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PONTOS VIRTUAL TRAINING MODULES

December 2022

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AUA ACOPIAN CENTER
for the ENVIRONMENT



CERTH
CENTRE FOR
RESEARCH & TECHNOLOGY
HELLAS



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ΠΑΝΕΠΙΣΤΗΜΙΟ
ΘΡΑΚΗΣ




GREEN
ALTERNATIVE





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Module 3

The Application of Earth Observation: Forest Cover Changes Assessments via PONTOS Platform



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Responsible Partner - Green Alternative

Supporting partner - CERTH

Slides and scripts prepared by - Eleftherios Katsikis, Ioannis Manakos, Giorgi Mikeladze, Irakli Matcharashvili

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This module is developed in the frames of the BSB 889 PONTOS Project



Project funded by
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LEARNING OBJECTIVES OF MODULE 3

Objective 1. To familiarize with the PONTOS Platform tools and services related to assessment of forest cover changes

Objective 2. To present methodology of assessment of forest cover changes in wetland forests (example of Kolkheti lowland forests)

Note: Georgian Pilot site – Kolkheti lowland is covered by humid forests, connected with wetlands and classified as a temperate rainforests. Various methods were tested to determine forest cover changes (both - deforestation and forest degradation) in this complex, multilayered forests. The second part of this module presents this methodology.



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MODULE STRUCTURE (draft)

Background knowledge:

- 1. Introduction**
- 2. Images download via Copernicus access hub**
- 3. Add layers to QGIS and preprocessing**
- 4. Phenology metrics map generation**

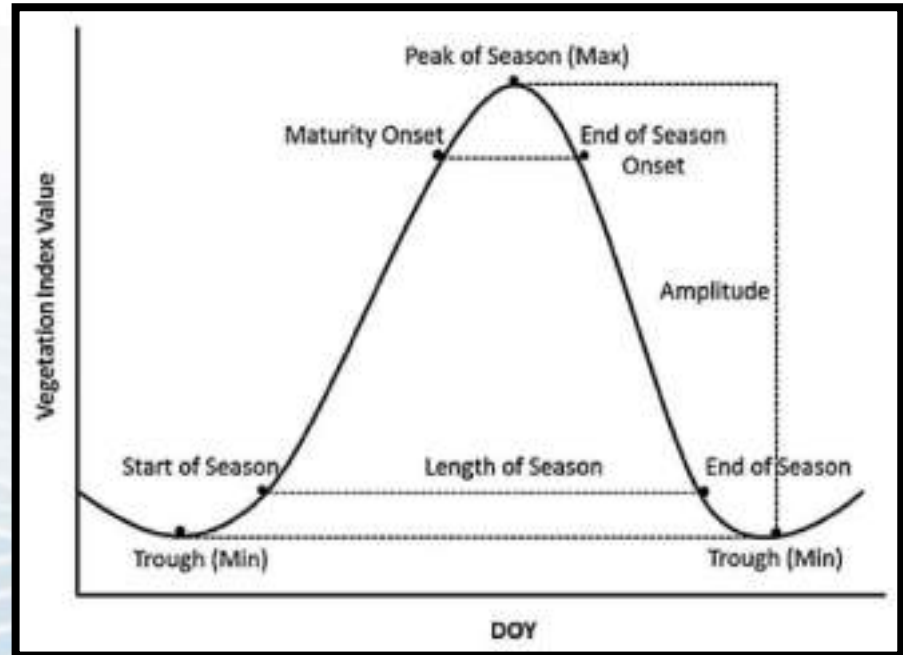
Phenology metrics map generation via PONTOS Web Application:

- 1. Register and login**
- 2. Dataset Viewer**
- 3. Phenology metrics map generation, visualization and output download**

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Phenology Metrics module2 utilizes a time-series NDVI images and aims to identify the phenological cycles of one year. The outputs are the day of the year, when the “greenup”, the “senescence” and the “max NDVI” in each phenological cycle occurred (see Figure 1):

- Start of Season (Greenup): The day of the year that identified as having a consistent upward trend in time series NDVI.
- End of Season (Senescence): The day of the year that identified as having a consistent downward trend in time series NDVI.
- Peak of Season (Max NDVI): The day of the year that the maximum NDVI exists



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1. Extract Phenology Metrics GeoTIFF

Steps:
1a. Open PONTOS Web
Application >
Services >
Existing Data >
Phenology Metrics



The screenshot shows the PONTOS Web Application interface. At the top, there is a navigation bar with the title "PONTOS Web Application" and links for Home, Services, Submit Feedback, and a user profile section showing "Logged in as: [username]" and a Logout button. Below the navigation bar, there is a central area with a large image of a map showing the Black Sea region. To the right of the map, there is a "Welcome to the Application" section with a brief description of the application's purpose and a list of features. Below this, there is an "Instructions" section with a list of steps for using the application. At the bottom, there is a footer with information about the project's funding and copyright.

PONTOS Web Application

Home Services Submit Feedback Logged in as: [username] Logout

Welcome to the Application

PONTOS aims to enhance transborder environmental monitoring across the region. This application is part of the PONTOS to manage airborne and in-situ data, and to provide a common platform for data exchange between users.

It offers:

- Spatiotemporal calculations
- Data visualization ability
- Extraction of descriptive statistics and generation of graphs
- In-situ and airborne data uploads
- NDVI from CO2 to GeoTIFF conversion
- Statistical data analysis

Instructions:

- All web browsers are supported. The system has been tested with Google Chrome, Mozilla Firefox and Opera.
- In order to use the applications, you should sign in or register, if data you want to have an account.
- From Menu > Services > Existing Data, you may select an analysis results, airborne and satellite data.
- From Menu > Services > Upload Data, you may upload and analyze your own in-situ, airborne and satellite data.


PONTOS project has received funding from the ENI CBC ARI Operational Program and Black Sea Basin 2014 – 2020 under Grant Agreement 505 899

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Steps.1. Extract Phenology Metrics GeoTIFF

1b. Select Pilot Site



The screenshot displays the PONTOS Web Application interface. At the top, there is a navigation bar with the text "PONTOS Web Application" on the left and "Home Services - Submit Feedback" on the right. On the far right of the navigation bar, it indicates "Logged in as: jefesto" and a "Logout" button. The main content area features a light-colored background with a grid of four circular map thumbnails. Each thumbnail is accompanied by a text label below it:

- Top-left: GR - Nestos River & River Delta
- Top-right: AM - Sevan Lake & Sevan Lake Basin
- Bottom-left: GE - Rioni River Delta & Kolikheti National Park
- Bottom-right: UA - Dniester River Delta area & adjacent estuaries

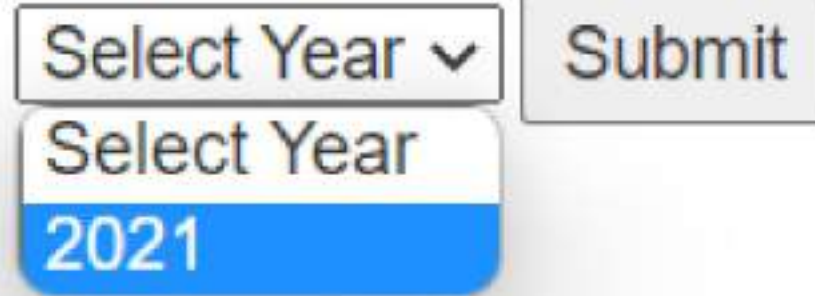
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Steps.1. Extract Phenology Metrics GeoTIFF

1c. Select year & submit



Select Year ▾ Submit



Select Year ▾ Submit

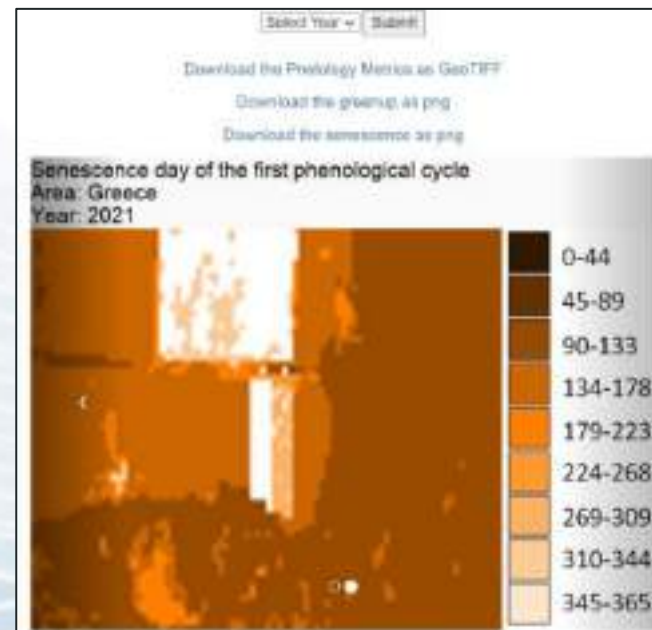
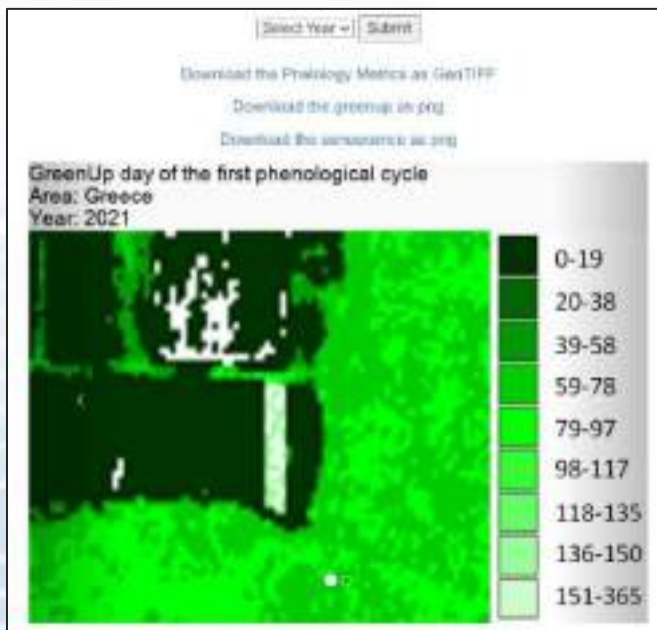
Select Year

2021

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Steps.1. Extract Phenology Metrics GeoTIFF

1d. Download the Phenology Metrics as GeoTIFF



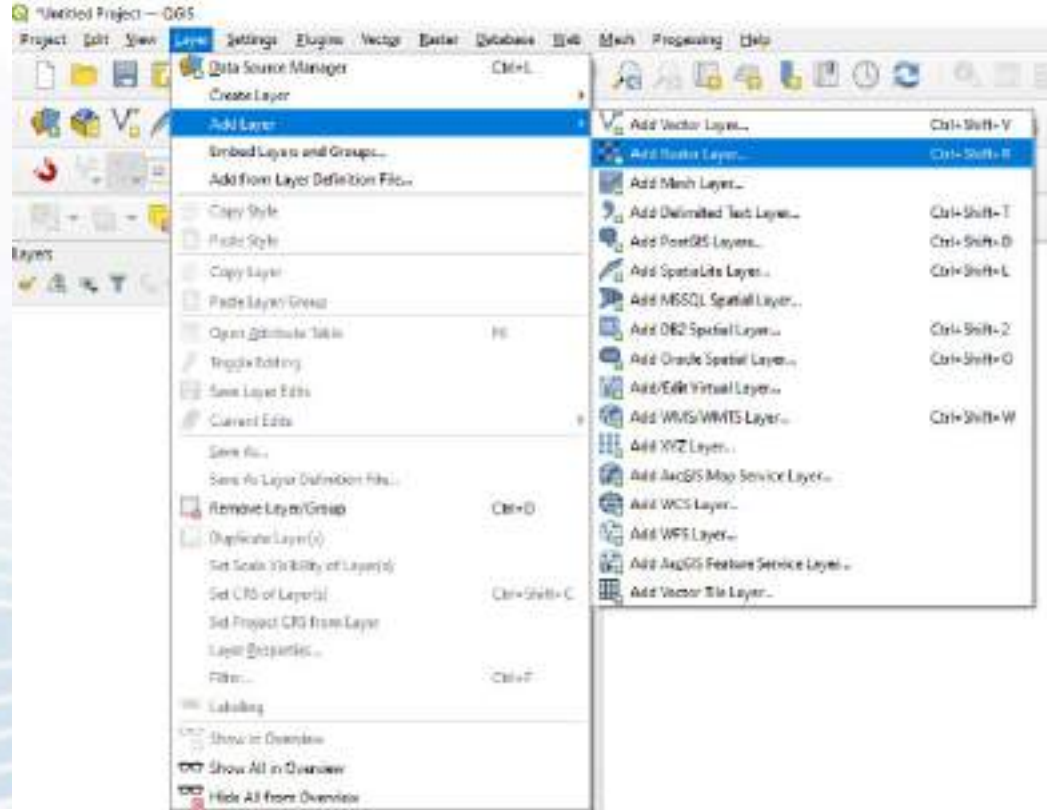


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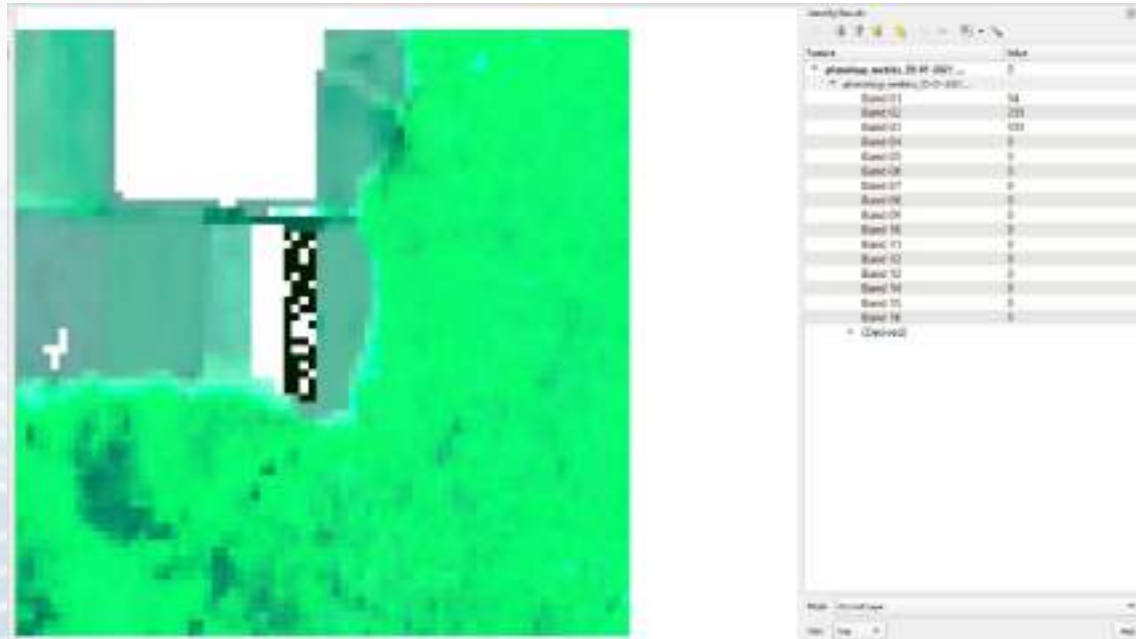
2. Import Phenology Metrics GeoTIFF in QGIS software



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3. Phenology Metrics results' interpretation

Phenology Metrics GeoTIFF output consists of multiple layers. For each one of the detected NDVI peaks, 3 consecutive layers are recorded sequentially, i.e. for the first NDVI peak the first 3 layers, for the next NDVI peak the next 3 layers, and so on. Pixel values denote the distance in days from the starting date, that represent: a) Day at which greenup takes place; b) Day at which senescence takes place; c) Day with highest NDVI value. Finally, there is one last layer that denotes per pixel (i.e. pixel value) the total number of the phenological cycles that have been detected within the set date range.





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Assessment of forest cover changes in Kolkheti lowlands

*Responsible Partner: Green Alternative
Assessment prepared by Giorgi Mikeladze*





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The Purpose of the Assessment

- To develop and test a satellite-based model of forest change in Kolkheta that would reveal the extent of both deforestation and forest degradation.
- An important condition of the study was to use free, multispectral images of the Sentinel-2 satellite using open source applications



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Limitations of the Assessment

- The forest change model, based on the objectives of the project, was tested only in the lowland areas of Kolkheti where satellite imagery was not affected by spectral distortion caused by mountain shadows.
- At this stage, the modeling methodology is applicable only for lowland areas
- In future it will be possible to create a universal model that will work for mountainous areas where the forest vegetation is different, and the slopes are steep and rugged



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Description of the Pilot Area

- Kolkheti has a warm temperate climate. Humid Kolkheti lowland is covered by endemic alder forests and the wetlands connected to it (including unique percolating bogs) belonging to the tertiary flora of Kolkhuri refugium and classified as temperate rainforests.
- Peatland are closely connected with the forests of the Kolkheti lowland, forming a unified wetland system. In the forest, common alder (*Alnus glutinosa*) grows directly on the swamp, mainly on the wetland territories of *Sphagnum*, sedge and mixed grasses. In addition to alder, other plants can be found in forest swamps: *Pterocarya pterocarpa*, *Frangula alnus*, *Carpinus caucasica*, *Ficus carica*, *Quercus hartwissiana* (Ketskhoverli 1959).

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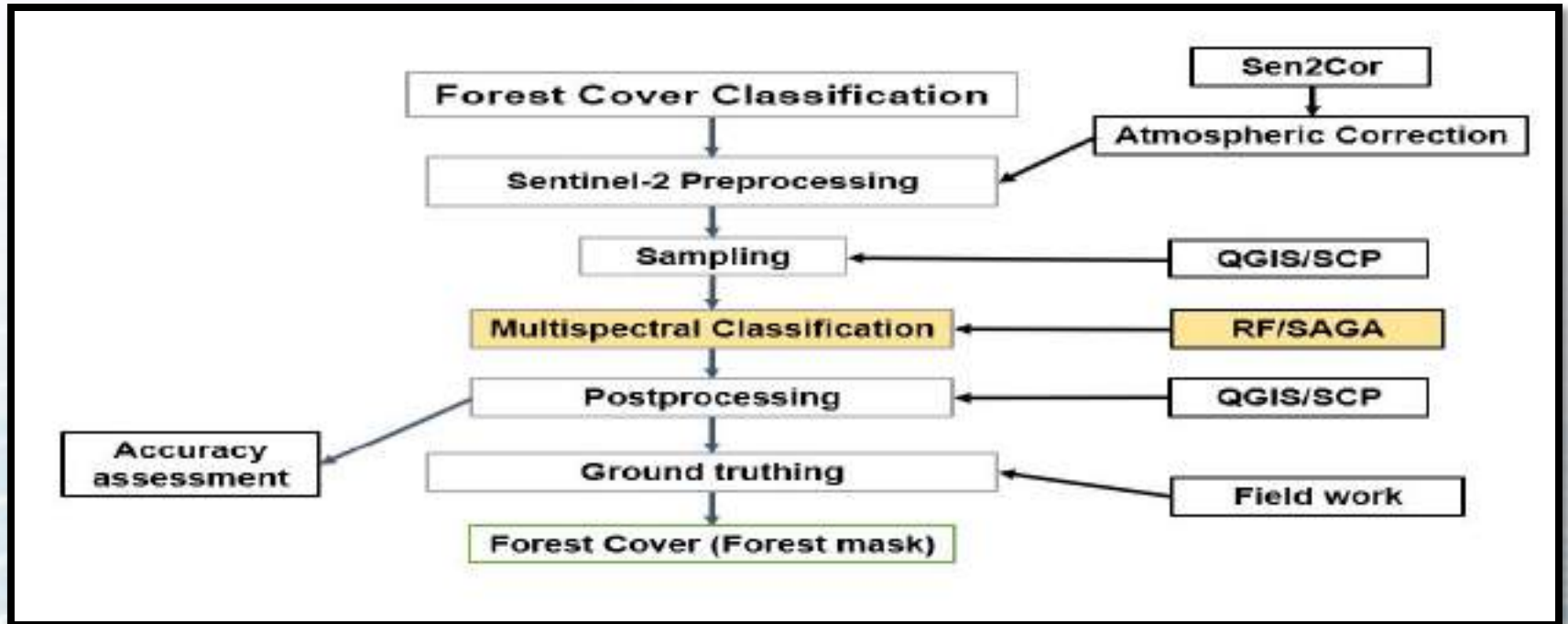
Status of the Area

- Kolkheti National Park (founded in 1999)
- Ramsar site (1996)
- Emerald site (2018)
- UNESCO World Heritage List (2021)



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Workflow for forest cover delineation 2016-2021





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Pre-processing of S2 Products

Two methods were tested:

- 1) Forest cover multispectral classification
- 2) Multivariate Alteration Detection.

- Orthorectified multispectral Sentinel-2A images with 13 spectral bands and a spatial resolution of 10, 20, 60 meters were used for the analysis of the changes.
- Images were downloaded from the Copernicus data portal <https://scihub.copernicus.eu/dhus/#/home> For comparative analysis, the spectral bands of the September 2016 and 2021 images were selected.
- In order to improve the quality of interpretation of satellite images for the spectral bands, an atmospheric correction was performed.

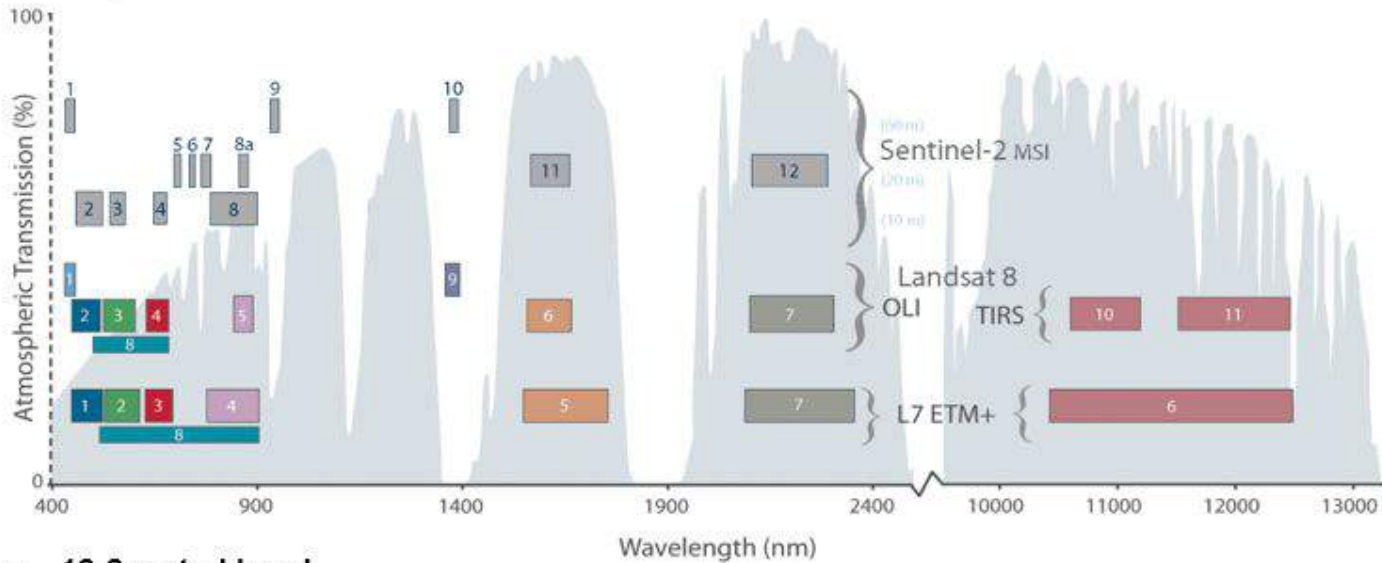


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Common borders. Common solutions. Image Selection Sentinel-2

Comparison of Landsat 7 and 8 bands with Sentinel-2



- 12 Spectral band
- 10, 20-meter spatial resolution

Advantages of Sentinel-2

- Free
- Spatial resolution 10 m.
- More spectral bands than Landsat



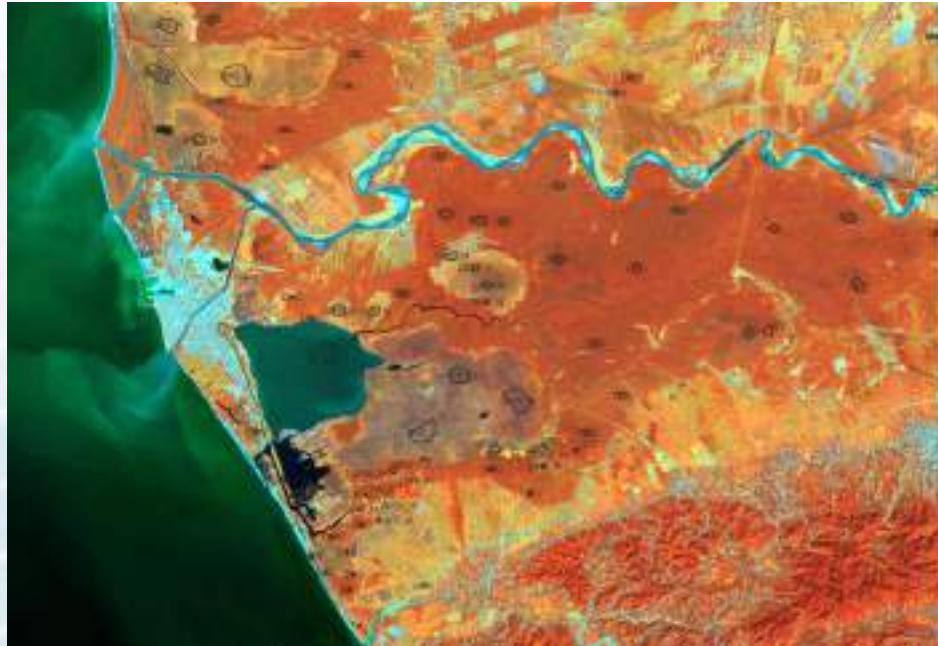
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Pre-processing of S2 Products

- The Sen2Cor tool, which is a Sentinel-2 Level 2A generation and formatting processor, was used for image atmospheric correction.
- The reflectance image of the lower 2A level of the atmosphere was developed based on the following parameters: solar zenith angle, sensor viewing angle, relative azimuth angle, surface height above sea level, visibility and type of aerosols.
- Parameters were obtained from image metadata, except for altitude and aerosol types, which were determined by specific location.
- Thus, Sentinel-2 channels were created and prepared for analysis.

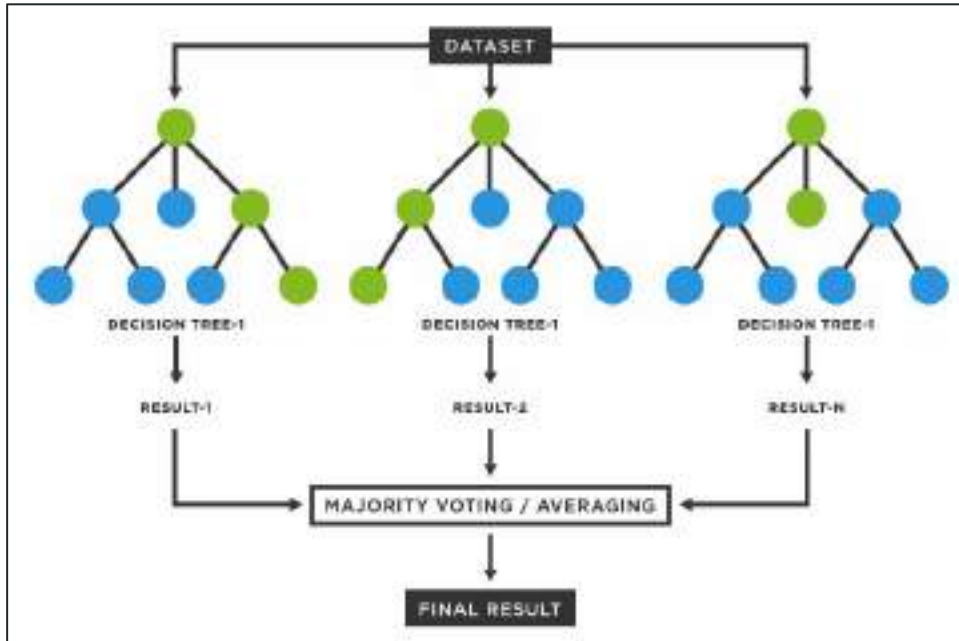
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Sample collection for Image classification



- To train the algorithm, training and validation data were created.
- Samples were made by photo-interpretation using very high-resolution ancillary images (Google imagery, World View 2, World View 3).
- 124 training plots were created with a total area of 1439.71 hectares.

Classification algorithm



<https://www.tibco.com/reference-center/what-is-a-random-forest>

Random forest is a supervised machine learning algorithm. It is one of the most used algorithms due to its accuracy, simplicity, and flexibility.

- Image classification was performed using the Random Forest (RF) algorithm of the SAGA-System for Automated Geoscientific Analyses software.
- Each tree in the Random Forest predicts a certain class, and the class characterized by the maximum score becomes the determinant of the model.



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Creating Forest Mask in the Pilot Area

- The training data was categorized into 7 land cover classes: bare ground, coniferous forest, deciduous forest, grass cover, water bodies (lakes and rivers). Agricultural lands were grouped either into class of the grass cover or bare land.
- Classification was carried out in two sets, 2016 and 2021, of spectral channels, where the composition of each set was determined by the following channels (B02, B03, B04, B05, B06, B07, B08, B8A, B11, B12).
- The training data was selected on the basis of the principle that the sample area equally reflected the state of both 2016 and 2021. Samples were not taken in areas where the land cover category changed over a given time period, for example: forest/grass cover; arable land/forest).



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Creating Forest Mask in the Pilot Area

- Two classified classification images were created, 7 classes each, of which in post-processing only two - forest and non-forest area classes were highlighted using classification editing.
- To improve the data, forest stand areas were filtered into small clusters of grouped pixels not exceeding 0.5 hectares, as spectral classification errors occurred in smaller forest areas. As a result, we got clearer and cartographically readable data.

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Classification Accuracy

Confusion matrix		Classified values			User accuracy	Total class area (km ²)	Wi
		1 (Not Forest)	2 (Forest)	Total			
Thematic raster	1	227	4	241	0.9234	648.07	0.607
classes	1	6	349	355	0.9612	418.931	0.293
	total	243	353	596		3067.00	
	Producer accuracy	0.97531	0.97386		0.9747		
Overall Accuracy:							
							0.974

Confusion matrix		Classified values			User accuracy	Total class area (km ²)	Wi
		1 (Not Forest)	2 (Forest)	Total			
Thematic raster	1	235	30	245	0.9591	645.841	0.605
classes	1	7	344	351	0.9636	421.180	0.294
	total	242	354	596		3067.00	
	Producer accuracy	0.97107	0.93506		0.9570		
Overall Accuracy:							
							0.957

- Accuracy was assessed with 396-point validation data which were identified using very high-resolution satellite imagery (Llano 2022),
- The quantity of validation data was determined by the area of classification classes (Olofsson et al. 2013).
- The statistical accuracy of the classification was reflected using an confusion matrix where the overall accuracy for the 2016 image was 0.974 and 0.957 for the 2021 image

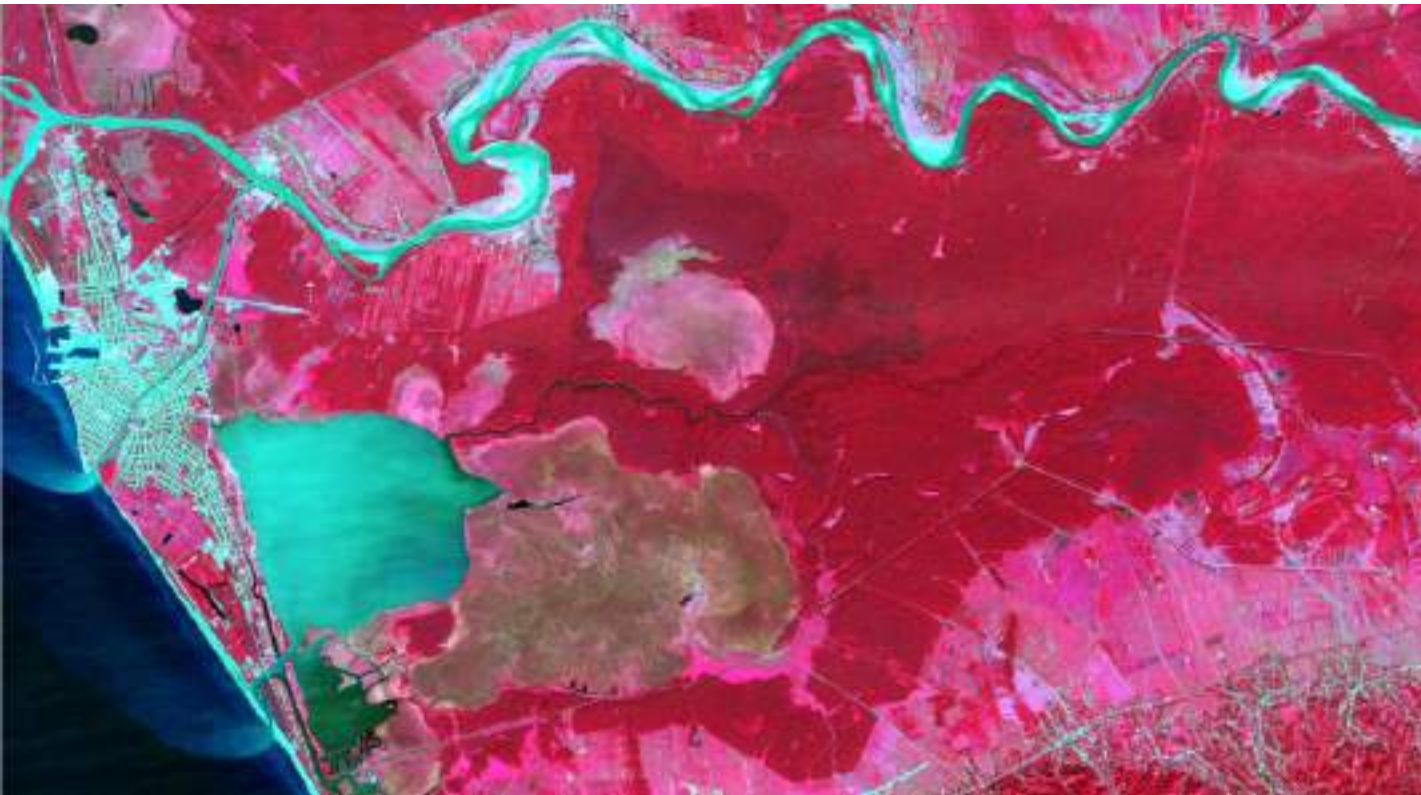


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**Forest masks:
2016-2021 overlap
analysis**

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**Forest masks:
2016-2021
overlap analysis**

Forest Mask that
was used to
distinguish forest
from non-forest
during change
detection
processing



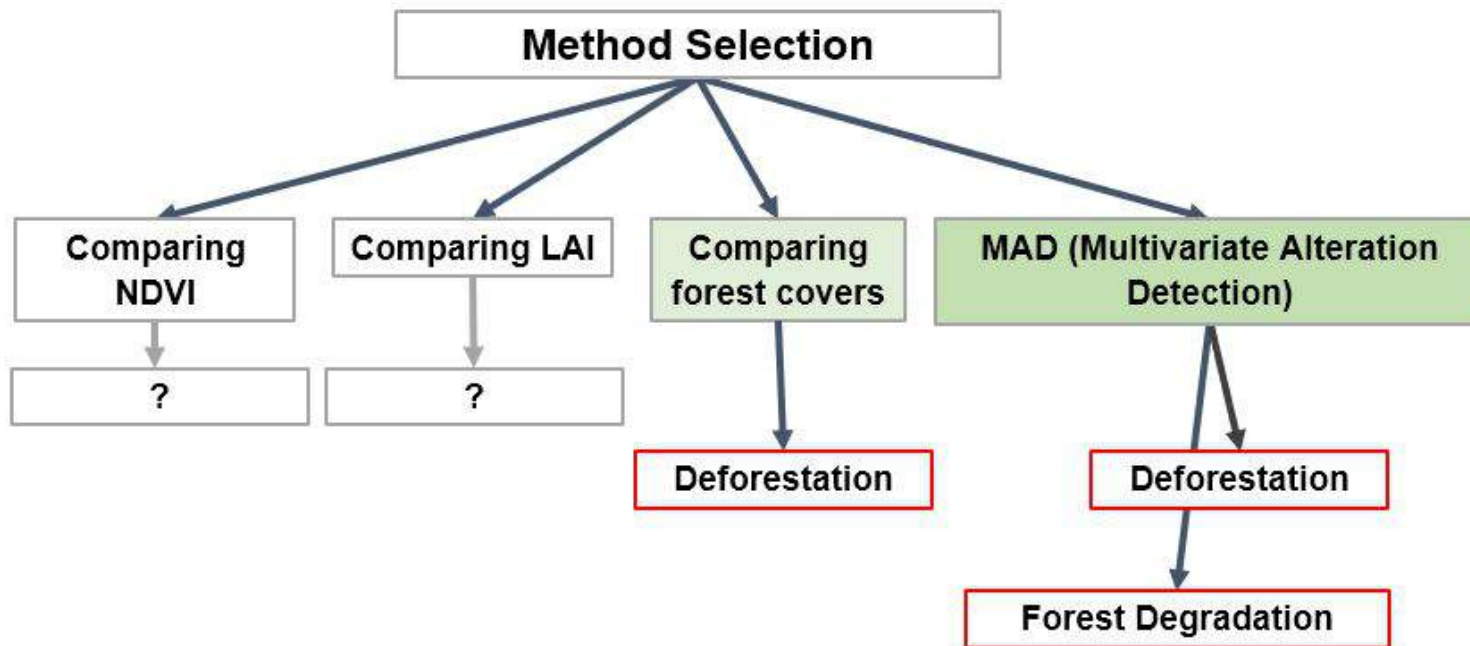
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Method Selection

Multivariate Alteration Detection

- 4 methods were tested for determining changes in the forest; only one of them fully reflected the processes taking place in the forest.
- Models based on NDVI and LAI images did not work because they did not show the changes in the complex, multilayered forests.
- Comparing 2016 and 2021 forest cover shows only net loss of trees due to deforestation (not forest degradation).
- Best solution - Multivariate Alteration Detection (MAD) algorithm: identification of deforestation and forest degradation

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Multivariate Alteration Detection



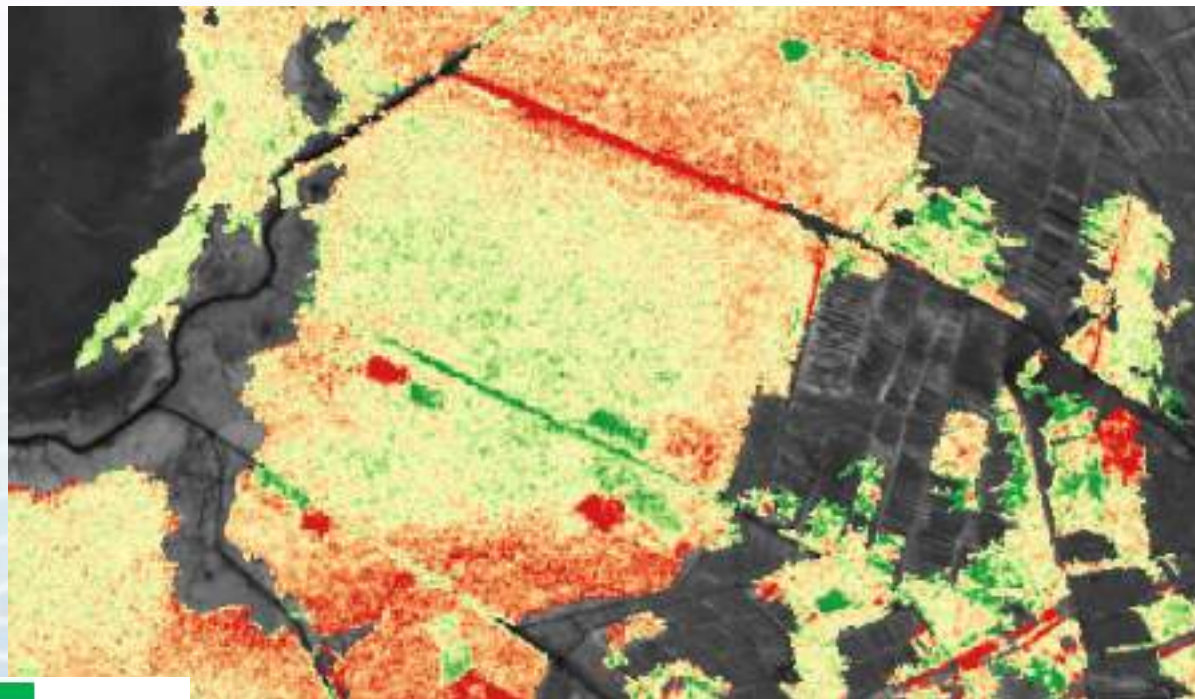
MAD algorithm performs change detection between two multispectral images; compares all bands with all bands.

MAD algorithm is used for accurate detection of spatial changes in coherent patterns in satellite images.

The change detection process was performed using Orfeo ToolBox (OTB) 8.0. Comparable images from both 2016 and 2021 were compiled with a set of full spectral bands (B02, B03, B04, B05, B06, B07, B08, B8A, B11, B12).

As a result, a multi-channel composite image reflecting the changes that occurred in 2016-2021 was received.

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Tree Loss

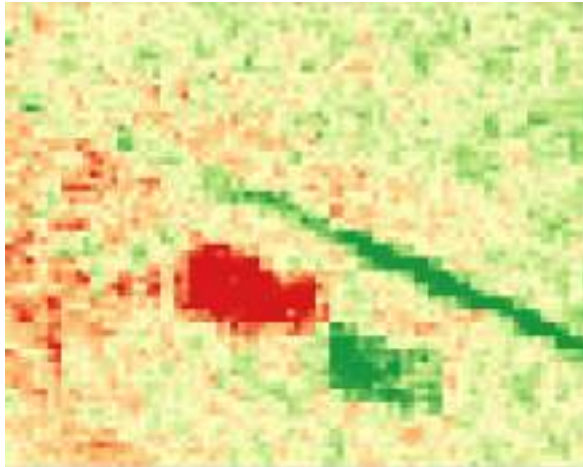
Tree Gain



WV 2016



WV 2021



WV 2016 and 2021 images taken near Nigvziani (PSh. RGB 6,7,5) above, and the change model obtained by the MAD algorithm of the same area (below) where red pixels show tree loss and green pixels gain.

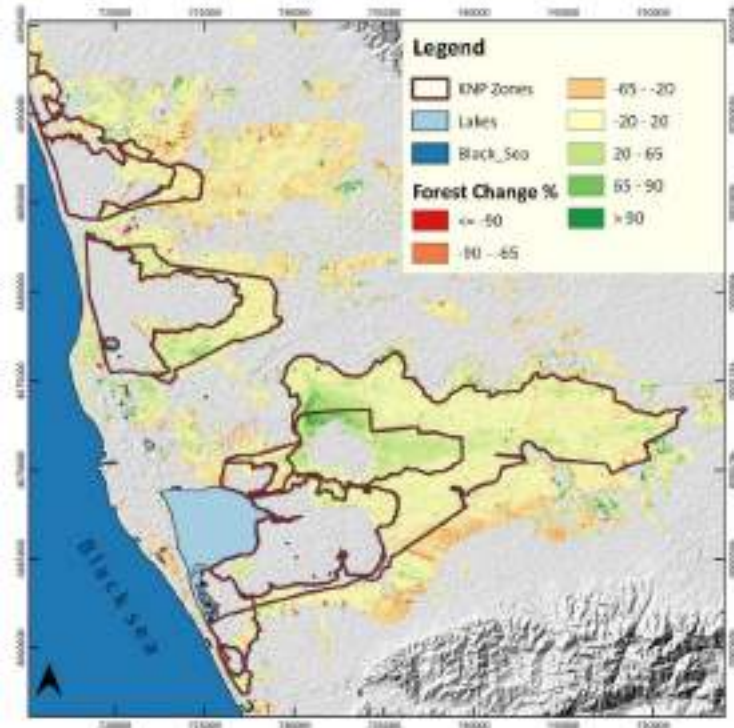
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Validation



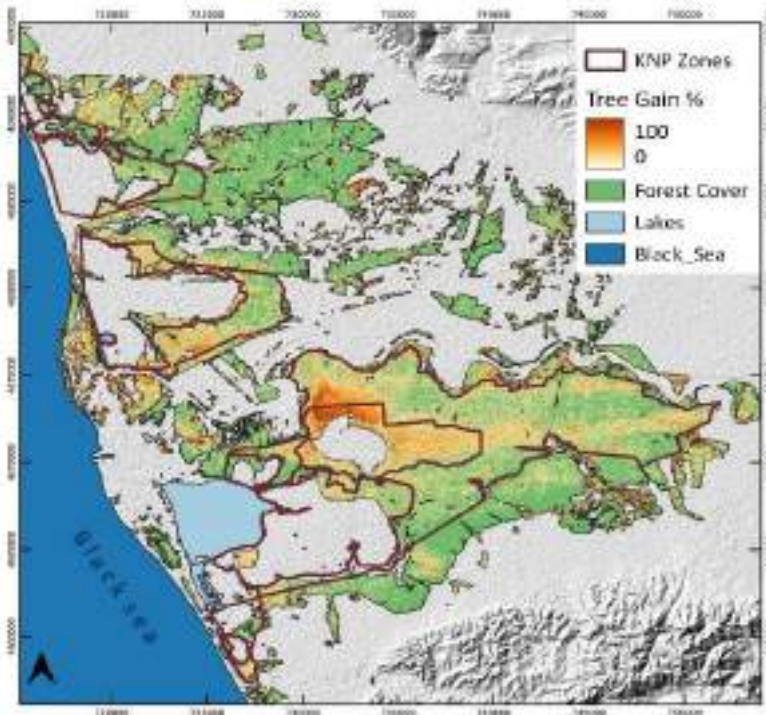
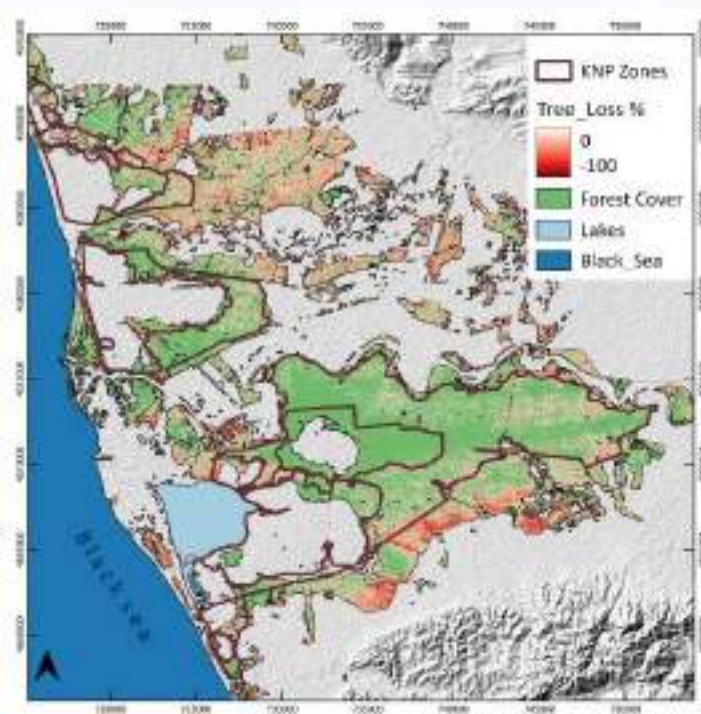
Photos taken near Nigvziani. Sept. 2022. Left: tree loss area, right: tree gain (recovery) area

Common borders. Common solutions. Results



- Forest change is mainly related to human activity and is quite intense in outside Kolkheti National Park
- Forest change is more related to forest degradation than to deforestation, as wood extraction by the population is largely carried out by selective cuts
- In the study area not only degradation, but also afforestation is observed, which, in our opinion, is related to the change of climate and hydrological regimes, which leads to an increase in the biomass of trees

Common borders. Common solutions. Multivariate Alteration Detection



- Forest loss/degradation mainly outside protected areas, close to settlements.



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Copernicus Assisted Environmental Monitoring across the Black Sea Basin - PONTOS
December 2022

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