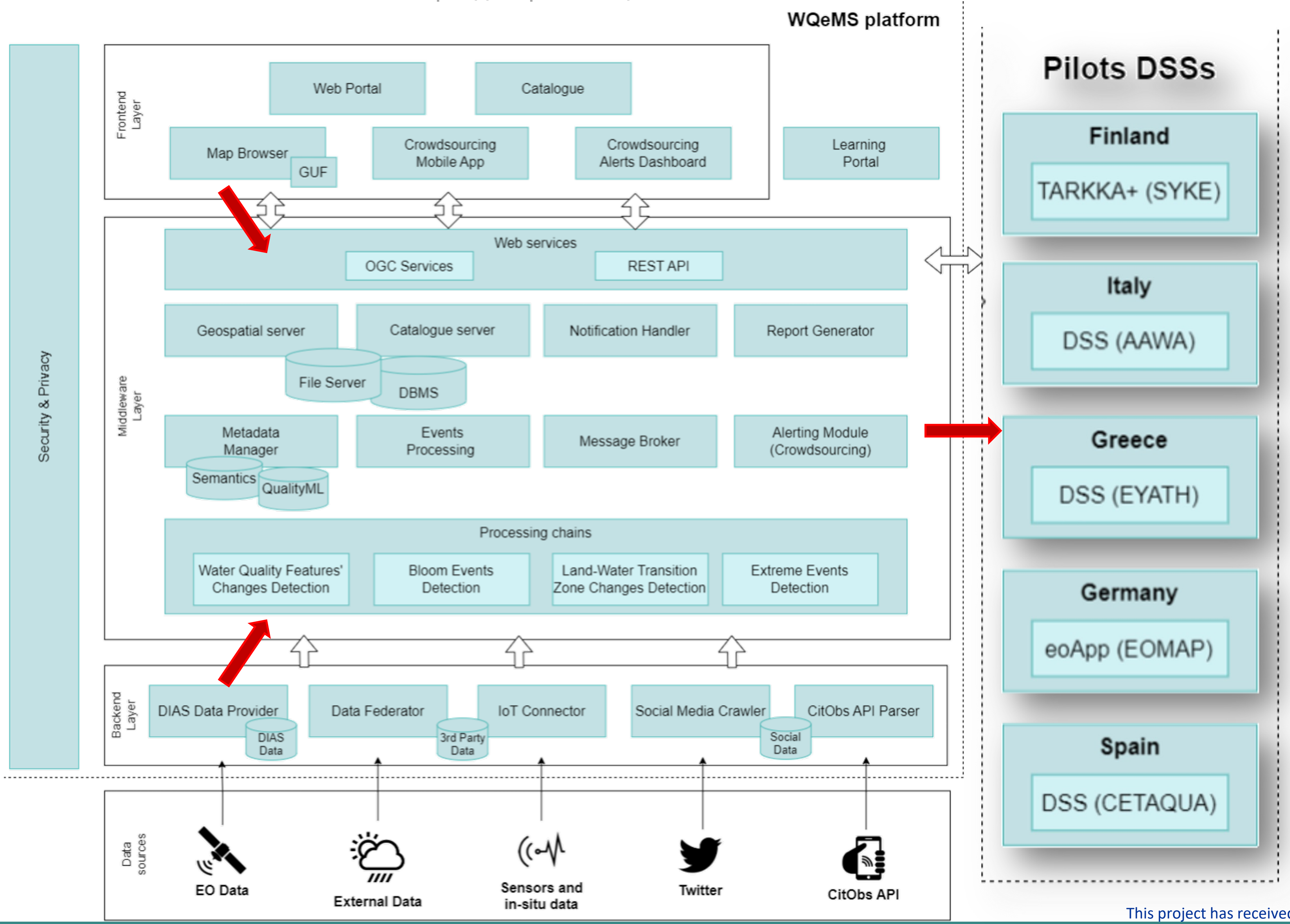
A variety of DSSs at different level of technological maturity shall be served: a set of service subroutines have to be developed

https://wqems.eu/

Shows to the points of the workflow, where EO data and their derivatives may be directly treated by the users or the service providers



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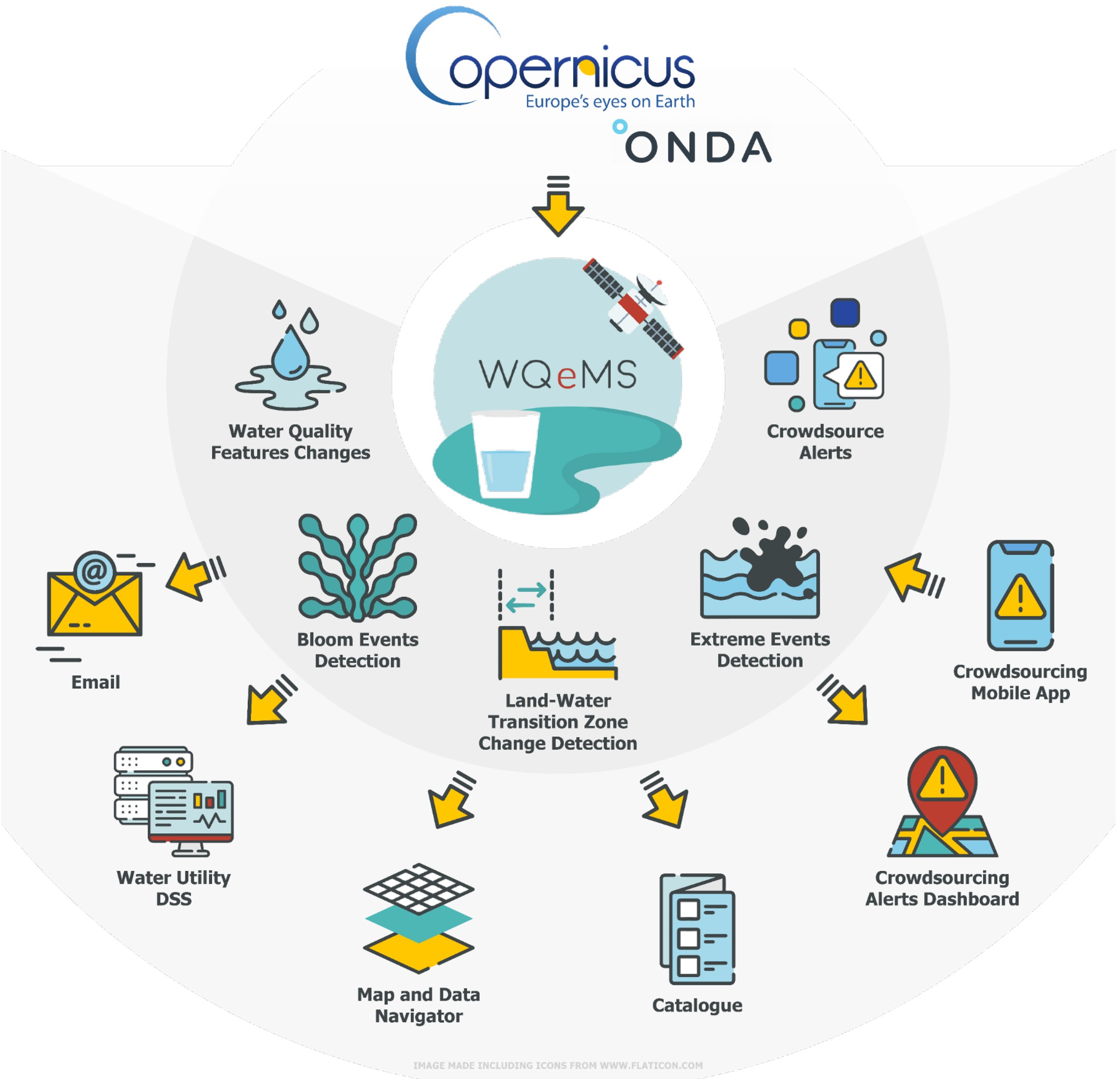
the WQeMS platform

https://wqems.eu/



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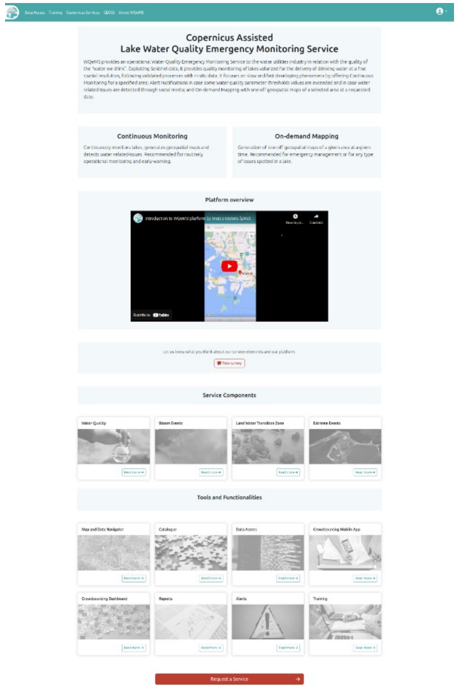
WQeMS platform interaction with the user

https://wqems.eu/

CERTH
CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

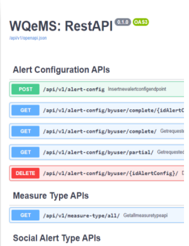
WQeMS framework enablers services EO research

1. Send requests for data products on dates interval (on demand or continuous monitoring)

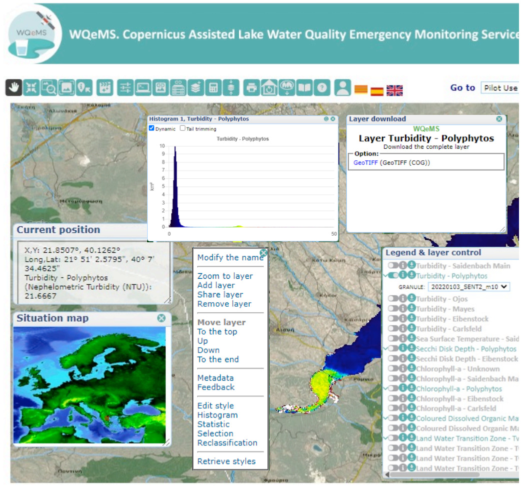


2. Access the generated data products (both GeoTIFF and metadata)

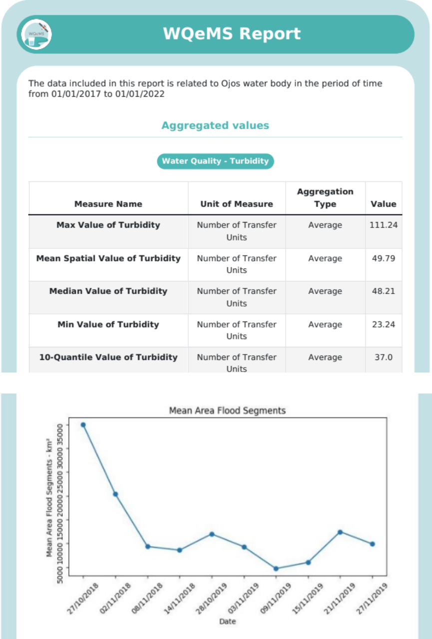
OGC WMS
GeoServer
HTTP File Server
FTPS Server



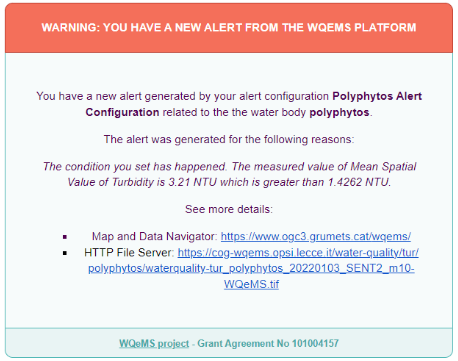
3. Get statistical data (i.e. time-series) obtained analysing the tiff files generated for the area of interest

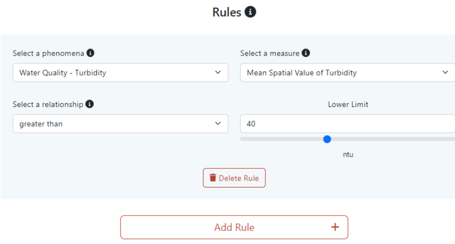


4. Request a PDF report for a water body to be sent by email



5. Configure the platform to send alert notifications by email or to HTTP API of an external system





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WQeMS platform innovation

https://wqems.eu/

- **Facilitate the adoption of EO monitoring services in the water utilities' operations**
- **Increased awareness of the water utilities** in relation to water-related issues (early warning, fast response to phenomena)
- Fast and automated services: The platform is realized adopting **cloud micro-services approach**, **ensuring scalability and extensibility**
- **Federated approach –** enable new service providers to easily extend the WQeMS platform service portfolio
- **Adopting both standard and modern protocols for the interconnection of systems (i.e. APIs, OGC Web Services)**

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WQeMS service components

Service	Sub-service
Water Quality	Turbidity
	Chlorophyll-a
	Coloured Dissolved Organic
	Secchi Disk Depth
	Sea Surface Temperature
Bloom Event Detection	Harmful Algae Bloom Indicator
Land Water Transition Zone	Two Dates
	Hydroperiod
Extreme Event Detection	Oil Spill
	Muddy Water
	Flood

There are three different types of output data (for each service component) managed by the platform: **GeoTiff** files, **statistical data** in json format, and **metadata** in xml format

Metadata

An XML file describing the metadata of each GeoTiff image.

For example, some parameters are: the file size, the HTTP link to the file, the Data Provider, and so on.

GeoTiff

A raster layer that contains data about a specific feature monitored by each service.

Statistical Data

A JSON that contains some statistical values associated with the GeoTiff image,

such as mean value, maximum value, median, and so on

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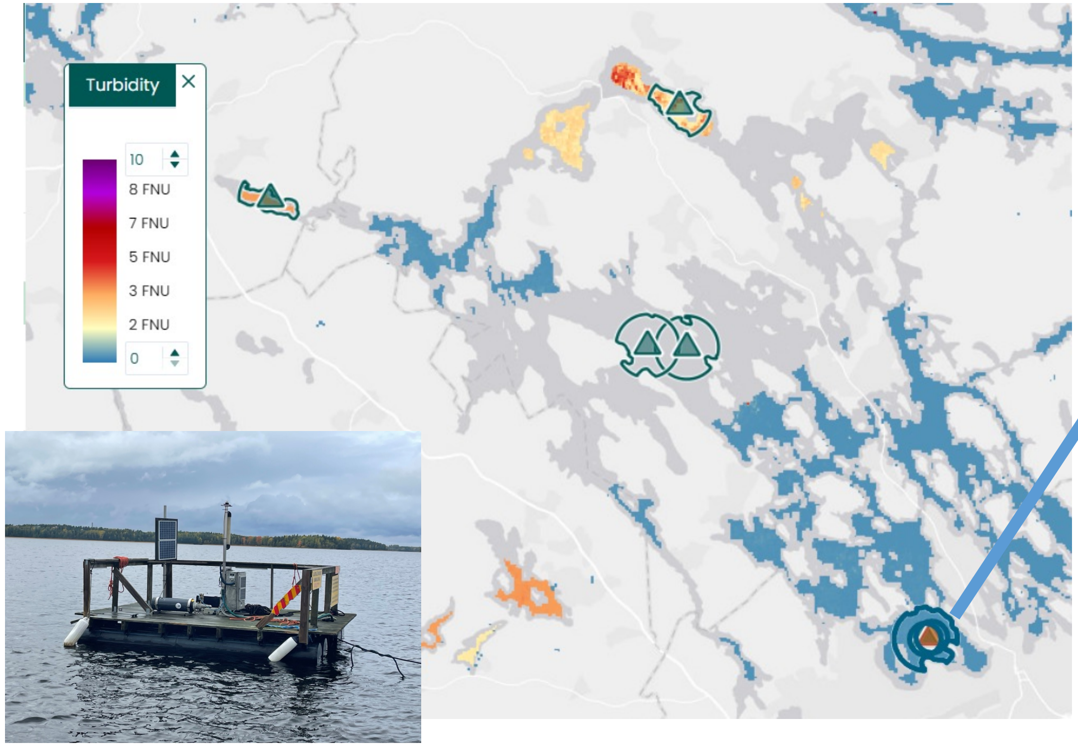
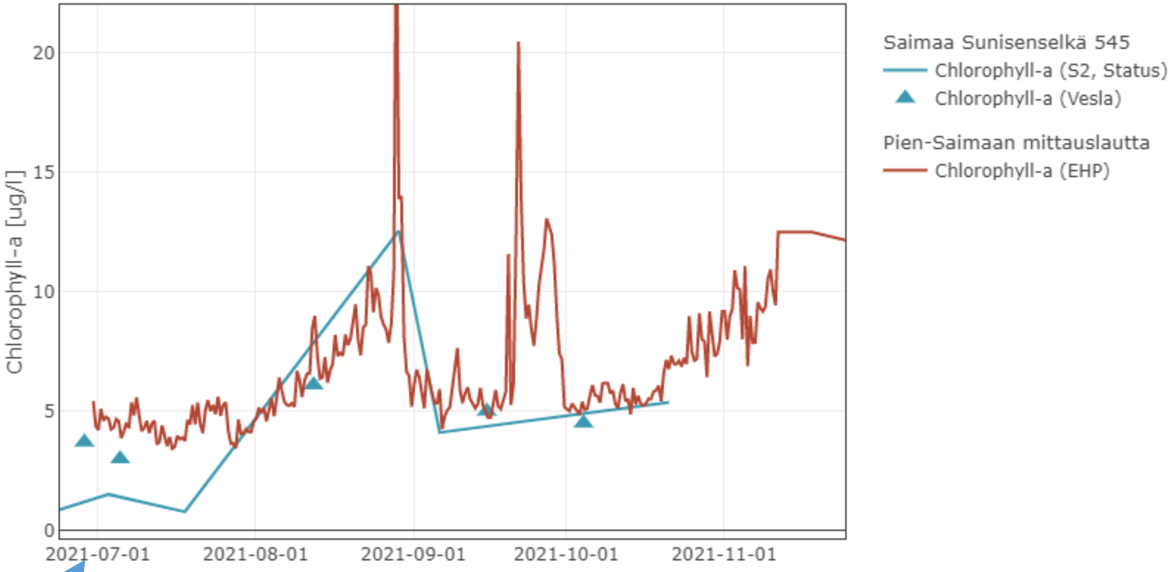
(SC1) Water Quality Features

Comparison of in situ and satellite observations about water quality

Learning from the free and open water quality information through Syke's TARKKA web application and EOMAP's Modular Inversion Processor





Chl-a values observed at the location of the automated station with Sentinel-2 satellite (S2, blue line), laboratory samples (Vesla, blue triangles) and automated instruments (EHP, red line)

Location of the automated water quality monitoring station

Innovation: Expansion of known workflows and techniques for the needs of the water utility industry.

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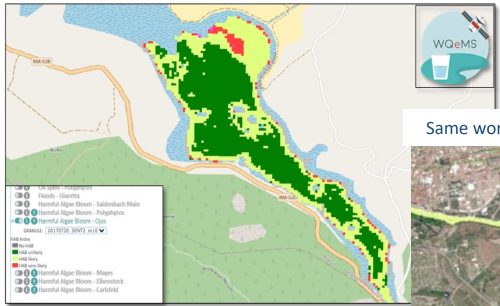
(SC2) Harmful Algal Blooms

- In situ sampling (Azud de Ojós and DWTP Reservoir) to adjust the values detected in the Sentinel-2 images.

- Historical data of algal monitoring are used to test performance of hyperspectral images.



Same workflow result with WorldView, 0.5m

Innovation:

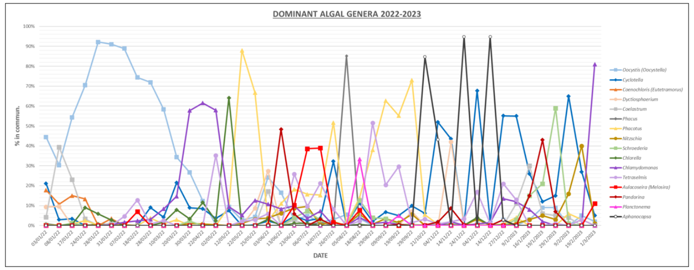
- **Detection of potentially harmful cyanobacteria blooms**
- **Worldwide data even for small water bodies (< 1ha)**
- **For emergency and baseline scenarios**

- Tested (in GR, DE, FI) and in an operational DSS in Spain

…using **different type of sensors and data sources** (it combines data from satellite and in-situ online monitoring station; data from regional water basin agency and national weather agency, etc.)

…able to provide **forecast of cyanobacteria risk from coupled models** based on machine learning methods

…in a form that has been **co-created with and for the Drinking Water Plant Operator** that is using it since 2021



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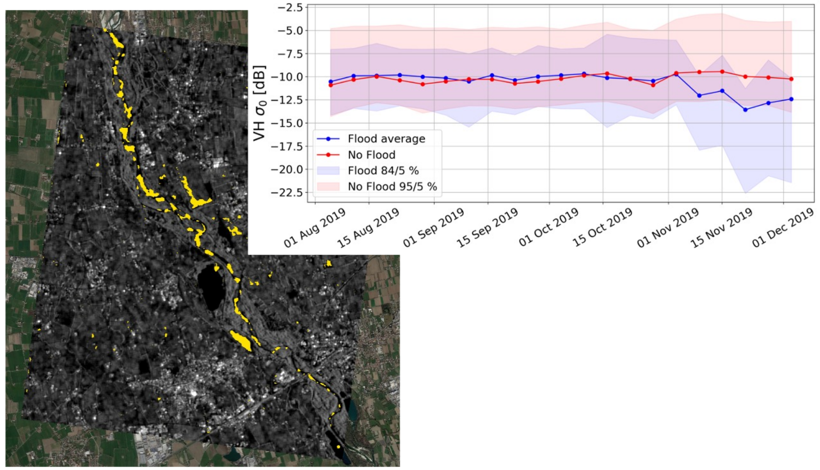
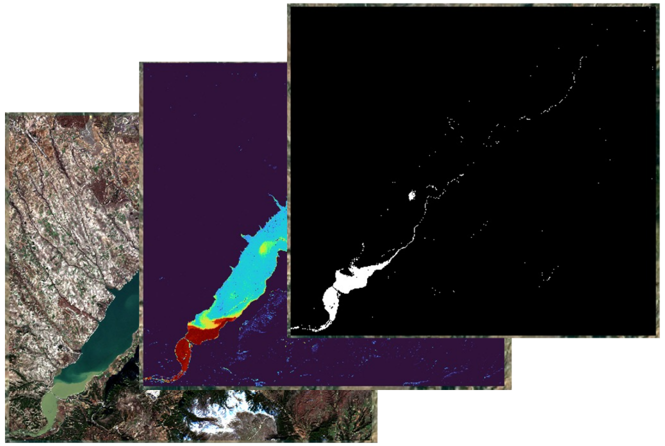
(SC3) Extreme Events

Flood sub-service maps extreme flood events using **Sentinel-1** every **~6 days** (both satellites) with a **10m** pixel size based on **Deep Learning**



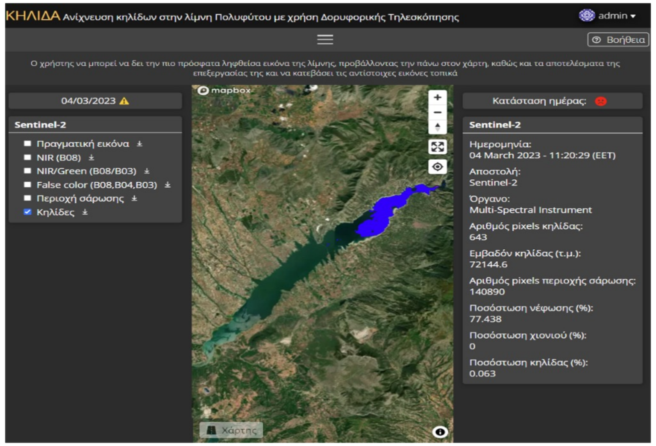
Innovation:
- **Explicitly exploits time series patterns**
- Uses deep learning
- **AOI-invariant model**

Muddy water sub-service maps muddy waters (extreme suspended sediment values in the water) using **Sentinel-2** every **~5 days** with **10m** pixel size based on **Ensemble Machine Learning**



Innovation:
- **Unique muddy water mapping service** using machine learning

Oil spill sub-service maps potential hydrocarbons using **Sentinel-2** every **~5 days** with **10m** pixel size based on **Deep Learning**



Innovation:
- **Unique hydrocarbon mapping service for inland waters using deep learning & optical data**

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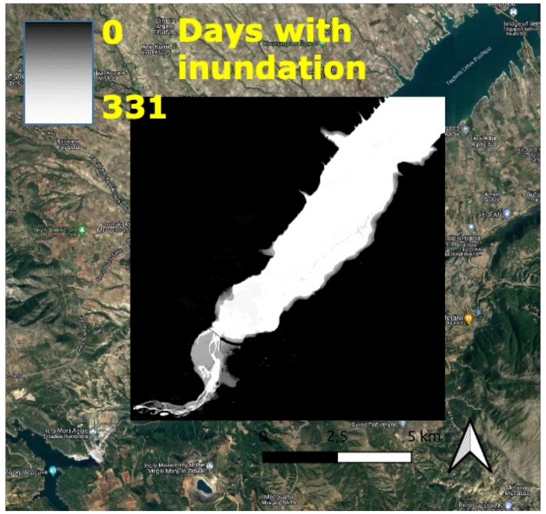
(SC4) Land-Water transition zone



Three modes for two-dates service:
- S2 mode: Only Sentinel 2 data
- S2-S1: Based on the user dates, the products (either S2 or S1), whose acquisition date is the closest to the user preference, will be used for the processing.
- S1 mode: Only Sentinel 1 data

Two modes for hydroperiod service:
- S2 mode
- S2-S1 mode

Polyphytos Lake (subset), land to water change detection between: 21-10-2017 and 02-12-2017

Innovation:

- **Proven and adapted workflows at multiple sites across Europe** reaching up to **98% accuracies** (multiple alternative methods for various scenery types)
- Exploitation of **both optical and radar data to enhance frequency of information** retrieval with proven credible results
- **Fully unsupervised performance**

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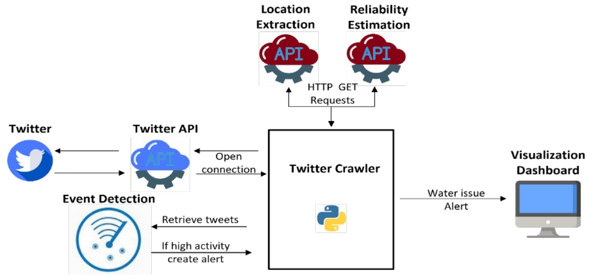
(SC5) Alerts Generation

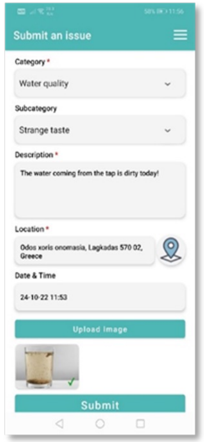
The Social Media Crawler collects water related tweets from Twitter in real time.

- Analysis of each retrieved tweet:
    1. Extract tweet location from text
    2. Estimate whether tweet is fake or not
- Detect water related events based on Twitter activity and location.



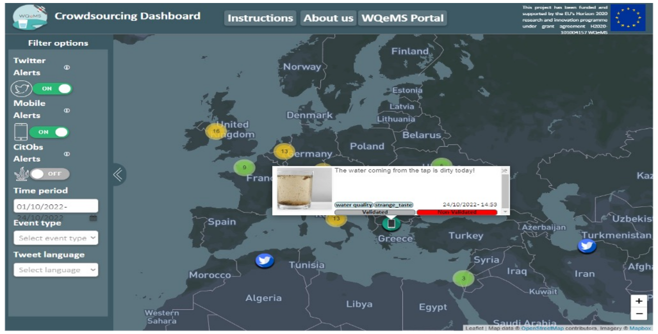
Innovation:
Analyzes **large volumes of crowdsource water related information in real time** and provides potential water issues that need to be investigated.

The Crowdsourcing Mobile App allows citizens to post water related complaints through their smartphone.



Innovation:
Enables a more efficient and **streamlined way for water utilities to receive and handle complaints** and improving the quality of service and customer satisfaction.

The Crowdsourcing Dashboard visualizes the alerts collected from multiple sources including alerts generated by social media crawlers and complaints submitted through the crowdsourcing mobile app



Innovation:
The crowdsourcing Dashboard combines and **visualizes data from multiple sources,** enabling quick identification and responding to emerging issues.

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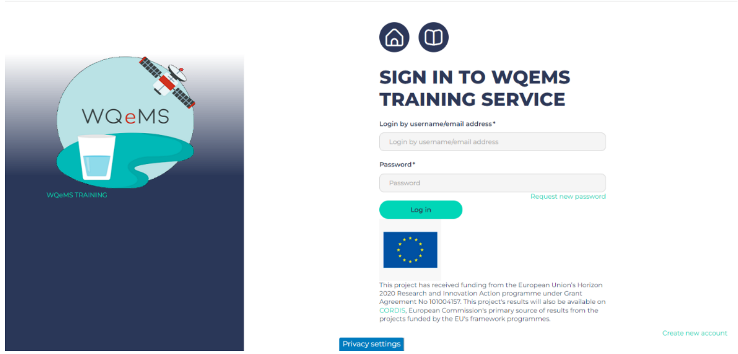

WQeMS e-Training Platform

(https://wqems.phoebeinnovations.com)

Content

- Understanding Copernicus data and services
- Technical aspects in earth observation services
- Inland water features' estimation services enabled by earth observation
- Use-cases and applications

Training guidance

- **Training Pathway 1: Full-range training**
- **Training Pathway 2:** Familiar with background knowledge; Requiring **strong WQeMS-related skills for specific services**
- **Training Pathway 3:** Training to **attract interest of domain experts**
- **Training Pathway 4:** Focusing on **Academia**
- **Training Pathway 5:** Focusing on **Industry**

Innovation:

- **Dedicated training pathways** through the material per level of competence and target audience.
- **Facilitate the acquisition of required skills and competences** by WQeMS users, related to the operation and **content interpretation of the developed solutions.**
- Help **sustain the operation of the WQeMS platform beyond project duration.**

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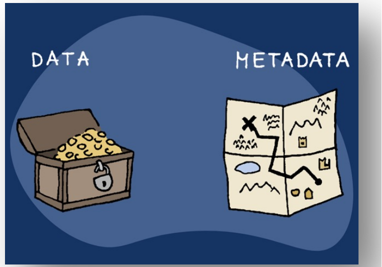
(SC7) Metadata & Feedback

WQeMS follows the FAIR principles: Data should be **Findable, Accessible, Interoperable and Reusable** to the greatest extent possible



How to decide that a dataset is useful for our purposes (fit per purpose)?
How to choose the best dataset in terms of the quality of the data?
How policy makers can know better the results of policy and monitoring?

METADATA!

Innovation:

- **New keywords that describe the dataset in a way to bring it closer to management, monitoring and policy,** following the GEO Essential Water Variables, i.e. "Lakes/reservoir levels", "Water Quality", "Water use/demand", "Evaporation", etc. and the UN Sustainable Development Indicators, i.e. Target 6.3.
- **Quality parameters included in the metadata based on QualityML dictionary.**

```
<gmd:errorStatistic>
    <gco:CharacterString>https://www.qualityml.org/1.0/metrics/RootMeanSquareError</gco:CharacterString>
</gmd:errorStatistic>
```

- All Metadata is **uploaded to the GeoNetwork catalogue and also allows connection to the GEO yellow pages**
- Metadata is also available through **the interoperable WQeMS Map and Data Navigator, by which feedback to the dataset can be provided.**

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Main innovation elements

- Use of multi-sensor-fusion technologies
- Spatial and temporal resolution, and product consistency
- Treatment of small (also uneven shaped) open surface water reservoirs
- Minimization and documentation of uncertainty
- Ontology and semantics of water quality supporting regulations
- Metadata tool documentation
- Interoperability with existing Decision Support Systems and multiple DIAS
- Cloud based micro-services structure
- Federated approach, enabling further service providers to expand WQeMS service portfolio

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EO research in WQeMS

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Focusing on SC4: Land-Water Transition Zone

Land-Water Transition Zone Change Detection

Hydroperiod — On-demand

Start Date: mm/dd/yyyy
End Date: mm/dd/yyyy

- Multispectral Data (selected)
- Multispectral + Radar Data

Two Dates — On-demand

Start Date: mm/dd/yyyy
End Date: mm/dd/yyyy

- Multispectral Data
- Multispectral + Radar Data (selected)
- Radar Data

Inundation maps and hydroperiods are produced

→ **WITHOUT** user input

→ with spaceborne data use **ONLY**

→ **Interoperable with existing applied international workflows and norms**

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Sentinel-2 data:

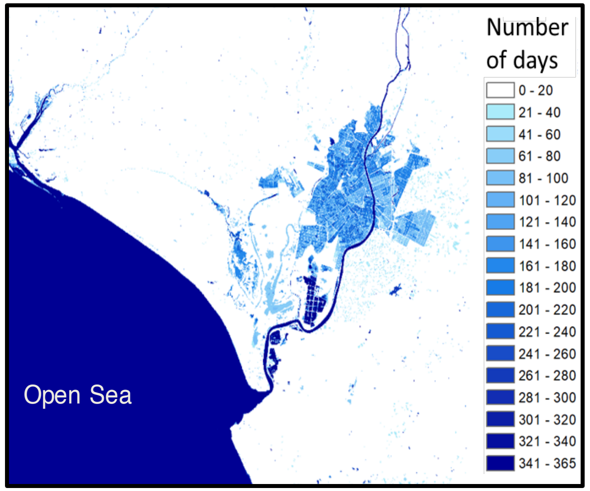
- **Adv.:** High accuracy in inundation mapping
- **Lim.:** Available and useful in non-regular time intervals throughout the year, because of cloud presence in the study area

Sentinel-1 data:

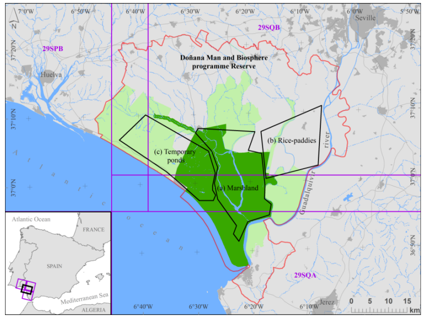
- **Adv.:** Available independently to weather conditions
- **Lim.:**
    - Specific regions (i.e. **sand dunes, bare ground**) may be misregistered as inundated due to low backscatter
    - **Emergent vegetation** that appears bright in S1 images confuses the water detection in SAR data.

Opportunity:

- Improve accuracy of Sentinel-1 based inundation maps fusing information from Sentinel-2 based masks



Hydro-period generated for 2016-2017 using Sentinel-2A data



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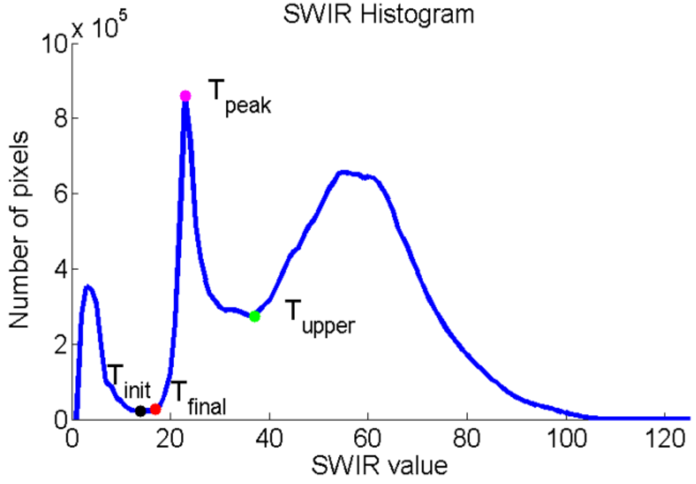
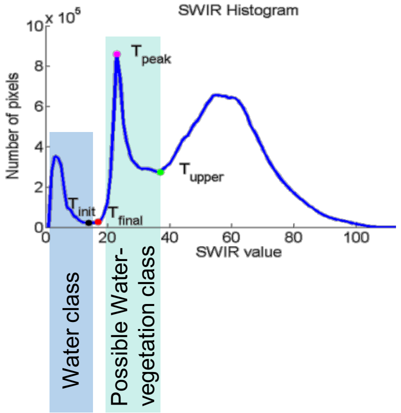
Inundation mapping: S2 thresholding approach

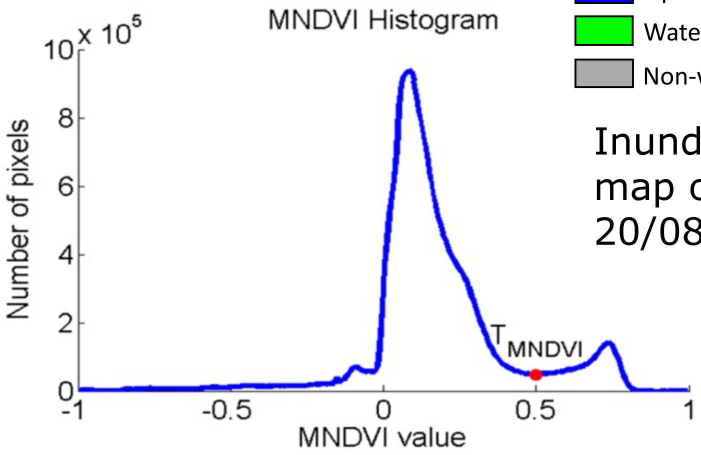
Methodology in a nutshell

- Initial threshold $\mathbf{T_{init}}$, corresponding to the first deep valley of the **SWIR** histogram, separates coarsely inundated / non-inundated pixels
- Sentinel-2 image is segmented into non-overlapping segments
- Expanding patches are set around the centroids of segments with high percentage of inundated pixels, and the median of the "splitting" thresholds of all patches is the optimal threshold per segment. Final threshold $\mathbf{T_{final}}$, estimated as the median of optimal thresholds, separates the **open-water subclass**.
- In parallel, a TMNDVI threshold, corresponding to the first valley greater than 0.4 on the MNDVI histogram, is detected.
- $\mathbf{T_{final}}$ in combination with $\mathbf{T_{upper}}$ and TMNDVI are used for estimating the water-vegetation subclass.

Kordelas GA, Manakos I, Aragonés D, Díaz-Delgado R, Bustamante J. Fast and Automatic Data-Driven Thresholding for Inundation Mapping with Sentinel-2 Data. *Remote Sensing*. 2018; 10(6):910. https://doi.org/10.3390/rs10060910

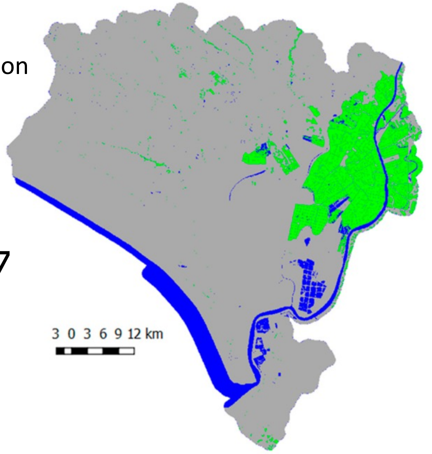






Open-water
Water-vegetation
Non-water

Inundation map on 20/08/2017



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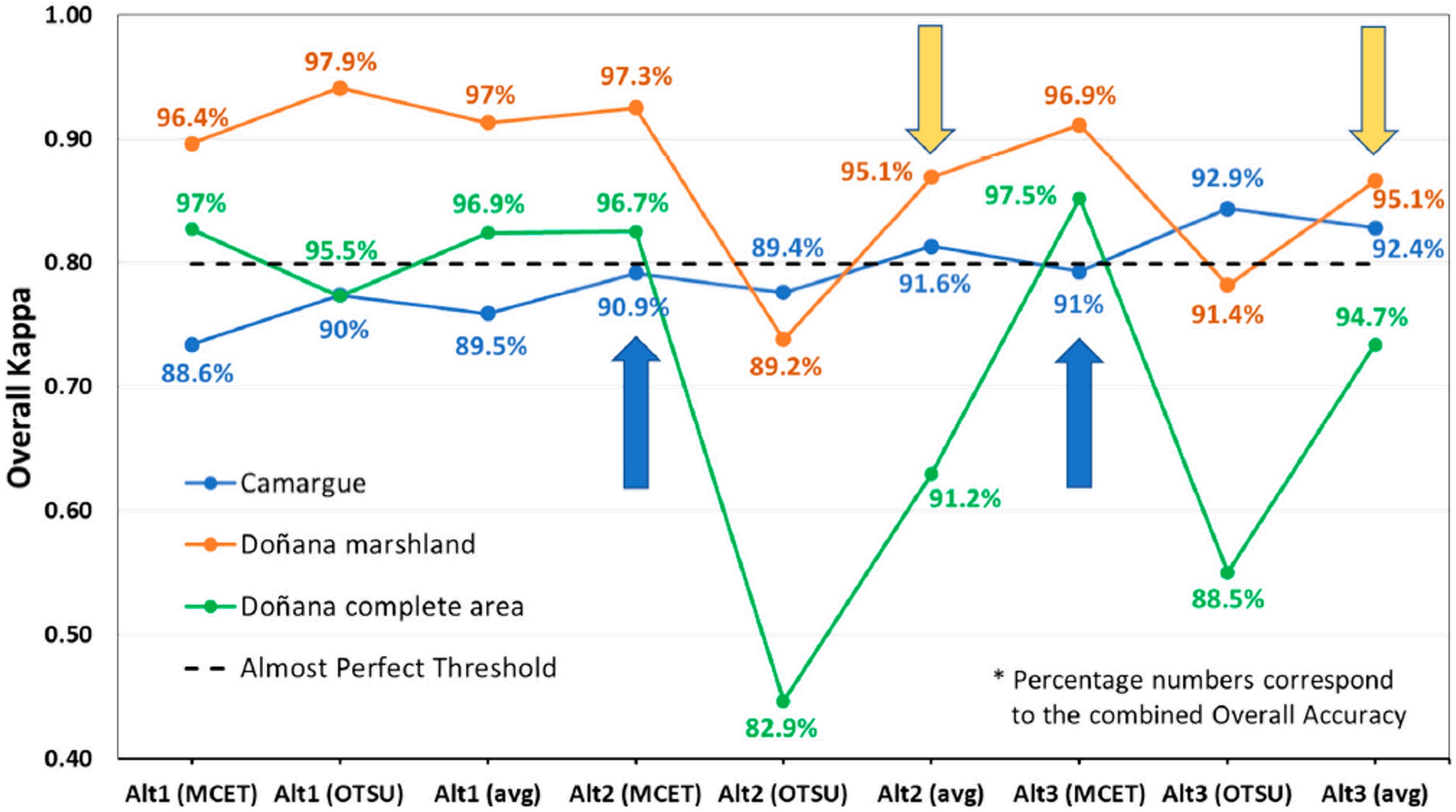
Inundation mapping: Transferable results

The **modified automatic local thresholding unsupervised** methodology*:

1. Detects water class, by estimating automatically a threshold on:
    1. Alt1: SWIR1 – Band 11 (λ = 1610 nm),
    2. Alt2: The product (per pixel multiplication) of Band 12 (λ = 2190 nm, SWIR 2) and Band 8A (λ = 865 nm) (Band 12 * Band 8A),
    3. Alt3: The product of Band 11 (SWIR 1) and Band 8A (Band 11 * Band 8A)
2. For the **estimation of splitting thresholds**, the following approaches were tested:
    1. MCET algorithm,
    2. Otsu's algorithm,
    3. Average of 1 and 2

* Kordelas GA, Manakos I, Lefebvre G, Poulin B. Automatic Inundation Mapping Using Sentinel-2 Data Applicable to Both Camargue and Doñana Biosphere Reserves. *Remote Sensing*. 2019; 11(19):2251. https://doi.org/10.3390/rs11192251



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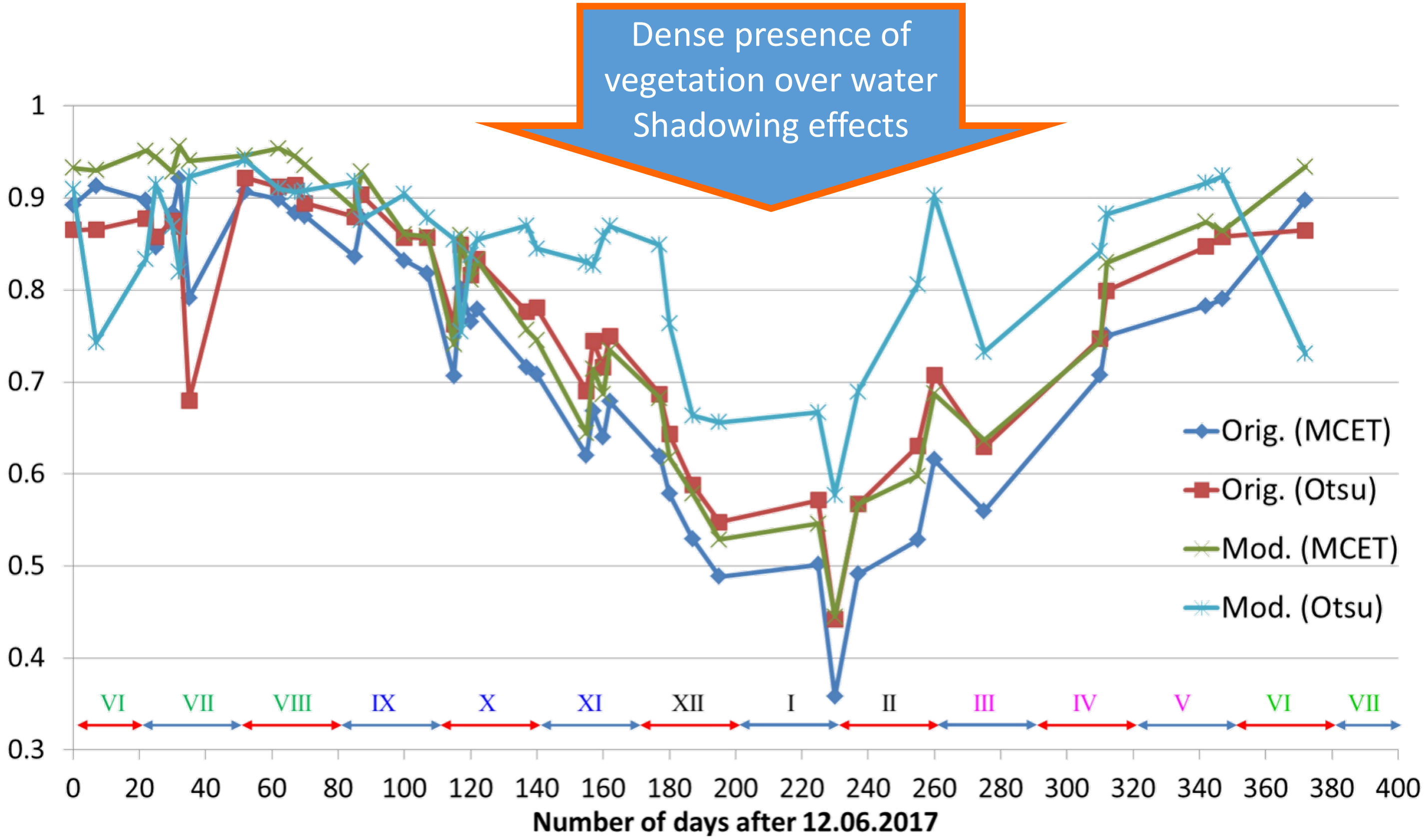
Inundation mapping: challenges with S2 data

Mean Overall Accuracy (Mean kappa):

- Original + MCET: 88.0% (0.72)
- Original + Otsu : 89.5% (0.76)
- Modified + MCET: 90.4% (0.78)
- **Modified + Otsu : 92.1% (0.83)**



Kappa coefficient variation between 12.06.2017 and 16.06.2018 in Camarque area, France

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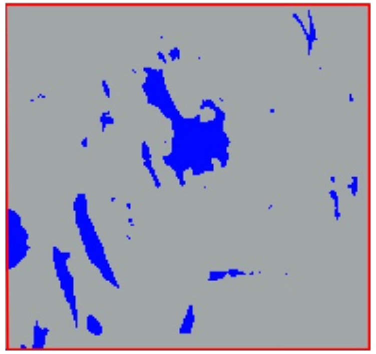
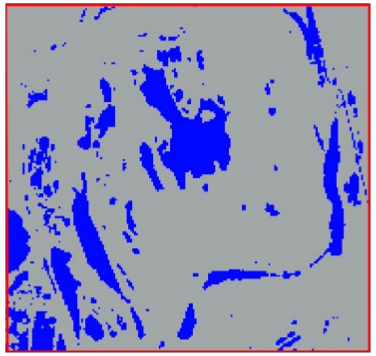
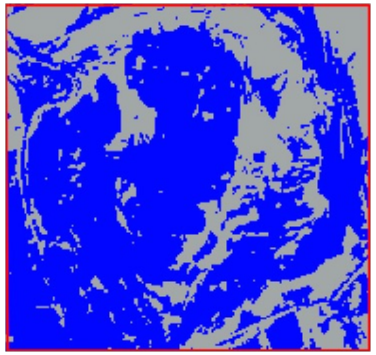
Inundation mapping: challenges with S2 data (examples)

Underestimation example of automatic thresholding in halophilous scrubs

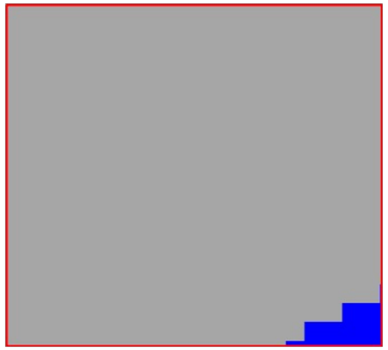

Original Thresholding (MCET)

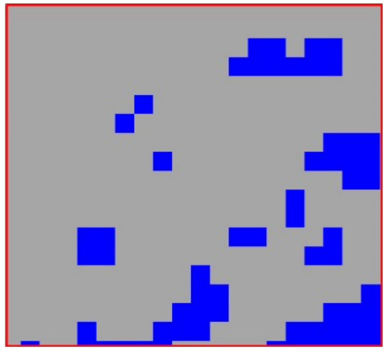

Modified Thresholding (Otsu)

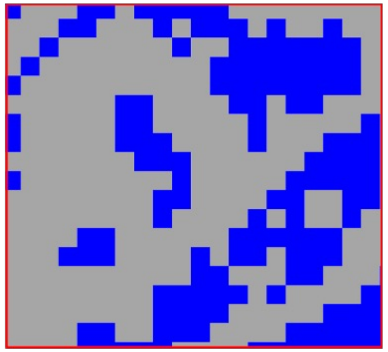

Strict Thresholding
correct


Google Image

Overestimation example of strict thresholding in urban areas due to shadow presence


Original Thresholding (MCET)
correct


Modified Thresholding (Otsu)


Strict Thresholding


Google Image

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Inundation mapping: Radar refined with S2 data

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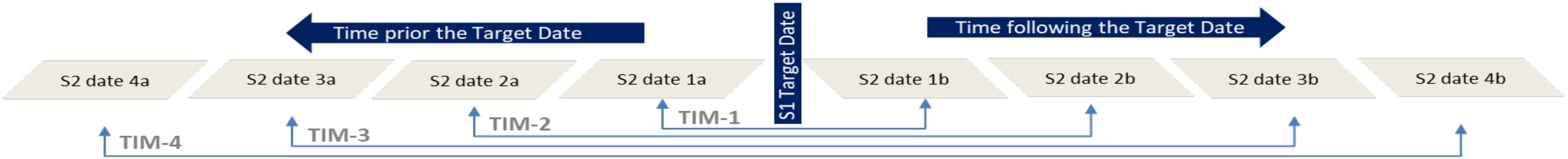
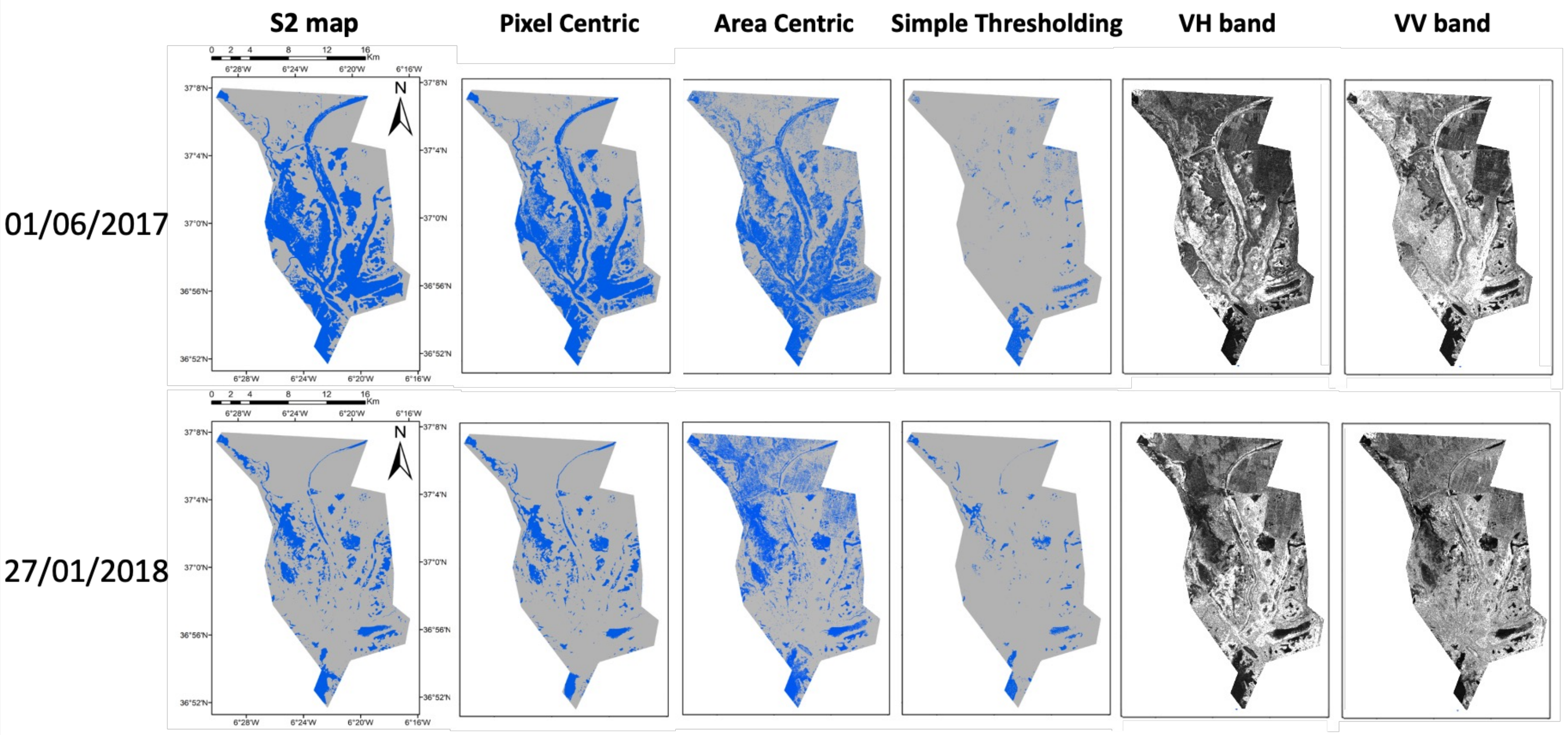
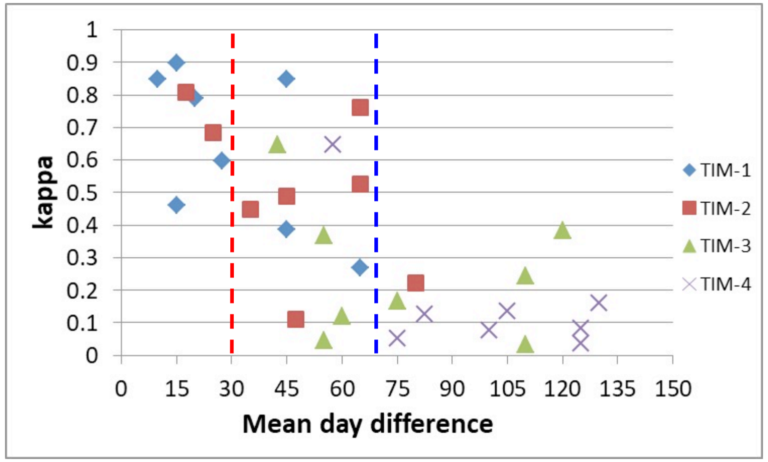




Average ***k***:

- **TIM-1: 0.64**
- **TIM-2: 0.51**
- TIM-3: 0.25
- TIM-4: 0.16
- Area Centric : 0.45
- Simple Thresholding : 0.23



correct

I. Manakos, G. Kordelas, K. Marini, Fusion of Sentinel-1 data with Sentinel-2 products to overcome non-favourable atmospheric conditions for the delineation of inundation maps", 2019, European Journal of Remote Sensing, DOI: 10.1080/22797254.2019.1596757

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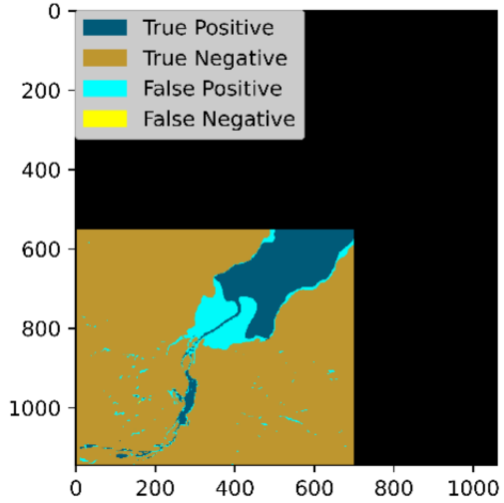
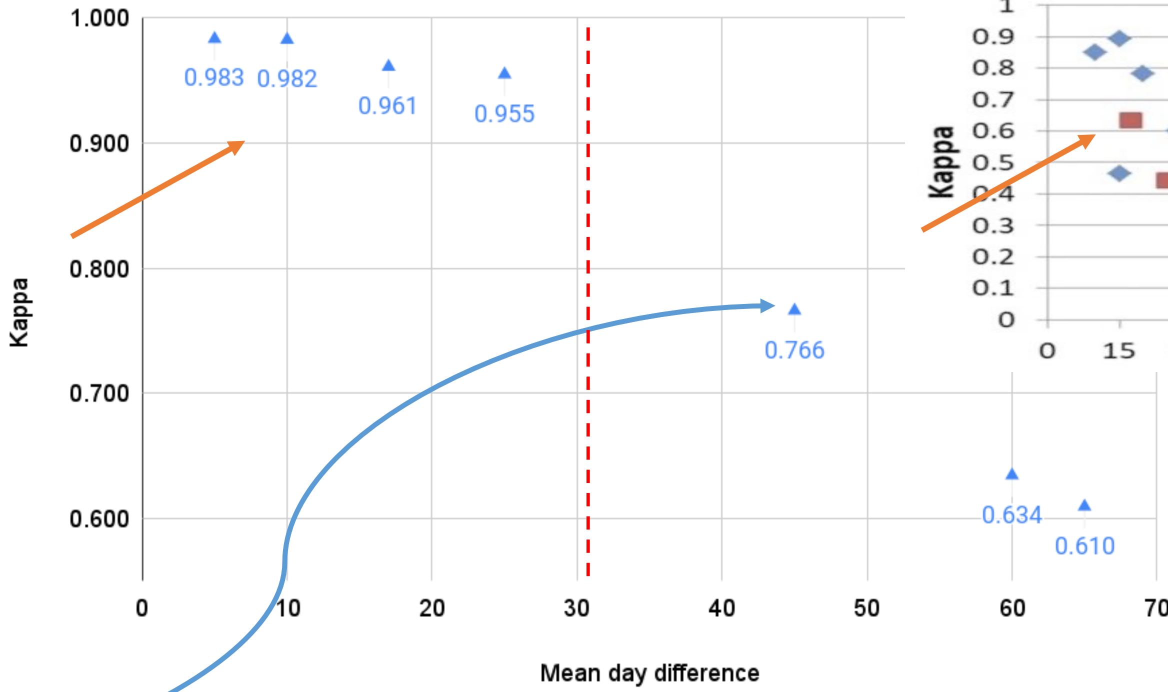
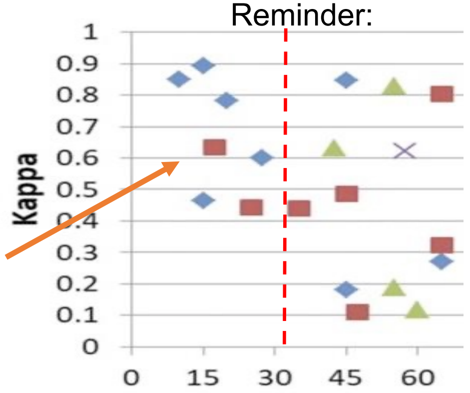
Inundation mapping: lakes vs. wetlands results



Target date: 16-10-2019
S2 reference maps:
16-09-2019 | 15-12-2019
mdd: 45





… performs better than Donana due to the size of the area and the complexity of the landscape elements; thus, becoming more appropriate for the open water reservoirs used by the water utilities

The **mean day difference (mdd)** is calculated by the mean difference between the two S2 reference inundation maps and the target date.

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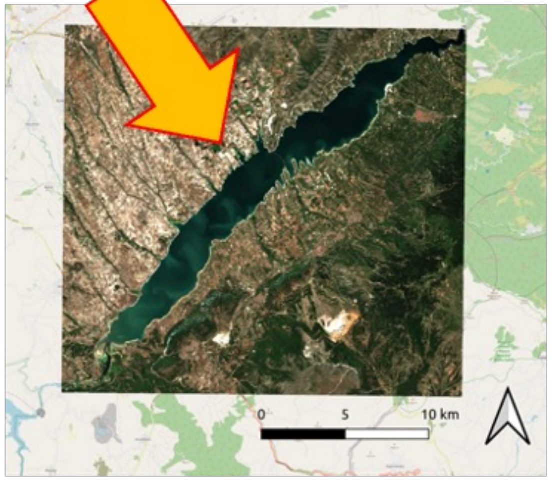
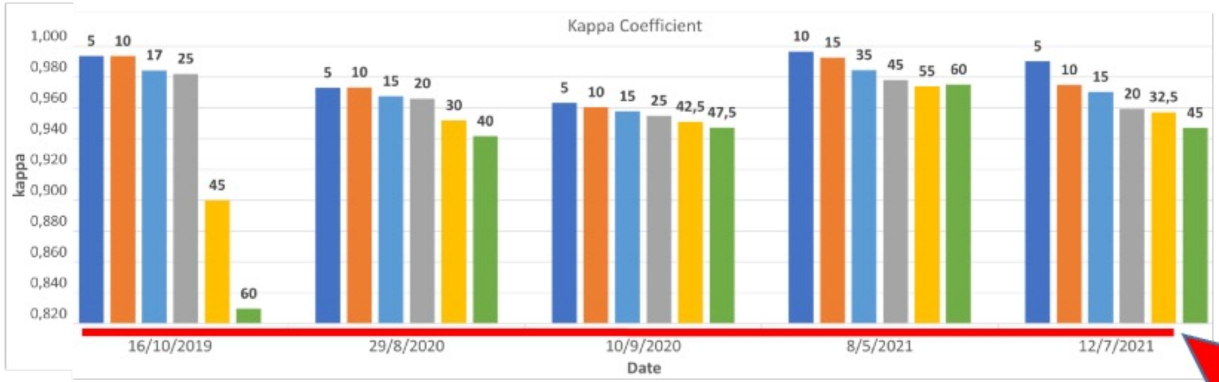
Inundation mapping: the time (and spatial) change effect

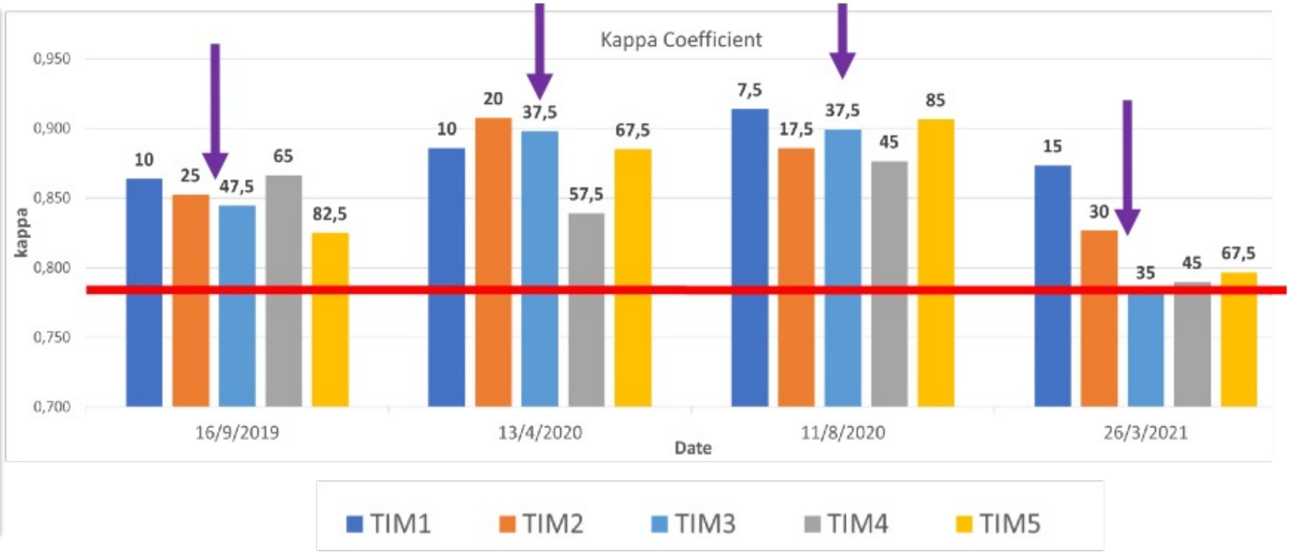
Polyphytos (slow water level changes) →





vs.

Giaretta (incl. Brenta river with fast water level changes) →



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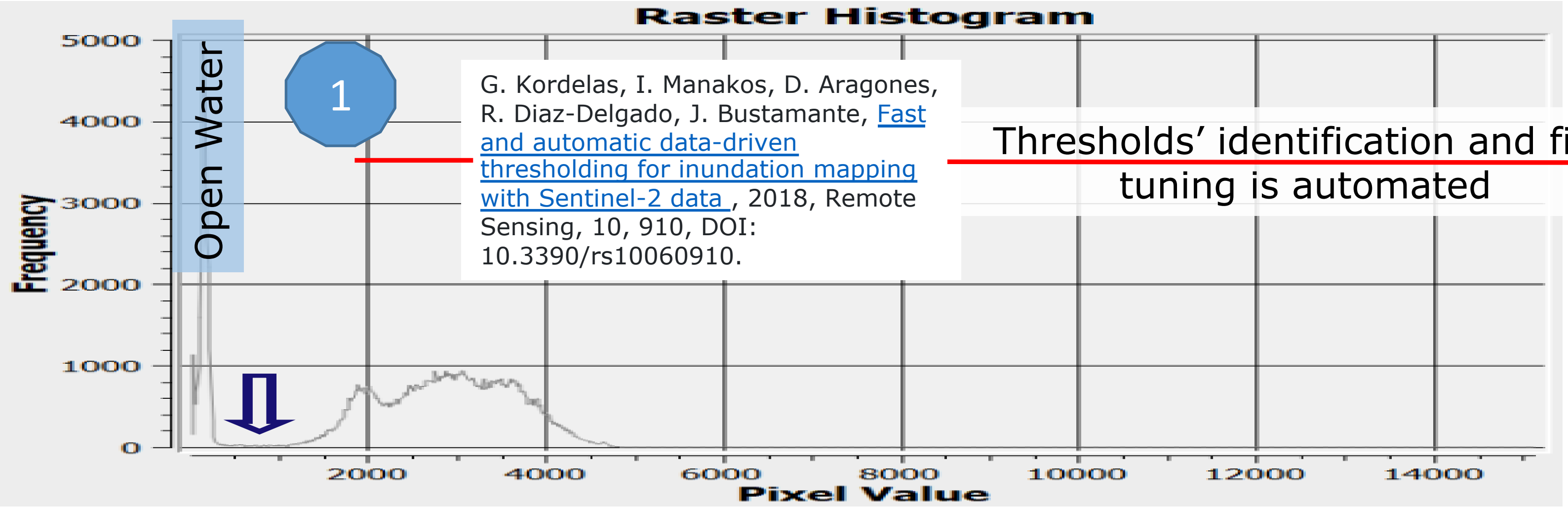
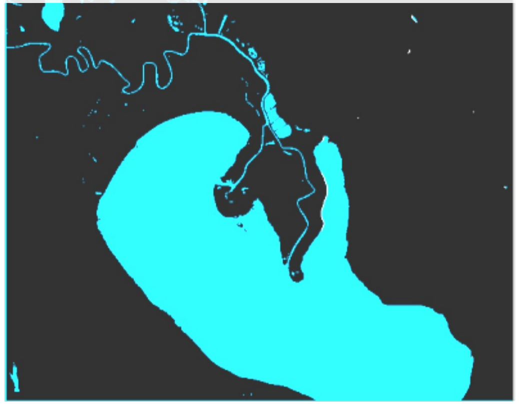
Floating vegetation mapping: 1st attempts (part I)

SWIR (B11) histogram

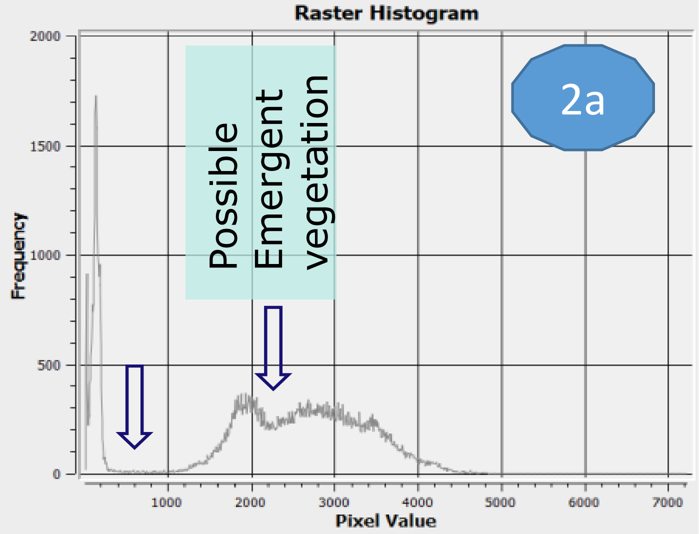


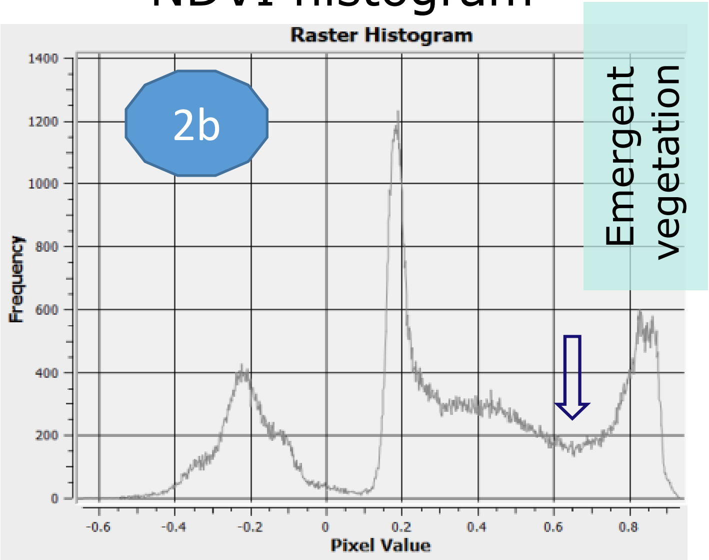
G. Kordelas, I. Manakos, D. Aragones, R. Diaz-Delgado, J. Bustamante, Fast and automatic data-driven thresholding for inundation mapping with Sentinel-2 data , 2018, Remote Sensing, 10, 910, DOI: 10.3390/rs10060910.

Open water, including floating vegetation

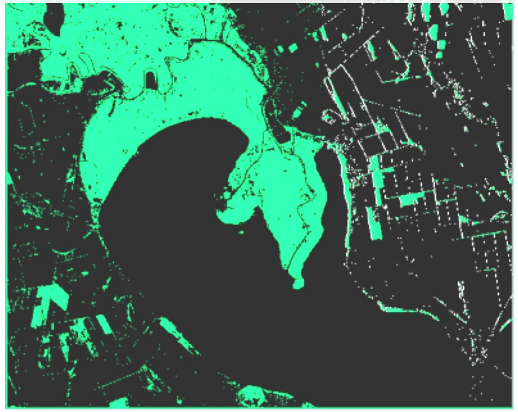


NDVI histogram





Emergent Vegetation, including floating vegetation



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Floating vegetation mapping: 1st attempts (part II)

3

Conditions:

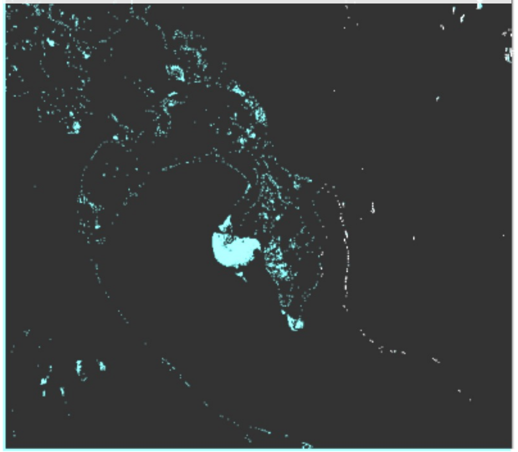
$B05/B11 \in (0.6, 1.5)$

$NDWI \in (0.2, 0.45)$

$B12 \in (100, 900)$

Thresholds' identification could become automated →

Floating vegetation

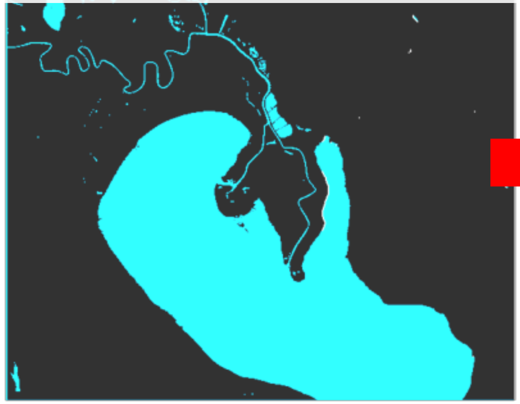


4

Combine the 1,2 &3

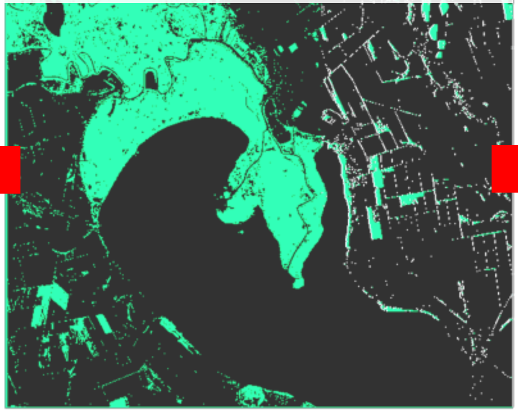
1. Where is Open water is Open water
2. Where is Emergent vegetation is Emergent vegetation
3. Where is Floating vegetation, keep it & overwrite pixels of (1.) & (2.)

Open water, including floating vegetation



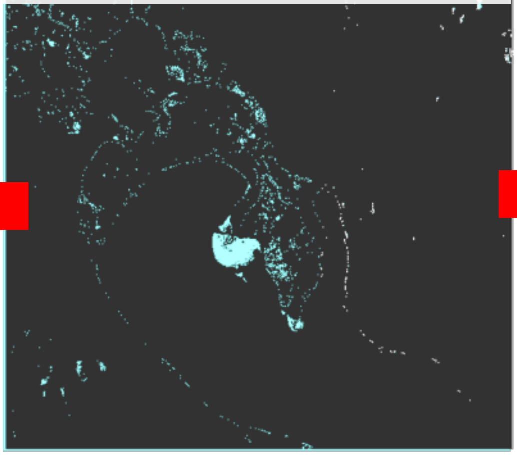
\+

Emergent Vegetation, including floating vegetation



\+

Floating vegetation



\+

Area of interest boundaries: the more specific the better the result as land cover synthesis influences thresholds' identification

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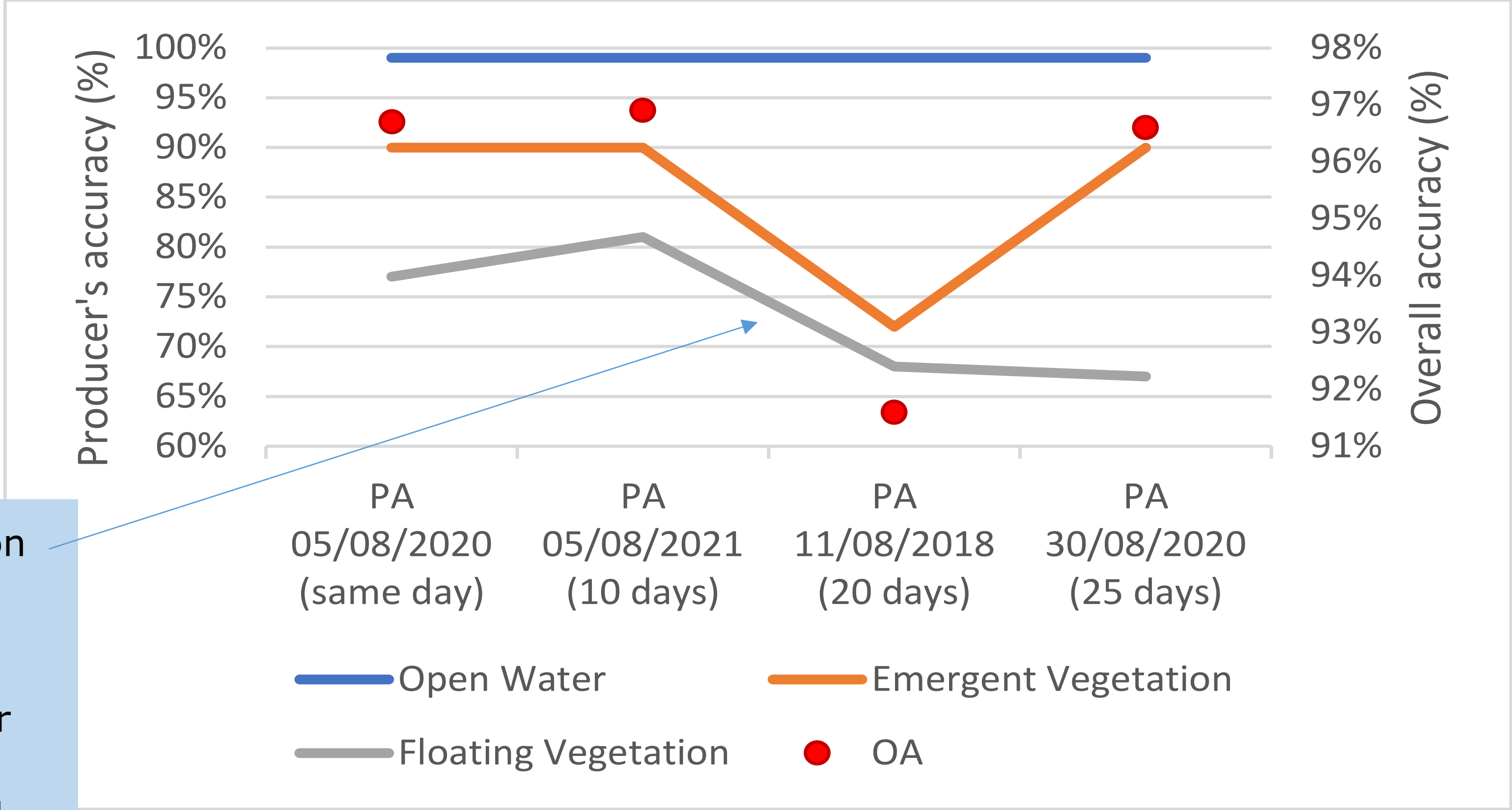
Floating vegetation mapping: 1st attempts (part III)

Overall high OA (> 91%) at all dates is in this case misleading for the performance of the approach in each class, as the assessed dataset is imbalanced (surface extent per class).



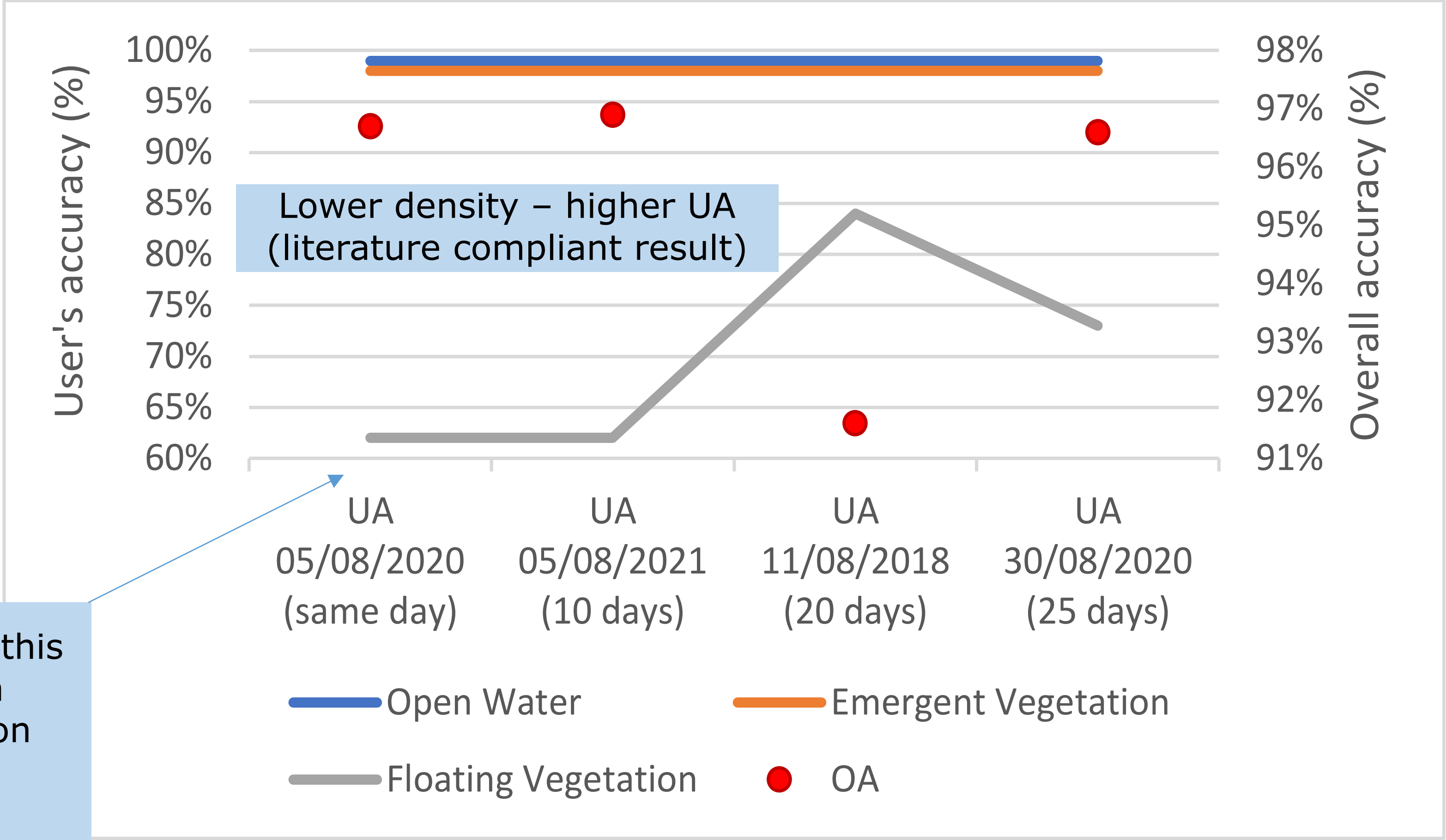
(i) Patches distribution change; and/ or
(ii) wind-induced density/ geometry change/ shift, and/ or
(iii) wave- or water-level-induced floating plant leaves moistening/ partial flooding

🏆 Best Paper Award

I. Manakos, E. Katsikis, S. Medinets, Y. Gazyetov, L. Alagialoglou, V. Medinets, Identification of Emergent and Floating Aquatic Vegetation Using an Unsupervised Thresholding Approach: A Case Study of the Dniester Delta in Ukraine, 9th International Conference on Geographical Information Systems Theory, Applications and Management, 25-27 April 2023, Prague, Czech Republic, DOI: 10.5220/0012024000003473

This project has received funding from the European Union's Horizon 2020 Research and Innovation Action programme under Grant Agreement No 101004157

Floating vegetation mapping: 1st attempts (part IV)



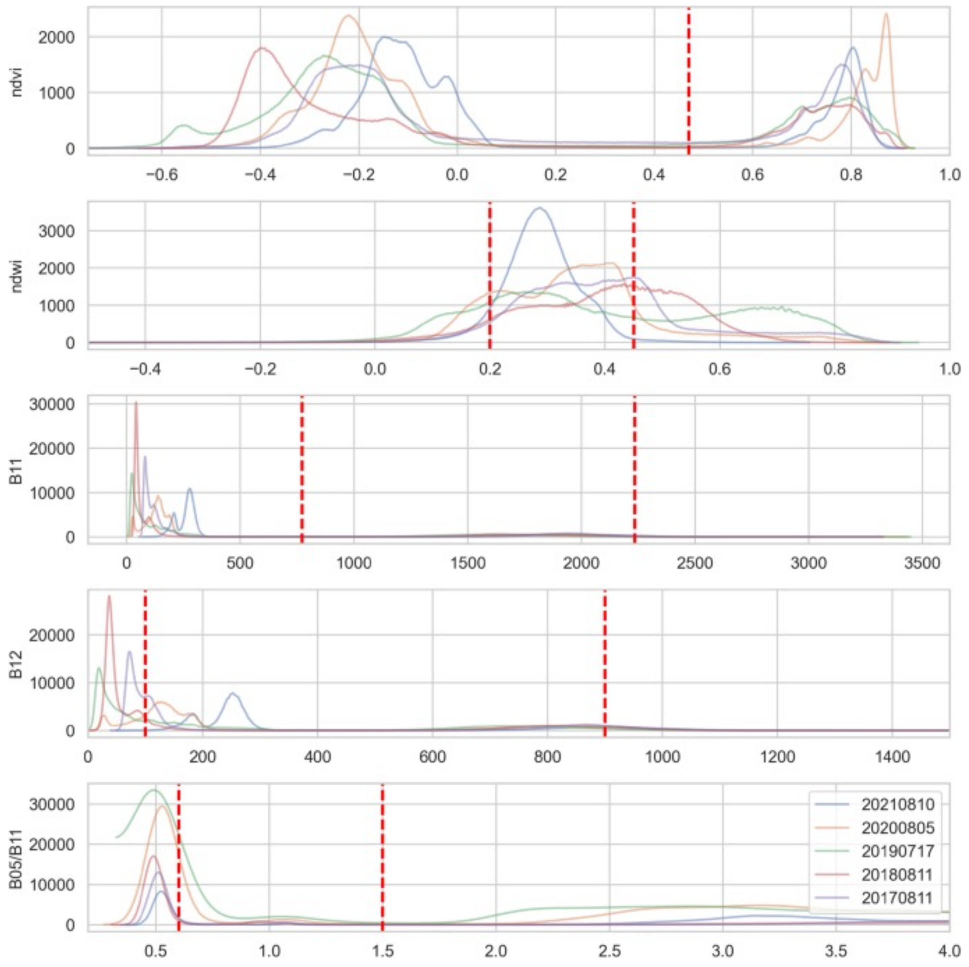
It is registered that this type of classification error depends also on
i) the floating vegetation species (water lilies/ chestnuts, else), and
ii) the density-level

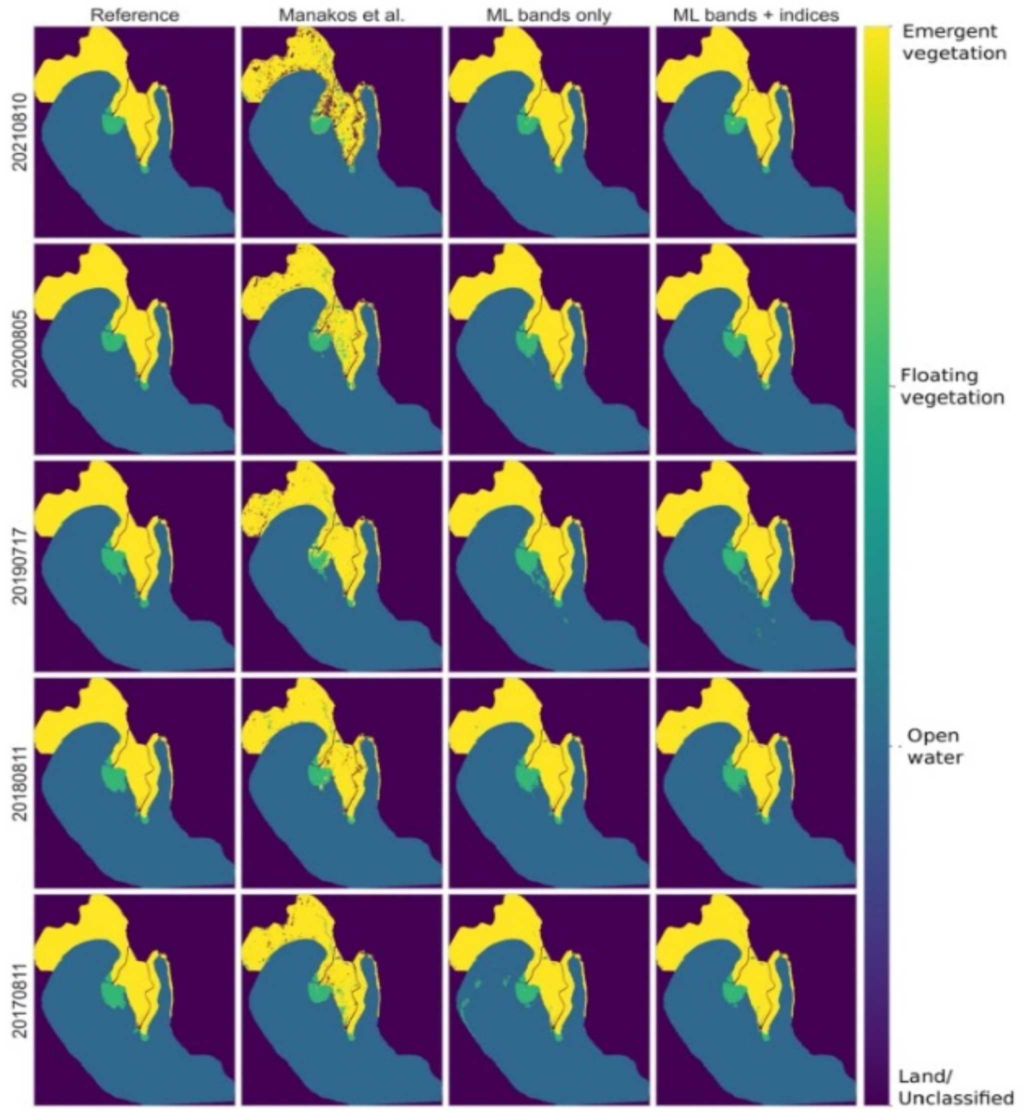
PUBLISHED next: Machine Learning for Identifying Emergent and Floating Aquatic Vegetation from Space: A Case Study in the Dniester Delta, Ukraine, SN Computer Science; with user's accuracy over 85% for the floating vegetation

This project has received funding from the European Union's Horizon 2020 Research and Innovation Action programme under Grant Agreement No 101004157

Floating vegetation mapping: Machine learning approach (part I)

L. Alagialoglou, I. Manakos, E. Katsikis, S. Medinets, Y. Gazyetov, V. Medinets, A. Delopoulos, Machine Learning for Identifying Emergent and Floating Aquatic Vegetation from Space: A Case Study in the Dniester Delta, Ukraine, 2024, SN Computer Science, DOI: 10.1007/s42979-024-02873-7.





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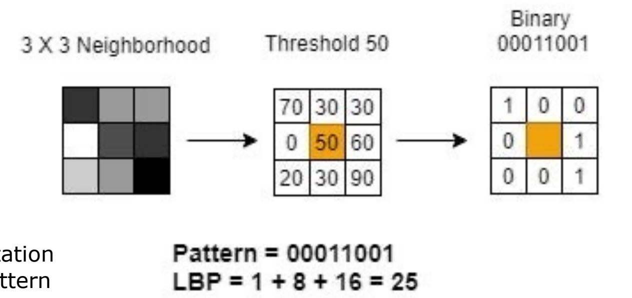
Classification/ Evaluation

- Classifiers: Random Forest (RF), XGBoost
- A leave-one-date-out strategy: evaluating various ML models on a single date after they have been trained on all other dates, and this process is iteratively carried out for each date
- Metrics: F1-score, Recall (producer's accuracy), Precision (user's accuracy)

Used Features

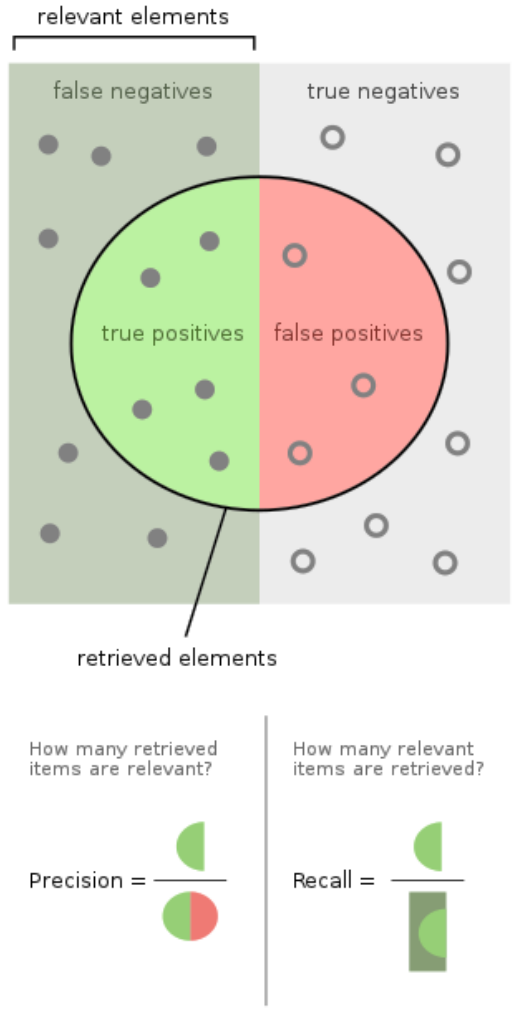
- the 12 bands of the Sentinel-2 L2A products
- additional features based on the domain knowledge acquired from our previous work (e.g., Normalized Diference Vegetation Index (NDVI), Normalized Diference Water Index (NDWI), ratio B05/B11)
- texture features for each band are derived using the Local Binary Pattern (LBP) method*.



* Ojala T, Pietikainen M, Maenpaa T. Multiresolution gray-scale and rotation invariant texture classifcation with local binary patterns. IEEE Trans Pattern Anal Mach Intell. 2002;24(7):971–87.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Action programme under Grant Agreement No 101004157

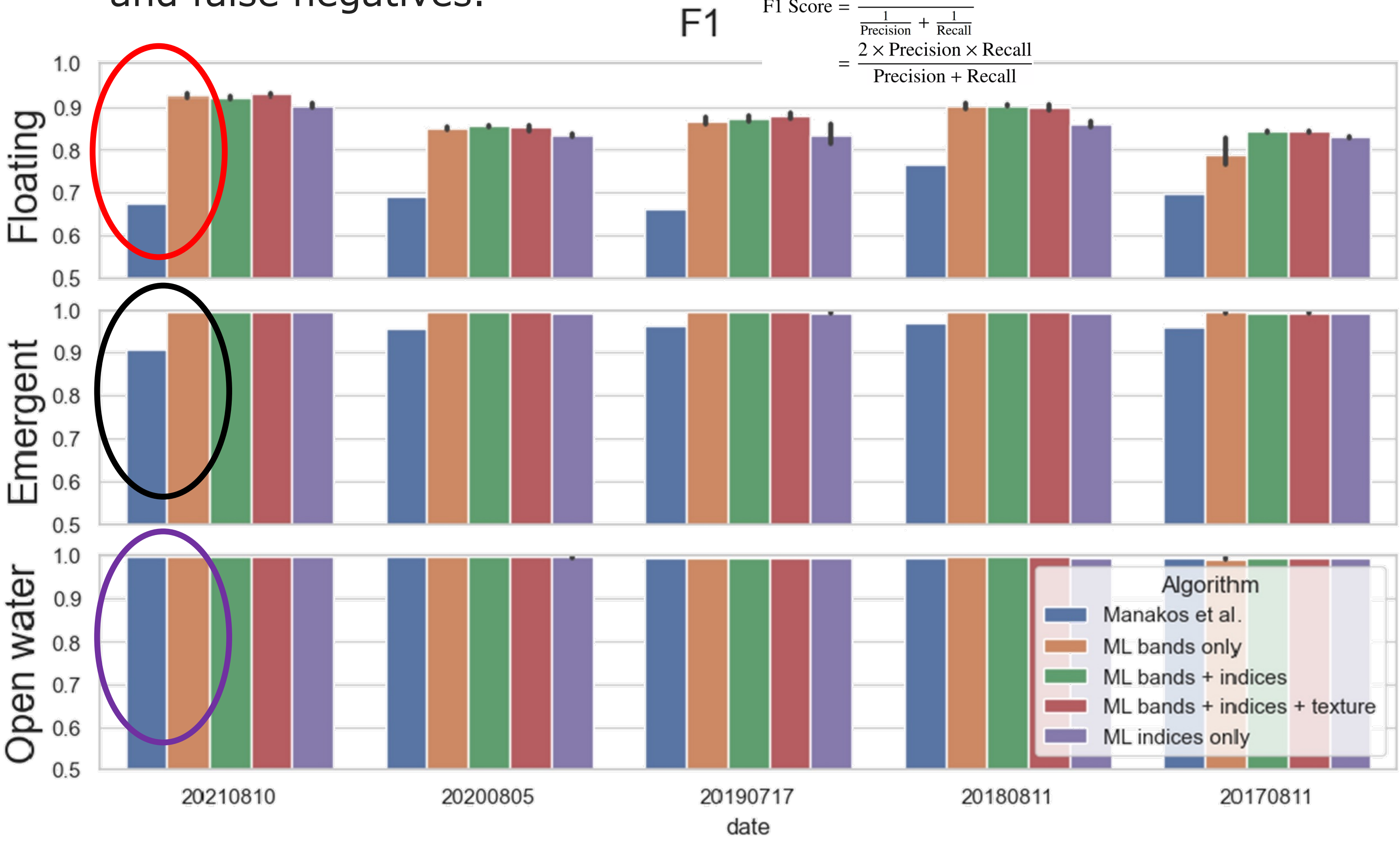
Floating vegetation mapping: Machine learning approach (part IV)



Source: https://en.wikipedia.org/wiki/Precision_and_recall

The F1-score is a measure that harmoniously integrates UA and PA, yielding a single score that accounts for both false positives and false negatives.

$$\text{F1 Score} = \frac{2}{\frac{1}{\text{Precision}} + \frac{1}{\text{Recall}}} = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$



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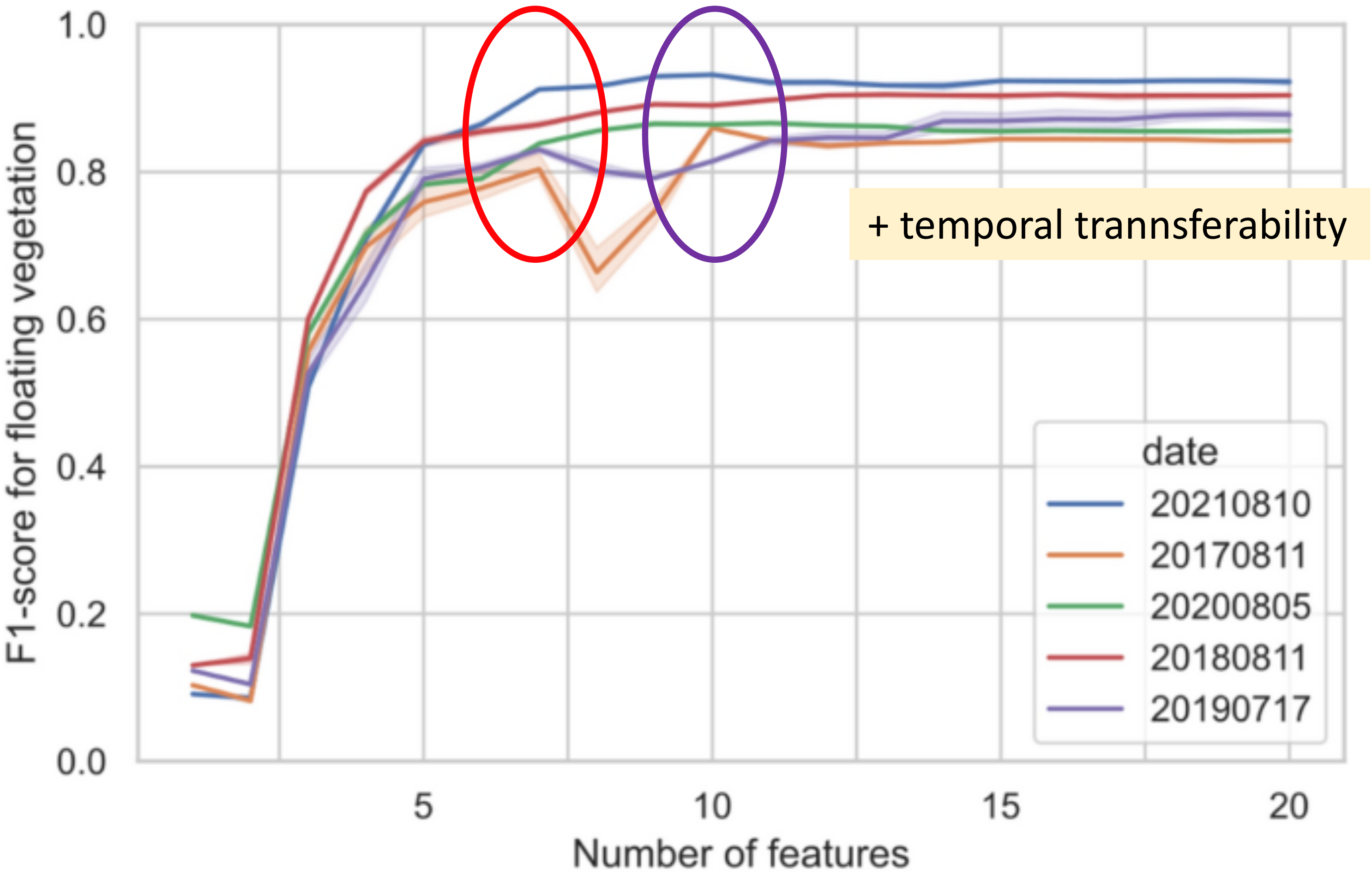
Feature Importance Analysis

- the Max-Relevance Min-Redundancy (MRMR)* algorithm was employed to quantify and rank the significance of features

- maximizing the relevance of features with the target class while simultaneously minimizing the redundancy among the features themselves



* Ojala T, Pietikainen M, Maenpaa T. Multiresolution gray-scale and rotation invariant texture classifcation with local binary patterns. IEEE Trans Pattern Anal Mach Intell. 2002;24(7):971–87.

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Floating vegetation mapping: Machine learning approach (part VI)

Algorithm	F1	Precision (UA)	Recall (PA)
ML bands + indices	**0.880 ± 0.031**	0.904 ± 0.049	**0.858 ± 0.037**
ML bands + indices + texture	**0.881 ± 0.032**	**0.912 ± 0.048**	0.853 ± 0.041
ML bands only	0.864 ± 0.055	0.867 ± 0.082	0.862 ± 0.037
ML indices only	0.852 ± 0.031	0.888 ± 0.051	0.822 ± 0.045
Manakos et al	0.697 ± 0.041	0.720 ± 0.099	0.690 ± 0.080

Improved from ~ 0.7 to > 0.85

Rank	Feature	Rank	Feature	Rank	Feature	Rank	Feature
1	B11	6	B07	11	B8A	16	LBP_{B08}
2	B12	7	B06	12	B02	17	LBP_{B07}
3	B09	8	B01	13	NDWI	18	LBP_{B04}
4	NDVI	9	B05	14	B03	19	LBP_{B06}
5	B08	10	B05/B11	15	B04	20	LBP_{B02}

Ranked low, but may offer a slight improvement still

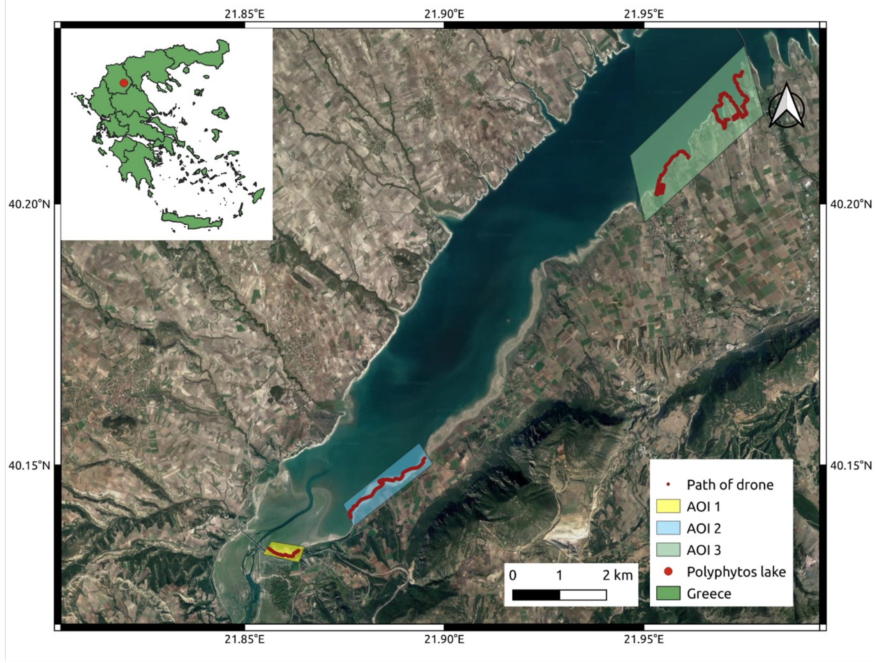
This project has received funding from the European Union's Horizon 2020 Research and Innovation Action programme under Grant Agreement No 101004157

Submerged vegetation mapping: 1st attempts with foundation models (I)

Assess the effectiveness of AI models in mapping and analyzing underwater aquatic vegetation (UVeg) comparing traditional ML algorithms based on handcrafted features and a pretrained foundation model using a range of remote sensing data including multispectal, satellite and aerial imagery.

Data Sources:

- Air-borne images using the DJI Mini Pro UAV (3-6 cm resolution)
- Space-borne images: WorldView-2 (GSD: 1.8m) and Sentinel-2 (S2) (lowest GSD 10m)
- Annotations for S2 were extracted based on WorldView-2 imagery.



L. Alagialoglou, I. Manakos, S. Papadopoulou, R. Chadoulis, A. Kita, Mapping underwater aquatic vegetation using foundation models with air- and space-borne images: the case of Polyphytos Lake, 2023, Remote Sensing, Special Issue: Remote Sensing and Artificial Intelligence in Inland Waters, DOI: 10.3390/rs15164001

This project has received funding from the European Union's Horizon 2020 Research and Innovation Action programme under Grant Agreement No 101004157

Traditional ML models

- Pixel-based Logistic Regression
- Random Forest

Features: Spectral bands, total absorption, particle backscattering, diffuse attenuation coefficient, and Secchi disk depth (QAA-RGB algorithm*)

Foundation Model for Semantic Segmentation with Prompt-tuning

- Segment Anything (SAM)**: Mask Autoencoder (MAE) Vision Transformer (ViT), pretrained on a large-scale dataset, fine-tuned with limited annotations

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*Pitarch, J.; Vanhellemont, Q. The QAA-RGB: A universal three-band absorption and backscattering retrieval algorithm for high resolution satellite sensors. Development and implementation in ACOLITE. Remote Sens. Environ. 2021, 265, 112667
**Kirillov, A.; Mintun, E.; Ravi, N.; Mao, H.; Rolland, C.; Gustafson, L.; Xiao, T.; Whitehead, S.; Berg, A.C.; Lo, W.Y.; et al. Segment anything. arXiv 2023, arXiv:2304.02643

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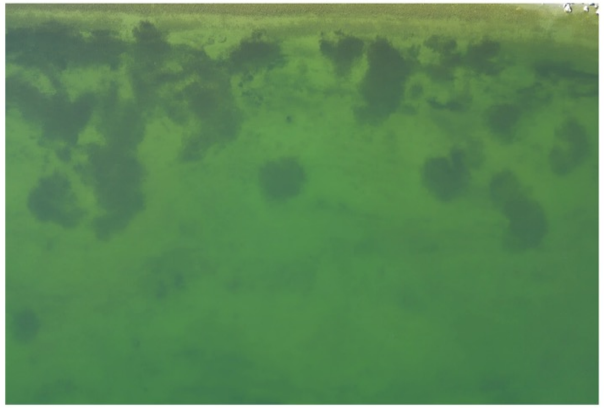
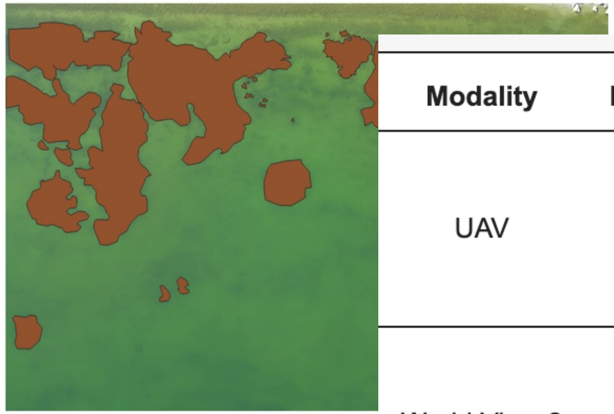
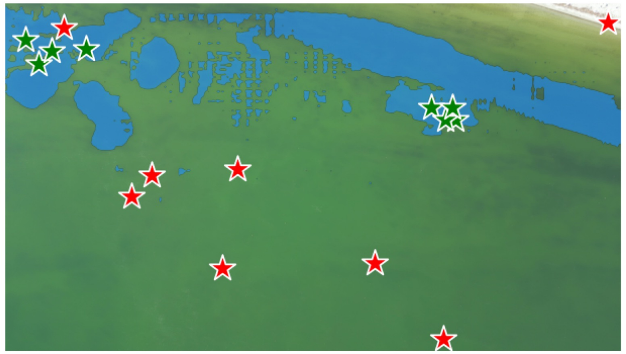
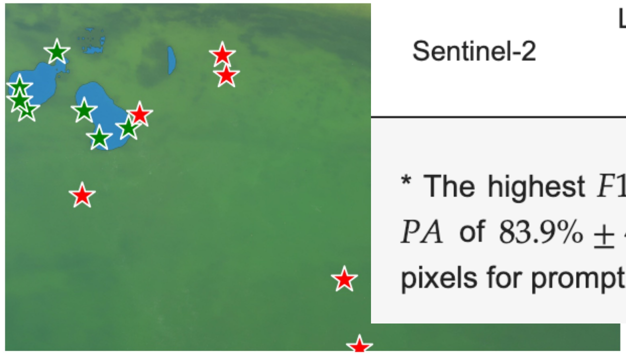
Submerged vegetation mapping: 1st attempts with foundation models (III)









Modality	ML Method	Size of Training Set	Dataset Size	*F1*	*UA*	*PA*
UAV	Log Regr	10-fold CV	~8M px	0.350	0.219	0.861
	RF	10-fold CV	~8M px	0.576	0.415	0.941
	SAM	20 px pairs	~8M px	**0.842** *	**0.957**	**0.751**
World View 2	Log Regr	20-fold CV	~400k px	0.340	0.207	0.956
	RF	20-fold CV	~400k px	**0.472**	**0.328**	**0.845**
	SAM	8 px pairs	~400k px	0.264	0.157	0.834
Sentinel-2	Log Regr	40-fold CV	~14k px	0.184	0.103	0.890
	RF	40-fold CV	~14k px	**0.331**	**0.231**	**0.581**

* The highest $F1$ score of $86.5\% \pm 4.0\%$, with corresponding UA of $89.6\% \pm 5.8\%$ and PA of $83.9\% \pm 4.8\%$, is achieved for UAV images using 40 positive/negative pairs of pixels for prompting the SAM model.

L. Alagialoglou, I. Manakos, S. Papadopoulou, R. Chadoulis, A. Kita, Mapping underwater aquatic vegetation using foundation models with air- and space-borne images: the case of Polyphytos Lake, 2023, Remote Sensing, Special Issue: Remote Sensing and Artificial Intelligence in Inland Waters, DOI: 10.3390/rs15164001

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Results - Feature Importance Analysis

UAV Imagery:

- Blue band most informative for single-feature classifier.
- Green + Blue bands combination nearly as effective as using all bands.

Sentinel-2 Bands:

- Most informative: B07, B08, B01, B09.
- Effective combinations: B01-B07-B12 and B01-B07-B11.

WorldView-2 Analysis:

- Green, RedEdge, Near Infrared1 bands most informative.
- Close-to-shore ("shallow pixels") analysis crucial for feature importance.

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Submerged vegetation mapping: 1st attempts with foundation models (V)

Conclusions:

- SAM shows potential for high-resolution air-borne imagery but requires further adaptation to low resolution spaceborne data.

- Random Forest resulted in the best performance for WorldView-2 and Sentinel-2 data.

- Logistic Regression was successfully transferred to different locations in the lake.

- Feature Importance analysis provided valuable insights for future research by identifying significant bands for each data source (e.g., the Blue band was found the most informative for single-feature classifier and UAV imagery).

Future Directions:

- Focus on adapting foundational models (e.g., SAM) to coarser resolution imagery.

- Explore one-shot prompt adaptation methods for better transferability and efficient segmentation across larger areas and different dates.

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Thank you
for your attention

imanakos@iti.gr

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