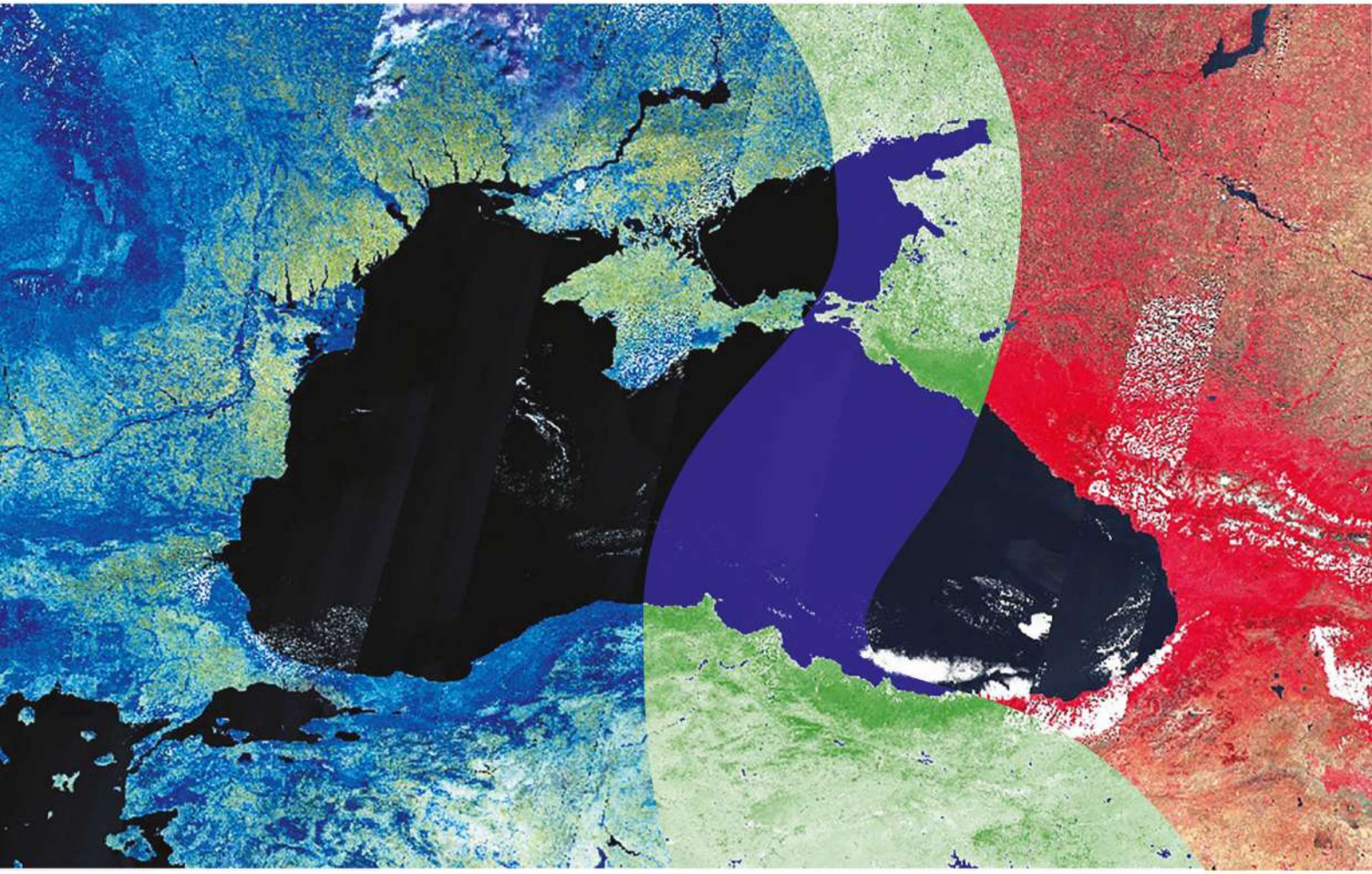
Project funded by EUROPEAN UNION

PONTOS

Black Sea CROSS BORDER COOPERATION

Copernicus assisted environmental monitoring across the Black Sea Basin – PONTOS

Project Public Report



November 2022

Common borders. Common solutions.

CROSS BORDER COOPERATION

CONTENT

INTRODUCTION

Copernicus assisted environmental monitoring across the Black Sea Basin-PONTOS is a 30-month project funded by the European Union's ENI CBC Black Sea Basin Programme 2014-2020. The project includes six partners from four countries – Armenia, Georgia, Greece, and Ukraine.

The PONTOS partners are 1) the American University of Armenia (AUA) Acopian Center for the Environment (AUA-Lead partner), 2) the Environmental Protection and Mining Inspection Body of the Republic of Armenia (EPMIB), 3) Green Alternative (GRAL-Georgia), 4) the Centre for Research and Technology Hellas (CERTH-Greece), 5) Democritus University of Thrace (DUTH-Greece), and 6) the Odessa National I.I. Mechnikov University (ONU-Ukraine). Of the total EUR 999,967 project budget, 92% is funded by the EU ENI Cross-Border Cooperation Black Sea Basin Programme 2014-2020 with the remaining balance being co-funded by the project partners.

The EU funding enables the project partnership to deepen relationships among Armenian, Georgian, Greek, and Ukrainian teams and to build a transnational network with a solid environmental monitoring capacity using reliable interoperable methods and tools. Also, the PONTOS partnership incorporated past and ongoing relevant environmental initiatives funded by the EU and other donor institutions, looking for synergies and optimizing results. The main vehicle to achieving the PONTOS project goals is the wide use of the Copernicus data and services and particularly of those of Copernicus Land and Marine Environment Monitoring Services (CMEMS).

PONTOS brings together environmental science and field monitoring, data science, IT, mapping and remote sensing, and more to deliver an online platform that provides on-demand data and analysis in the partner countries. The challenge is complex, and the development and application of solutions require collaboration across borders and disciplines.

Each of the partner countries has pilot sites to showcase the efficacy and credibility of the online services. Thus, the Platform is tailored to the regional challenges with solutions being generated by utilizing a common information thesaurus and retrieving methods and by leveraging results of completed as well as ongoing EU and national, research and development projects.

The targeted beneficiaries were professionals, enterprises, civil society organizations and public authorities active in various activity sectors such as tourism, agriculture, aquaculture, and commerce in coastal and inland water areas. Amongst other novelties, PONTOS provided a credible way to measure effluents released in the Black Sea Basin environment and enabled the monitoring of crucial parameters such as surface water temperature, salinity, nutrients, potentially toxic elements, and algae presence with the use of spaceborne and in situ data

The focus was to engage citizens in implementation activities and enable them to benefit from project results. In addition to capacity development activities, PONTOS offers the means to exploit in tandem existing local monitoring networks and Copernicus products and services, to align its online services to existing hard- and software infrastructures, and to leverage cooperation and exchange of ideas and best practices across the region.

Capacity Building

- 8 capacity building trainings with about 200 young scientists trained in 4 countries
- 18 trainers trained
- Pontos platform built
- 4 assessments carried out in Lake Sevan
- 4 assessments carried out in Dinestr River Delta
- 5 assessments carried out in Rioni River Delta
- 5 assessments carried out in Nestor River Delta

Events

- 4 brainstorming events with 200 participants
- 4 local events for familiarization with the project
- Participation in 4 international events
- Hackathon organized
- 30 team meetings organized
- 7 press conferences organized
- 1 media tour for journalists in Armenian pilot site

Partnership

- 4 countries in a consortium
- 6 partner organizations
- 13 memorandums of understanding signed in four countries
- 4 local clusters formed on water management and pollution prevention in all participating countries

Outreach

- 170,000 members of the general public reached through newsletters, website, social media
- 6 newsletters prepared
- 6 virtual trainig modules prepared for the general public
- Website pontos-eu.aua.am built and managed
- About 5000 promotional leaflets distributed
- Project video prepared

BLACK SEA: COMMON TERRITORIAL CHALLENGES

The Black Sea (BS) is considered as one of the most vulnerable regional seas due to limited exchange of water with the open oceans and the large watersheds of continental Europe that drain into it. According to the Strategic Action Plan for the Environmental Protection and Rehabilitation of the BS, the following problems are deemed high of priority:

- eutrophication/nutrient enrichment
- changes in marine living resources
- chemical pollution (including oil)
- biodiversity/habitat changes, including alien species introduction.

The Convention on the Protection of the Black Sea against Pollution addresses these challenges through enhanced cooperation among the involved countries. Joint efforts in preserving ecosystems and protecting marine and coastal living resources shall be intensified over years to ensure the sustainable development of coastal states' well-being, health, and security.

PONTOS advances the environmental monitoring at transboundary and regional levels with strategies that remain detailed enough to apply at the local level. PONTOS focuses on land cover and use changes, as a result of geogenic and anthropogenic processes at significant parts of key watersheds and coastal strips around the Black Sea and significant inland water bodies.

The project adopts smart synthesis of validated Earth Observation data and results from numerical models to produce quantitative estimations of physicochemical variables, descriptive of environmental conditions in the Black Sea region. Significant issues like agricultural water footprint, nutrient fluxes, eutrophication processes, coastal erosion/deposition zones, land-use changes and afforestation/deforestation will be assessed by PONTOS at representative pilot sites in all partner countries. During and after the implementation of the project a series of national agencies, regional authorities, municipalities, bureaus and bodies managing protected areas, private stakeholders and the broader public will benefit from the results, the developed platform, and the databases. A direct link to pre-existing and existing monitoring mechanisms was established, ensuring the sustainability of the results by interfacing and incorporating PONTOS knowledge generation mechanisms with governmental structures.

THE PONTOS PILOT SITE IN ARMENIA: LAKE SEVAN

The Armenian pilot area is comprised of the largest freshwater source in Armenia, Lake Sevan, and its catchment area. Urgent challenges to the regional ecosystem are diverse and range from pollution to illegal fishing. Urban encroachment, as well as land use changes resulting from fluctuations in water levels are also becoming important challenges.

Image 1: Lake Sevan, project pilot area of Armenia. Photo Credit: Sevan National Park

AGRICULTURAL WATER BALANCE, WATER PRODUCTIVITY, AND WATER STRESS INDICES

- Four assessment pilot sites were selected for a detailed analysis.
- Pilot site data was collected from a variety of sources, including satellite imagery, pre-existing datasets, and field interviews.
- NDVI/NDMI indices were calculated for the pilot sites for the 2017-2022 vegetation seasons based on the Sentinel-2 data.
- Time and depth (mm) criteria were applied to determine the most efficient irrigation scenarios for selected crops.
- These irrigation parameters can be adopted by farmers throughout the study area to optimize agricultural water use and increase yields.
- Based on the calculated benchmark values of irrigation for the most popular crops in Lake Sevan basin, the total irrigation water demand in the basin was calculated.

Image 2: Cabbage field in Vardenik

Image 3: Wheat field in Noratus

Using the AquaCrop model and the collected data in combination with applied and hypothetical irrigation scenarios, we identified optimal irrigation strategies for the most popular crop types in the Lake Sevan basin. The application of these strategies should result in decreased water usage and water stress, and increased agricultural productivity. However, these practices still need to be tested on the ground, and adjusted based on actual results.

Nonetheless, there is also another problem concerning the poor condition of irrigation infrastructure, with average water losses of 50% and a lack of measurements on water usage. While agricultural production has been boosted through the use of pesticides, this practice further contributes to environmental problems in Lake Sevan. Therefore, future basin development activities must focus on solving water use efficiency problems, and irrigation practices must become knowledge-based while taking into account climate change trends.

Copernicus data is crucial for monitoring agricultural land changes and for helping to devise responses to both climatic and anthropogenic challenges. To continuously and automatically generate environmental indices and detect relevant changes to the Lake Sevan basin, we have deployed the Sen2r programming package. Relevant indices for monitoring of agricultural lands include NDVI, MSAVI2, NDWI, and NDWI2. Tools like Sen2r and the PONTOS platform will help to automate data acquisition and monitoring, which will save time for both analysts and decisionmakers.

WETLAND AND FLOATING VEGETATION COVER ASSESSMENT IN ARMENIAN PILOT SITE

We combined remote sensing imagery with field data to explore long-term spatio-temporal changes in Lake Sevan's aquatic vegetation. We primarily used moderate resolution images and from them calculated vegetation indices. Methodologically, our results demonstrated the potential in using freely available, medium resolution satellite images from Landsat and other sources to monitor environmental changes in a reproducible and continuous manner.

Image 4: Aquatic vegetation near Norashen Reserve

Image 5: A mixture of aquatic vegetation and trees left in the water after level rise near River Dzknaget Mouth

Our study results show that a long-term decrease in water levels favors the spread of macrophytes. Changes to aquatic vegetation and water levels can also be assumed to be linked with anthropogenic disturbances.

This work runs a comparison of different VIs in mapping aquatic vegetation (AV) and assesses the capabilities of three indices to analyze aquatic ecosystems: The Normalized Difference Vegetation Index (NDVI), Normalized Difference Aquatic Vegetation Index (NDAVI) and the Normalized Difference Water Index (NDWI). Results shows that aquatic vegetation of Lake Sevan is mainly represented by Emergent AV, which generally grows in the coastal zone, and not in deep lagoons. Dominant species are Butomus Umbellatus and Potamogeton Pectinatus.

One of the most important findings is that algal blooms can be a huge barrier to detecting aquatic vegetation from satellite imagery. This is particularly relevant for automated data collection and index calculation. To prevent this, we recommend that one avoid using images captured during the blooming season, which runs from mid-summer to mid-autumn, or to use more in-depth scientific approaches, such as algorithms based on the Sort-wave Infrared band.

FOREST COVER CHANGES AND ITS CONSEQUENCES FOR THE ENVIRONMENT

Included within the Armenian pilot site was the entire territory of Sevan National Park. The park's forestry was first inventoried in 1962, and then subsequently in 1972 and 1983. However, after that, inventories ceased, and only in 2005 was forest cover reassessed during a GIS-facilitated boundary adjustment of the park. The 2005 assessment showed the forest to cover 13,250.3 ha, which was 1,285.2 ha more than the area recorded in 1983. This forest expansion can be attributed both to the planting of artificial forests as well as the proliferation of shrubbery with high trunk-growth potential, such as sea buckthorn and yellow acacia—both of which have been observed in Sevan National Park on site visits.

Using satellite imagery, forest cover and forest cover loss were calculated for the years spanning from 2009 to 2020. Analysis revealed the loss of 510.7 ha of forest cover during this period. As relates to environmental quality, we found no relationship between this forest cover loss and water quality in Lake Sevan.

To facilitate further study, an up-to-date and precise inventory of forestry in Sevan National Park will be necessary. Additionally, water quality monitoring must take place at periodic intervals to allow for high quality research and informed forecasts.

INTEGRATED ASSESSMENT ON CHLOROPHYLL CONCENTRATION AND EUTROPHICATION DYNAMICS IN THE ARMENIAN PILOT SITE

Throughout the study period, we recorded spatial and temporal changes in Chlorophyll-A (chl-a) and total suspended matter (TSM) concentrations in Lake Sevan. Spatially, it was found that the southeastern region of Major Sevan often exhibited higher algal biomass. Temporally, algal blooms were recorded in the months between June and August, with the greatest intensity in 2018 and 2019. The fact that 2018 was the hottest year in Armenia in the past decade, indicates the potential role of heat in driving algal blooms. No significant correlations between algal blooms and levels of nitrogen (N) were found. However, high concentrations of phosphate ions (PO4-) were recorded in the spring and the autumn, thus correlating negatively with levels of algae and hinting at its potential to limit blooms.

These findings indicate that two of the most important factors in Sevan's algal blooms are temperature and phosphorous. Given that temperature is expected to rise due to climate change, if no action is taken, harmful algal blooms will continue to increase both in frequency and intensity. While temperature increases are unpredictable and beyond our direct control, sincere efforts to limit the external loading of phosphorus must take place to mitigate blooms in the near future. Possible policy responses include better management of sewage, fertilizer, and aquaculture activities around the lake. There are also nature-based solutions, such as constructed wetlands and macrophyte belts, which can filter and sequester runoff.

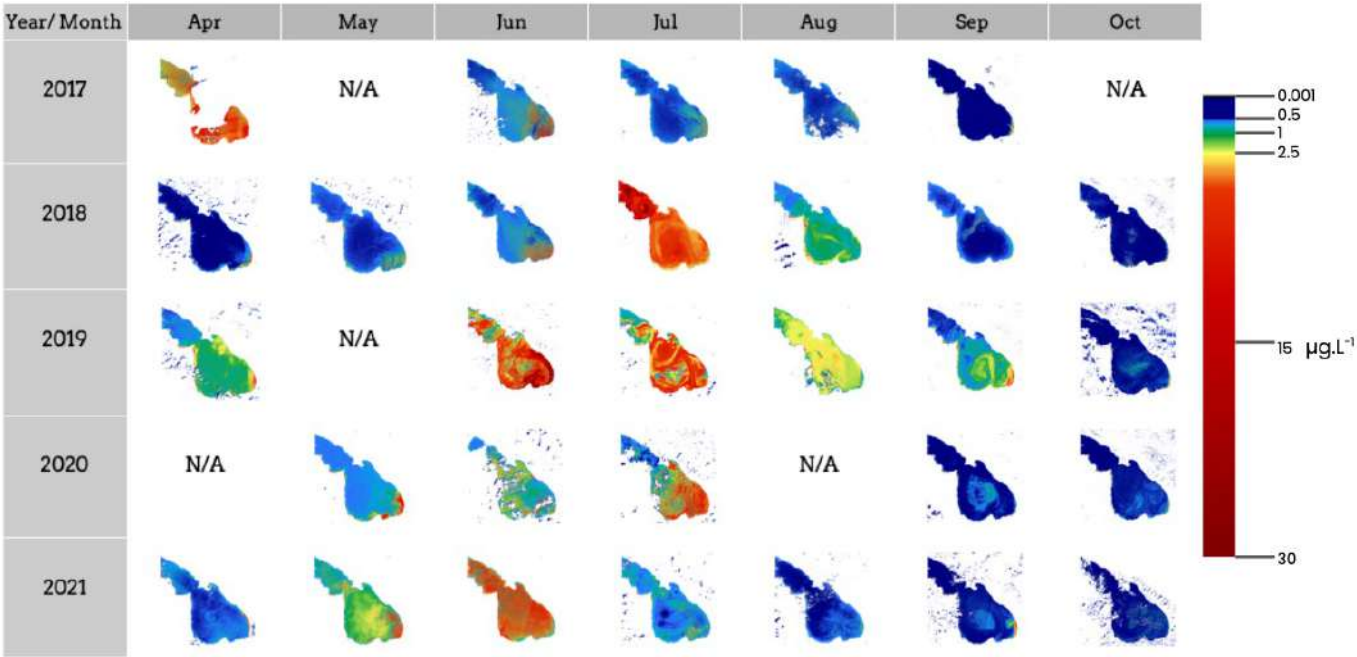


Figure 1: Temporal variations in chlorophyll-a concentrations in Lake Sevan between 2017 and 2021.

THE PONTOS PILOT SITE IN GREECE: THE NESTOS RIVER DELTA AND ITS COASTAL ZONE

The PONTOS project pilot area in Greece includes the Nestos River Delta and the Vistonida Lagoon complex, a wetland area of high ecological significance protected by the Ramsar Treaty and part of the Natura 2000 network. The coastline of the pilot area and the six coastal lagoons of the Nestos river and Vistonida complexes were at the centre of attention of the PONTOS Project.

These lagoons are: Eratino, Agiasma, Lafri, Porto Lagos, Xirolimni and Ptelea. The shoreline exhibits long-term signs of substantial erosion, especially after Nestos River damming. The lagoons are affected by agricultural residues, mostly nitrogen and phosphorus compounds, inducing frequent eutrophication incidents. Finally, the salinization of coastal aquifers and the freshwater mismanagement should be reversed utilising modern precision irrigation technologies. All the above issues have been studied within the PONTOS framework, using the Copernicus-developed satellite products.

COASTLINE DYNAMICS ASSESSMENT: WORKFLOW AND RESULTS

- Completed the shoreline change analysis covering the period from 1985 to 2020. The standard methodology was applied into four steps:
  - the creation of a data-list with all satellites and satellite images available,
  - the historical shoreline extraction from the relevant satellite images,
  - the evaluation of the shoreline movement throughout the study period, and
  - the offshore and nearshore wave analysis (extreme wave events, incident wave energy, longshore sediment transport, etc.)

- The entire coastal zone is characterized by intense erosion due to the operation of three hydroelectric and irrigation dams along the course of the Nestos River. Their construction began in the early 1960s, and they were completed by the end of 1996, resulting in a gradual disturbance in the erosion-deposition balance, especially at the vicinity of the deltaic zone with an estimated sediment supply reduction in relation to historical sediment yields at the deltaic zone of 84 %, due to the Nestos river damming.

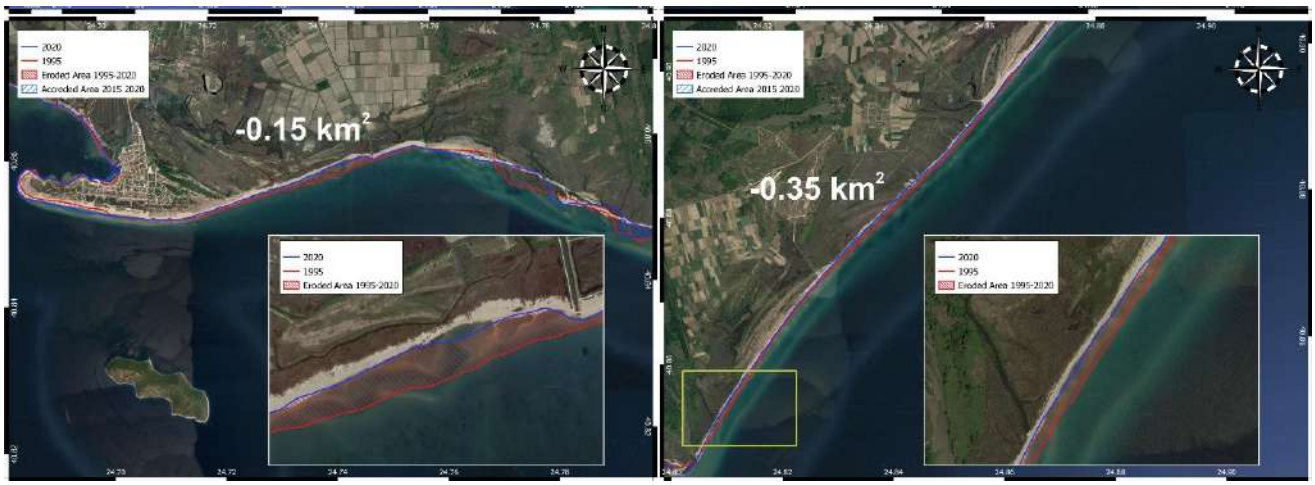


Figure 2 & 3: Impact of river dams on the coastal zone of Nestos river estuaries

INTEGRATED ASSESSMENT OF CHLOROPHYLL-A CONCENTRATION AND EUTROPHICATION DYNAMICS: SUMMARY

- Chl-a concentration in the coastal lagoons of Northern Greece was mapped and assessed.
- Those coastal lagoons have cultural, environmental and economic importance, consequently monitoring is needed to address the water quality changes.
- The focus was on the temporal and spatial evolution of Chl-a for the period 2013-2021.
- Landsat 8 satellite images were retrieved and processed for the time period 2013-2015 and Sentinel-2 images for the period 2015-2021.

➢ A detailed description of the annual evolution of Chl-a in Vassova lagoon, in Eratino and Agiasma, in Porto Lagos, in Xirolimni lagoon and in Ptelea was established.

Image 5: Porto Lagos lagoon

Image 7: Xirolimni lagoon

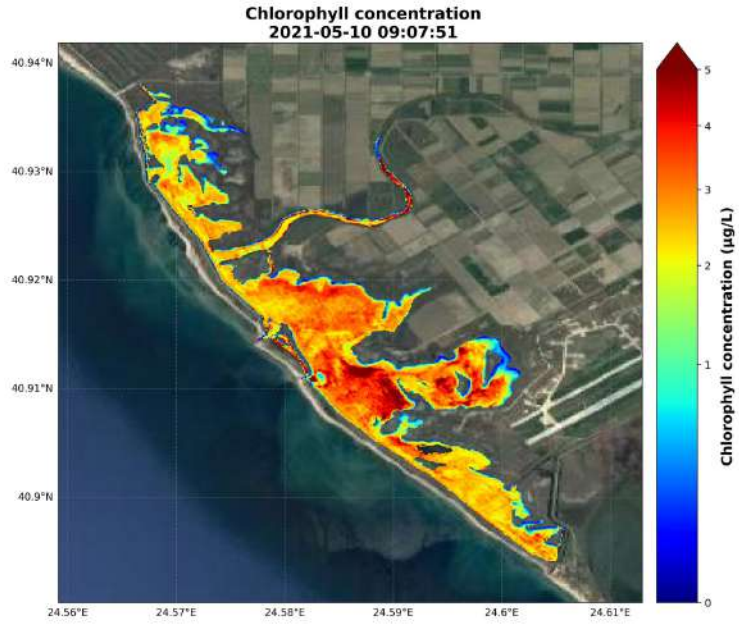


Figure 4: Spatial evolution of chlorophyll concentration in Eratino lagoon

AGRICULTURAL WATER BALANCE, WATER PRODUCTIVITY, AND WATER STRESS INDICES: WORKFLOW AND RESULTS

- Calculated the water use by the agricultural sector in the pilot area.
- Calculated and proposed water productivity benchmark values for most popular and water demanding crops.
- Estimated the potential annual water stress level that is induced by the farmers to the crops.

➢ Advance in the development of a functional tool that could contribute to the rational use of the available water resources from field to watershed level.

CONCLUSIONS

The numerous interviews with farmers in the study area showed that they tend to play safe and over-irrigate their fields, aiming to secure the maximum possible yield production. As a result, farmers overexploit the available surface and groundwater resources of the area downgrading their quantity, but also deteriorating the coastal zone salinization status, adversely affecting their quality. The project results indicated that a more rational use of the available water resources by the agricultural sector is feasible, if precision irrigation tools are integrated to the farmers' irrigation scheduling practice, decreasing crops water footprint in the area 10-30% depending on crop, soil type etc.

THE PONTOS PILOT SITE IN GEORGIA: THE COASTAL LINE & THE KOLKHETI LOWLANDS

The Georgian pilot areas are the Coastal Line and the Kolkheti (Colcheti) Lowlands in west Georgia.

The Coastal Line covering the entire coastline of Georgia, is facing a threat of severe coastal erosion caused by a combination of sea-level rise, the tectonic sinking of the land, alteration of the river, and the sediment flow.

The Kolkheti (Colcheti) Lowlands covers the downstream part of the Rioni river, including the delta area. The main ecosystems there, are ancient deciduous Colchic forests and wetlands, the Colchic rainforests being the most humid temperate deciduous rainforests that host 1,100 species of vascular plants, particularly woody species, bryophytes, almost 500 species of vertebrates, and a high number of invertebrates.

Among the environmental problems that the region faces is the reduction of the river and sedimentation flow, which affects the delta area and natural habitats due to the construction of several regulating dams and reservoirs in the Black Sea Basin, that caused severe degradation or loss of spawning sites of Sturgeon species (including Atlantic sturgeon). Other major threats include water pollution and the degradation of wetlands, as well as deforestation.

COASTLINE DYNAMICS ASSESSMENT: WORKFLOW

- Satellite images (Sentinel and LandSat) and historical data were collected for 1987–2021
- Shoreline movement analysis using DSAS tool was carried out
- Very High Resolution (VHR) space images were used to characterize coastal line changes in selected sub-areas (along Abkhazia and the second part includes the regions of Adjara, Guria and Samegrelo-Zemo-Svaneti) with higher accuracy

Images 8,9: Examples of Accretion (left) and Erosion (right)
Photo Credit: Irakli Macharashvili

COASTLINE DYNAMICS ASSESSMENT: RESULTS

- During the 1987-2013 period erosion is characteristic for 54.28% of the coastline in Abkhazia region, while the remaining 45.72% is characterized by the accretion.
- During the same period in the second part of the coastline we see that 22,21% is under erosion and 77,79% - under accretion.
- During the 1987-2013 period 54.28% of the coastline in Abkhazia region experienced erosion and the remaining 45.72% experienced accretion. During the same period in the second part of the coastline we see that 22,21% is under erosion and 77,79% under accretion.

WETLAND AND FLOATING VEGETATION COVER ASSESSMENT: WORKFLOW AND RESULTS

- The objective of the study was to develop methodology for the qualitative assessment of ake Partotskali, and habitats of floating vegetation using remote sensing and GIS and assign it a reference status.
- For mapping of floating vegetation habitats time series analysis was used with monthly NDVI images (2015-2021).
- NDVI raster images were generated using Sentinel-2 Red and NIR bands. Remote sensing was used for the assessment of Chlorophyll-a concentration in the water.

Photo Credit: Irakli Macharashvili

- According to the study, the lake maintained a healthy chemical and ecological status. We think that the healthy ecosystem of lake Partotskali provides the possibility to establish a monitoring program in accordance with the requirements of the EU water framework directive (EU WFD).

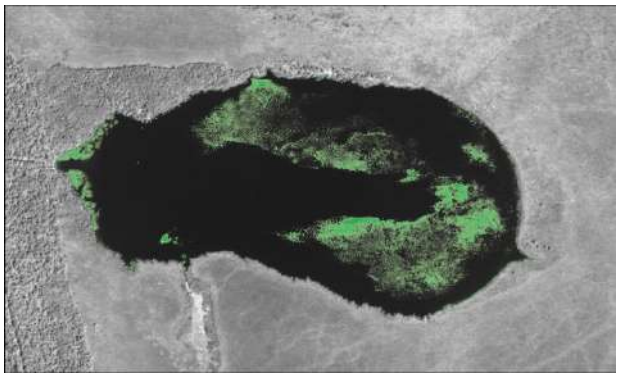


Figure 5: PhotoMap of lake Partotskali covered with water chestnut carpets (Panchromatic image: WV02, 2016)

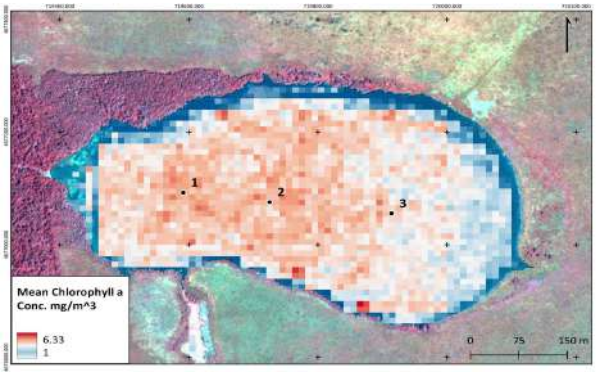


Figure 6: Lake Partotskali Multispectral image (22-08-2016) and Chlorophyll concentration model (10 m)

INTEGRATED ASSESSMENT OF CHLOROPHYLL-A CONCENTRATION AND EUTROPHICATION DYNAMICS: WORKFLOW AND RESULTS

- An integrated assessment of the dynamics of chlorophyll concentration and eutrophication in the Georgian pilot area, namely of the Paliastomi Lake and its surrounding area, was carried out using remote sensing methods and in-situ data.
- The study included an integrated assessment of chlorophyll concentration and eutrophication dynamics from 2013 to 2021.
- This part of the research was done by processing remote sensing Landsat 8, Sentinel-2 satellite images in the SNAP application.
- In addition, on-site studies were performed in November 2021, July 2022, and September 2022. We measured chlorophyll concentration, as well as its contributing chemical factors, such as: water temperature, pH, total hardness, alkalinity and acidity. Turbidity was measured and qualitative reactions were performed to determine the presence of phosphates and nitrates (nutrients). Data from the sensors installed by the non-governmental organization SABUKO (in the frame of project "BSB Eco Monitoring", BSB-884) on Paliastomi Lake were also used in the research. The results obtained by remote sensing and on-site studies were compared.

Photo Credit: Irakli Macharashvili

- The study has shown that Paliastomi Lake and its surrounding area are prone to eutrophication. The process is initiated both by natural events and anthropogenic factors (industrial activity, pollution).
- The annual evolution of Chl-a in Paliastomi lake records the maximum mark in the summer months. The first takes place in spring (May-June) and the second in summer around August. In general, it is a lake prone to eutrophication.
- In the Poti port area, the increased concentration of Chl-a is observed not only in the summer months, but also in late autumn and winter.

FOREST COVER CHANGES AND ITS CONSEQUENCES FOR THE ENVIRONMENT IN GEORGIAN PILOT SITE

Unsustainable use of forests, uncontrolled and excessive tree cuts, infrastructure projects, mining, intensive grazing, pests, diseases, and forest fires are named as the main causes of deforestation and forest degradation in Georgia. Deforestation and forest degradation also negatively impact ecosystem services, damage is caused to soil, water balances inside and outside forests, carbon sequestration and biodiversity. Kolkheti wetland forests were selected as a pilot area, which is located between the Enguri and Supsa rivers and extends to the Kolkheti lowland including Katsoburi Managed Reserve. Kolkheti National Park (founded in 1999) is an important part of the pilot area. The territory is protected by the Ramsar Convention (Ramsar site since 1996) and the Bern Convention (Emerald site since 2018). In 2021, the World Heritage Committee placed the Kolkheti (Colchic) Forests and Wetlands on the UNESCO World Heritage List.

Photo Credit: Irakli Macharashvili

Based on Sentinel-2 multispectral satellite images, maps of forest loss and degradation were created for the territory of the Kolkheti swamp forests. The results showed that forest change is mainly associated with human activities and is quite intense outside protected area.

Forest change is more related to forest degradation than to deforestation since the harvesting of timber by the local population is mainly carried out through selective cuts.
In the study area, not only degradation is observed, but also forest regeneration, which, in our opinion, is related to climate and hydrological regime changes leading to an increase in tree biomass. Various methods were tested to determine changes in the forest, however, depending on the specifics of the forest structure and cuts (felling area), it was best to observe the forest dynamics using a set of spectral channels and a Multivariate Alteration Detection (MAD). The accuracy of the model was determined by comparison with very high resolution Maxar images, where forest reduction or growth was visible at the individual tree level. For the validation of results field trips were carried out.

For the first time, a change model has been created for the forests of Kolkheti lowlands, which can be used by forest management authorities and environmental organizations for biodiversity monitoring.

THE PONTOS PILOT SITE IN UKRAINE: THE COASTLINE AND THE DNIESTER RIVER DELTA

The Ukrainian pilot area is located in the northwestern part of the Black Sea and consists of two sub-areas: the coastline and the Dniester river delta.

The coastline includes the most popular beaches and recreational areas in the south of Ukraine, from the city of Odessa to the Danube Delta. A significant part of the Dniester Delta is included in the Lower Dniester National Nature Park. The river is connected to the Black Sea through the adjacent Dniester Estuary, which is of great ecological and economic importance to the region.

The pilot area faces challenges such as coastal erosion, nutrient pollution affecting drinking and irrigation water quality and ecosystems functioning, disruption of river water flow (due to impacts of hydropower plants) affecting habitats/ biodiversity, agricultural water supply and wetland fires/ burning.

Within the framework of the PONTOS project, Odessa National I.I. Mechnikov University actively involved stakeholders in cooperation, informed them about achievements, developments and gained experience, and identified their requirements and wishes. For this purpose, a series online events for local stakeholders was held in 2021-2022, such as the brainstorming event to attract potential stakeholders (2021), Joint Open Workshop to inform the local community about the entire project progress, Local Open Workshop to present what has been done in the Ukrainian pilot and local event for familiarization with the PONTOS platform and its tools to improve the capacity of using Earth Observation (EO) data. Moreover, two training sessions for young scientists and practitioners were conducted during the project, where participants received hands-on instruction in the use of EO data and services. The participants included all stakeholder target groups. The important role of the PONTOS project was repeatedly underlined by event attendees, as the common problems faced by the countries of the Black Sea basin urgently require joint action and close cross-border cooperation.

COASTLINE DYNAMICS ASSESSMENT: WORKFLOW

- Satellite images (Sentinel and LandSat) and historical data were collected for 1980-2025
- Shoreline movement analysis using DSAS tool was carried out
- Very High Resolution (VHR) space images were used to characterize coastal line changes in selected sub-areas (Lebedivka village and Chornormorsk city) with higher accuracy

Image 10: Accumulative-erosive type of coast (Tuzly Sand Spit, 2019)

Image 11: Abrasion-landslide type of slope (Rybakivka village, 2020)

COASTLINE DYNAMICS ASSESSMENT: RESULTS

- DSAS-based shoreline movement analysis was found to be a useful tool for coastal dynamics assessment, while the VHR image use was highly recommended to estimate efficacy of landslide and coastal protection constructions.
- Maximal shoreline accretion and accumulation of depositions were detected in the areas of the Danube Delta and the sand spit near the Sasyk Estuary; also, accretion was registered in the areas in coastal areas prone to abrasion and landslides (Chornomorsk city, Odessa coast, Kryzhanivka and Fontanka villages) where landslide and coastal protection structures were in place.
- Shoreline retreat was observed in the remaining areas (e.g. erosion on the spit that separates the group of Tuzly Estuaries from the sea, abrasion and destruction of the coast in the segment from Lebedivka village to the Budakskyi Estuary).

WETLAND AND FLOATING VEGETATION COVER ASSESSMENT: WORKFLOW

- Satellite images (Sentinel and LandSat) and historical field data on aquatic vegetation were collected for 2009-2020.
- 4 field campaigns in the Dniester Estuary and the Bile Lake were conducted using unmanned aerial vehicles (UAVs); vegetation samples were also collected.
- UAV and VHR space images were used to accurately quantify emergent and floating plant species cover and their densities, estimate inter- and intra-annual changes.

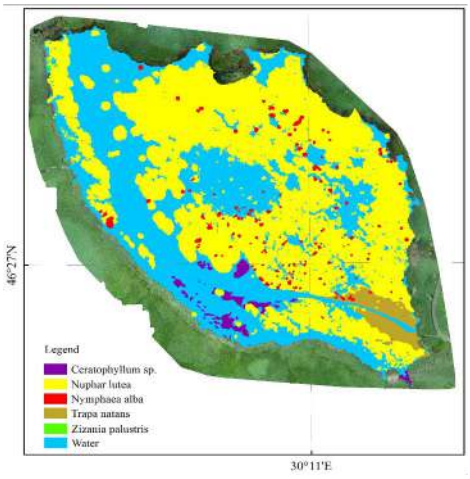


Figure 7: UAV-derived map (Bile lake, July 2021)

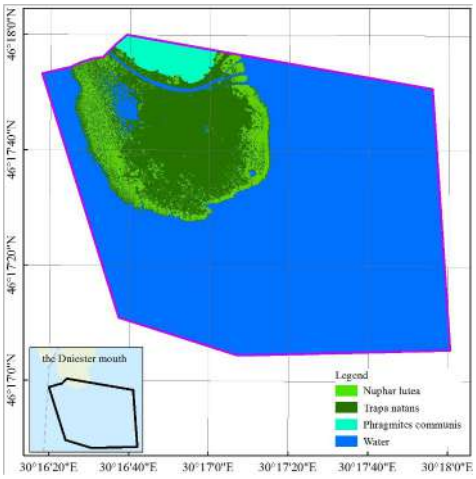


Figure 8: VHR-derived map (July 2021)

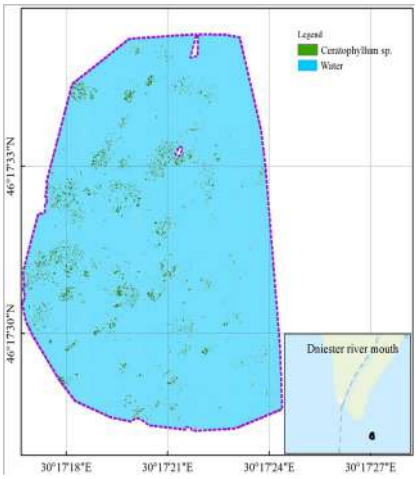


Figure 9: UAV-derived map (July 2021)

WETLAND AND FLOATING VEGETATION COVER ASSESSMENT: RESULTS

- Emergent vegetation cover was quite stable over the time in the Dniester Estuary, while deltaic lakes were more vulnerable (e.g. the Bile lake areas decreased by 16% since 1984.
- The river mouth areas were highly affected by overgrowth of floating vegetation; a gradual pronounced increase of its cover was detected from 2000 to 2019, while a decrease was recorded since 2020 onwards.
- VHR aerial and space-born images were found to be highly credible for distinguishing floating vegetation species/their cover densities and detailed vegetation map build-up.
- High resolution satellite image use was shown to be relevant for local authorities to monitor inter-annual and seasonal changes of vegetation cover in large areas.

INTEGRATED ASSESSMENT OF CHLOROPHYLL-A CONCENTRATION AND EUTROPHICATION DYNAMICS: WORKFLOW

- Satellite images (Sentinel and LandSat) and historical data were collected for 2003-2020
- 6 field campaigns were carried out in the Dniester Estuary and the Bile Lake over April-October 2021 for in-situ measurements and water sample collection
- Empirical algorithms for Chlorophyll-A (Chl) a calculation was developed based on in-situ data and characteristics of reflectance spectrum bands derived from SNAP

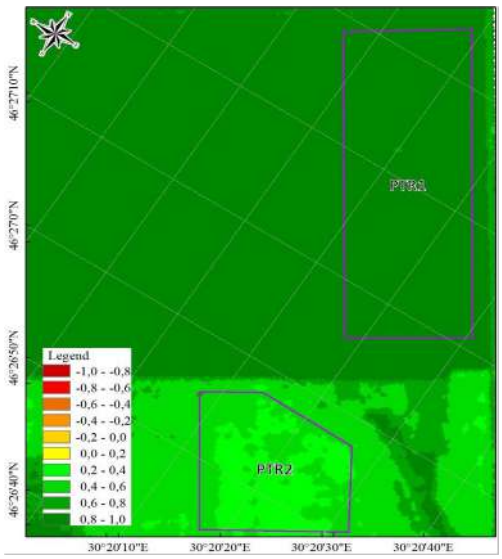
RESULTS

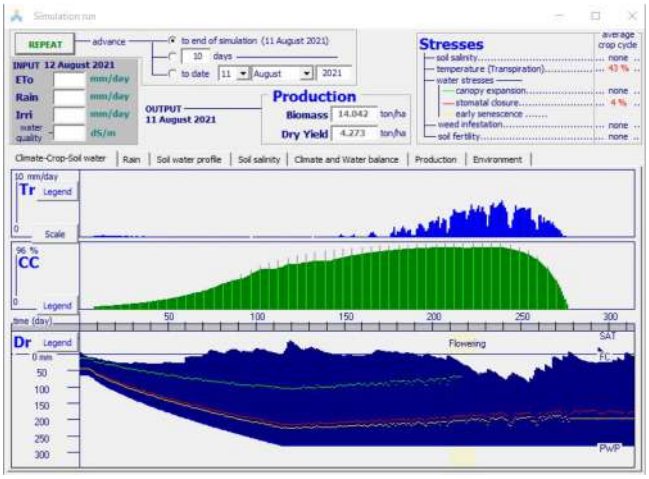
- Mean Chl concentration in the Dniester Estuary doubled in 2011-2020 compared to 2003-2010, while phytoplankton biomass increased 7-10 times.
- Floating and submerged aquatic plants in studied water bodies interfered with space-based results; it is strongly recommended to exclude aquatic plant polygons from the analysis.
- Higher eutrophication levels were typically registered in warmer periods and lower ones – in colder periods; monthly mean Chl concentrations were above the eutrophication threshold (10 mg L-1) year-round except in February.

Images 12-15: In-situ measurements of physicochemical parameters of water in the Dniester estuary during a summer campaign 2021 (top left), the Dniester mouth on July 26th, 2021 (top right), the Bile lake on July 23th, 2021 (bottom left), the Dniester estuary on July 26th, 2021 (bottom right) and the Nymphaea alba in the Bile lake on June 11th, 2021 (PIP in bottom right)

ASSESSMENT OF WATER BALANCE AND WATER STRESS INDICES IN AGROECOSYSTEMS: WORKFLOW

- Typical cultivars (winter wheat and sunflower) were identified and study fields were selected.
- Automatic meteostation and soil moisture loggers were installed; both historical and current agrometeorological, management, aerial and satellite data were collected.
- AquaCrop model was used to estimate water balance under current field condition and alternative scenarios.





Images: Sunflower field mapping with a UAV in June 2021 (top left), UAV-derived NDVI dated on June 26th, 2021 (top right), winter wheat simulation in the Aquacrop model (bottom left), automatic meteorological station and soil moisture & temperature loggers installed in the winter wheat and sunflower fields (bottom right)

ASSESSMENT OF WATER BALANCE AND WATER STRESS INDICES IN AGROECOSYSTEMS: RESULTS

- Usability of the AquaCrop model in the Odessa region (Southern Ukraine) was proved for winter wheat and sunflower at in-situ and satellite data availability.
- AquaCrop indicated a higher vulnerability of winter wheat to temperature stress (43%); both cultivars were affected by a slight stomatal stress (4%).
- Evapotranspiration Water Productivity for sunflower and winter wheat was around 0.66 and 1.00 kg yield produced per m3 of water evapotranspired, respectively.

THE PONTOS PLATFORM

The PONTOS Platform offers easy-to-use, easy-to-access and free-of-charge online services for various specialists, including those who do not have the technical expertise to write codes or algorithms to process data.

The PONTOS project makes information about the Black Sea environment from the EU Copernicus Earth Observation platform accessible to scientists, policymakers, citizens, and other relevant stakeholders through an operational platform, called PONTOS platform. The Platform combines various applications and tools for the users.

The PONTOS platform retrieves and manages satellite, airborne, and field data, automatically finds and utilises existing maps from Copernicus and other repositories, and allows data uploads from end users.

The Platform offers the following services:
- PONTOS Data Cube: easy production of maps from satellite data
- PONTOS Web Application: airborne and in-situ data management support and additional satellite data modules
- PONTOS WebGIS: a combination of already available information already existing on maps

An essential ingredient for enhancing the use of Copernicus products and services for the environmental monitoring of the Black Sea is to enable and enhance the participation, knowledge, and skills of as many local and regional actors as possible, from scientists to government employees and citizens.

The PONTOS Platform has already performed and incorporated custom analyses for the areas covered by its pilot sites:

- PONTOS - AM (Armenia): Sevan Lake and Sevan Lake Basin
- PONTOS - GE (Georgia): Rioni River Delta and Kolkheti National Park
- PONTOS - GR (Greece): Nestos River and Nestos River Delta
- PONTOS - UA (Ukraine): Coastline from Odessa city to the Danube river delta as well as Dniester river delta area and adjacent estuary.

Constant improvement and quality validation of the tools is an important part of PONTOS project. To achieve this, a feedback form is provided in the PONTOS Web Application and PONTOS Data Cube to enable users to provide continuous feedback about the quality of the application. Users are able to write their own message about their experience or suggest improvements. All user input is saved in the database in full compliance with GDPR legislation and super users can review them at any time.

PLATFORM SOLUTIONS: PONTOS OPEN DATA CUBE

The PONTOS Open Data Cube (ODC) empowers the end-users with the ability to easily explore, manage, analyze and visualize Analysis Ready Data (ARD) from satellite missions for each pilot area. PONTOS Data Cube contains Landsat 5, 7 and 8 ARD in a spatial resolution of 30m from 1984 to present and Sentinel-2 ARD in a spatial resolution of 10 m from 2015 to present.

BENEFITS OF USING ODC

- Decreased time and specialized knowledge to access, explore and process satellite data.
- Efficient time series analysis of EO satellite data.
- Consistent data architectures that allow tools and algorithms sharing.
- Open source software solutions that are promoted through community contributions.
- Constant user support.
- Free and open EO satellite data and application algorithms.

THE AVAILABLE TOOLS FOR PONTOS DATA CUBE

- Land (Urbanization, Spectral Anomaly, Fractional Cover, Spectral Indices)
- Water (Water Detection, Water Quality Total Suspended Matter (TSM), Coastal Change)
- General (Custom Mosaic, Cloud Coverage)

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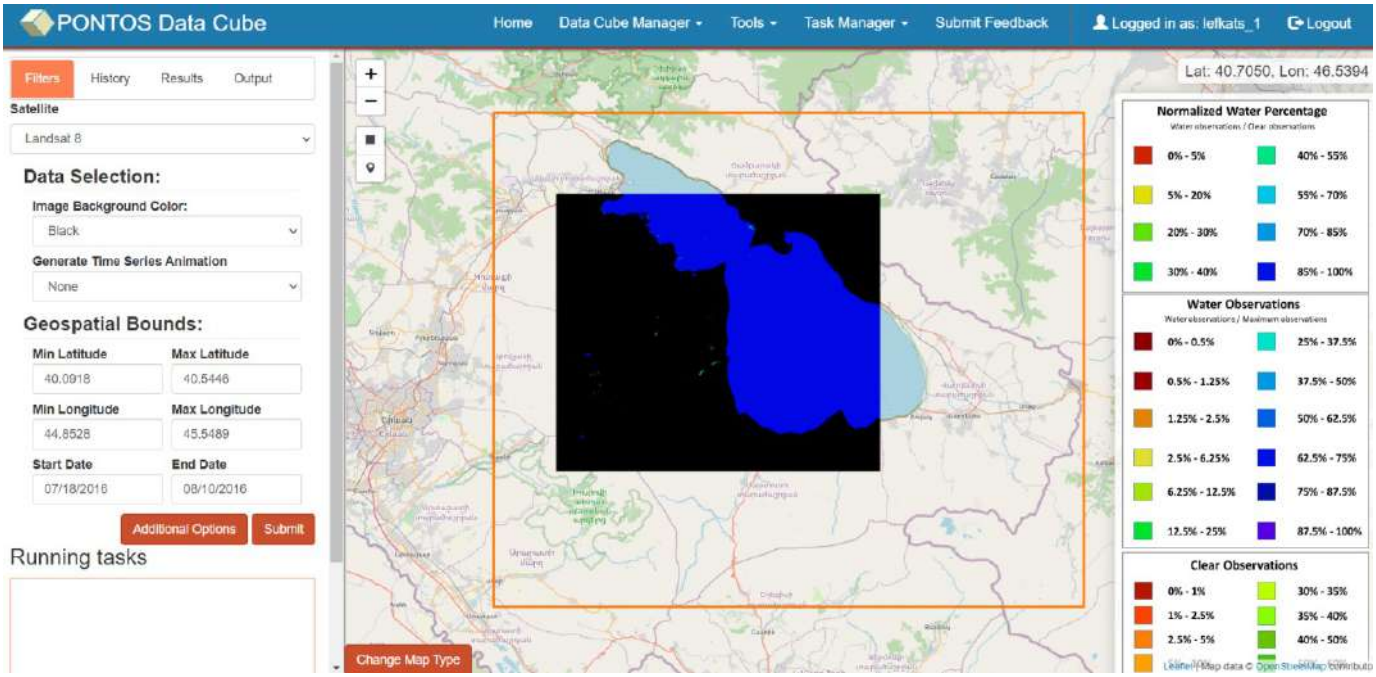

Figure 10: PONTOS Data Cube Water Detection tool (on the example of the Armenian pilot area)

PLATFORM SOLUTIONS: PONTOS WEB APPLICATION

The PONTOS Web Application is integrated into the PONTOS platform. It manages and analyzes the airborne and in-situ data created within the project. The Web Application is complementary to PONTOS Data Cube and PONTOS WebGIS. The Web Application Services are available in English, Armenian, Greek, Georgian, and Ukrainian languages.

WEB APPLICATION TOOLS

Existing Airborne Data Management
- Spectral indices calculation
- Data visualisation ability
- Output downloading in .png or GeoTIFF format

Data Uploads from End-Users
- Supports in-situ and airborne data uploads
- Extraction of descriptive statistics regarding the database
- Export outputs; Airborne data visualization
- *Spectral indices calculation*

Existing In-situ Data Management
- Generation of graphs
- Extraction of descriptive statistics regarding the dataset
- Output downloading in .csv format

Additional modules utilizing satellite data
- WaterMask
- Hydroperiod
- Phenology Metrics
- EODESM (semi-automatic land cover mapping)

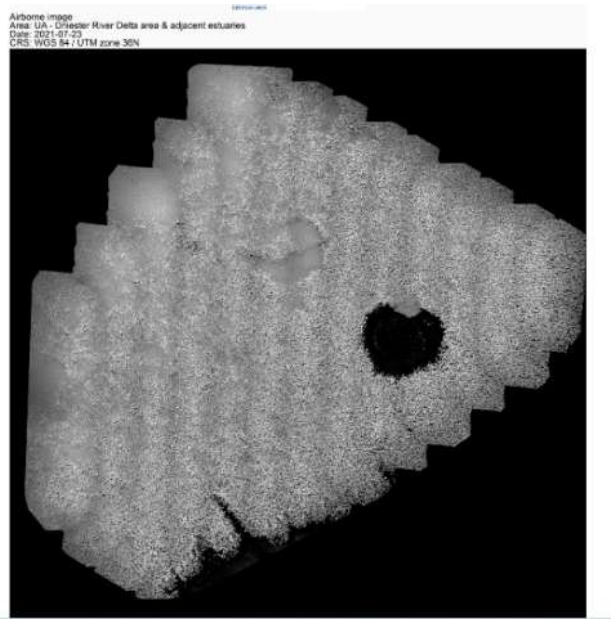

Figure 11: PONTOS Web Application airborne image visualization (on the example of the selected site within the Dniester estuary in the Ukrainian pilot area)

Figure12 : PONTOS Web Application HydroPeriod visualization (on the example of the Georgia's pilot area)

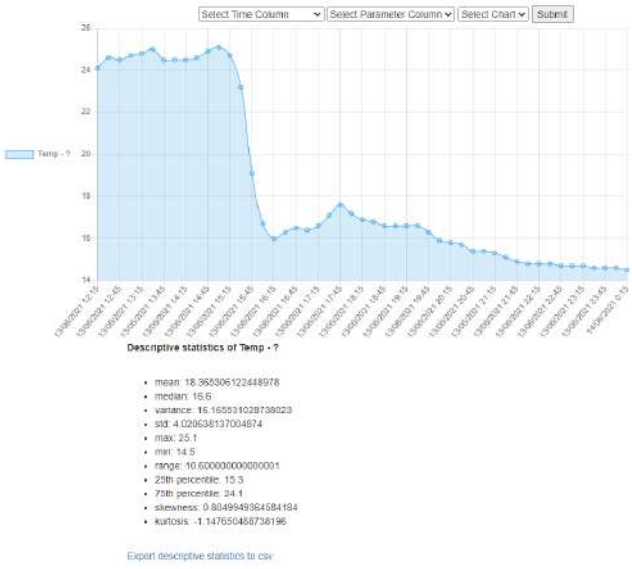

Figure 13: PONTOS Web Application in-situ data analysis (on the example of the Ukraine's pilot area)

PLATFORM SOLUTIONS: PONTOS WEBGIS

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The aim of creating the Web Geographic Information System (WebGIS) is to further enhance the user experience in terms of user accessibility, data aggregation and data visualisation. The WebGIS aids decision making, provides reliable datasets to scientists and engineers, engages active citizens and the broader public into coastal zone issues, promotes the distribution of information among coastal managers, stakeholders and the general public.

PONTOS WebGIS service interactively visualises the spatial data collected in the PONTOS project and organised in a common spatial infrastructure. The system combines the principles and tools of Geographic Information Systems (GIS) and aims to harmonise the large and multi-dimensional datasets collected within the Project.

WebGIS supports the visualisation of chlorophyll concentration, land use, salinity and temperature, hydrology, weather, and topography data.

Users of PONTOS WebGIS service can easily access, select, and visualise data on the four pilot areas obtained from the following sources:

- external data sources, like the Copernicus Hub for Sentinel satellite imagery, the Earth Explorer for other satellite data, the CMEMS and EMODnet repositories
- external data from national/regional databases
- data produced by the PONTOS Consortium within the frame of the project, to assess coastal erosion, water balance and uses, eutrophication, floating vegetation and forest changes
- geospatial data uploaded by end-users and stakeholders at the selected pilots.

Figure 14: Basemap modes available in PONTOS webGIS: Transport, Transport Dark, Watercolor, Satellite, and Terrain (on the example of the Greek pilot area

COPERNICUS

Copernicus is the European Union's Earth observation rogramme, looking at our planet and its environment to benefit all European citizens. It offers information services that draw from satellite Earth Observation and in-situ (non-space) data.

Implemented in partnership with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Océan the Copernicus Programme is managed by the European Commission.

Copernicus has been specifically designed to meet user requirements. Based on satellite and in situ observations, the Copernicus services deliver near-real-time data on a global level which can also be used for local and regional needs, to help us better understand our planet and sustainably manage the environment we live in.

Copernicus is served by a set of dedicated satellites (the Sentinel families) and contributing missions (existing commercial and public satellites). The Sentinel satellites are specifically designed to meet the needs of the Copernicus services and their users. Since the launch of Sentinel-1A in 2014, the European Union has been overseeing the construction of a constellation of 20 additional satellites, which is set to reach completion before 2030.

Copernicus also collects information from in situ systems such as ground stations, which deliver data acquired by a multitude of sensors on the ground, at sea or in the air.

SIX THEMATIC STREAMS OF COPERNICUS SERVICES

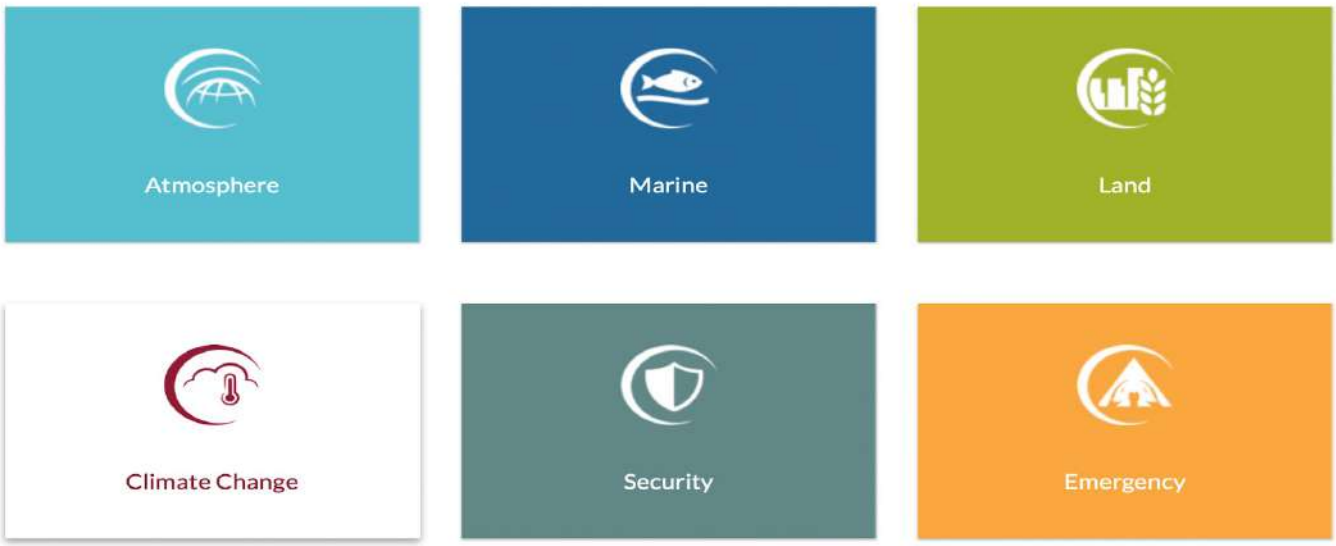

Photo credit: https://www.copernicus.eu/en/about-copernicus/copernicus-detail

FOR MORE INFORMATION
E-mail: pontos@aua.am
Website: pontos-eu.aua.am

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