GOSTEAM Summer School – Workshop II

Title: Ride like the wind: selecting an Offshore Wind Farm sites

Wednesday 07/07/2021

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Cross-cutting geospatial & environmental STEAM instruments for the new generation

Project Number - 2020-1-SE01-KA201-077972

Co-funded by the Erasmus+ Programme of the European Union

Metadata

Age and language of the students: 15 – 18, Greek

Number of Lessons – Duration (per lesson): 2 Lessons (45 minutes each)

Subjects: Spatial Modelling, Multi-Criteria Analysis, Overlay, Renewable Energy, Offshore Wind Farms

Curriculum and country:

Country: Greece | Class: High School | Grade: 2nd grade

Topic: Environment, Mathematics, Geography

Objectives (Max 100 words): Understand multi–objectivity in spatial analysis, Identify spatial patterns, Solve spatial problem for location-allocation procedures

Materials and Tools (Max 100 words): Spatial data acquisition, GIS application (QGIS – Open Source)

Metadata

Spatial concepts, skills and abilities:

Which spatial concepts and skills are covered by the activity?

Overlay, Buffer, Map, Surface, Map Projection

Spatial skills:

- Select an ideal location based on the given spatial features,
- Visualization,
- Delineation of spatial regions/ zones based on given features/properties

Geospatial concepts and spatial abilities documentation (see Section 3.2):
http://www.gosteam.eu/wp-content/uploads/2021/05/GOSTEAM_IO1_A1_final.pdf

Description of the activity in detail

Short Description (Max 500 words):

Spatial Multi-Criteria Decision-Making (MCDM) is used for decisions with a geographical element, most often in site-prospecting and risk assessment processes where multiple factors need to be considered. Some examples incorporate:

- Location-allocation problems
- Land use management
- Proximity to human infrastructures
- Environmentally sensitive areas and Ecological Risk Assessment
- Disaster Risk Management

What to do?

During this activity, students will get familiar with some of the procedures described in order to identify suitable areas for Offshore Wind Farms using different criteria, reclassification rules and overlay operations.

Keywords (Up to 5):

Multi-criteria analysis, Spatial Modelling, Renewable Energy Resources, Offshore Wind Farms

1. Questions eliciting activities

Provoke curiosity

Usually, the most effective way to provoke students' curiosity is by presenting an exciting video or a series of photos

https://www.youtube.com/watch?v=HqCVgRbPQcg

(Offshore Wind Farms characteristics)

Propose preliminary explanations or hypotheses

It is best to ask these questions in the context of a relative discussion.

Have you ever seen wind turbines at the sea?

Why we select the marine environment instead of onshore sites?

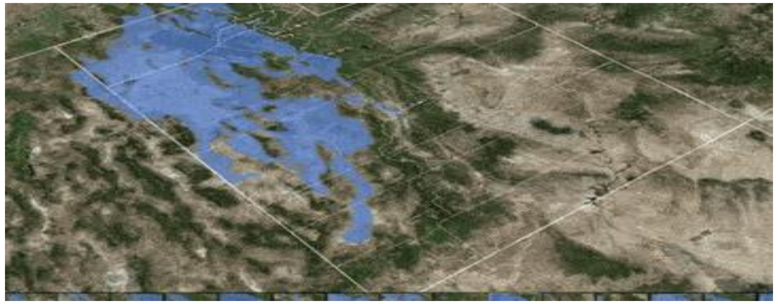
How many criteria are needed to be converged in order to allocate suitable areas for RES deployment?

What spatial data are needed and how can spatial modelling improve site-selection procedures at the preliminary assessment steps?

2. Active investigation

Plan and conduct simple investigation

This is the phase in which students are being prepared for the subsequent phase of evidence gathering during observation.



During this step, students may collect evidence regarding multi-criteria decision making and Offshore Wind Farms site-prospecting.

What criteria are considered as the most important?

What type of data are needed? How can we analyze these data?

What tools are used during spatial analysis procedures?

Which are the expected outcomes?

2. Active investigation

Provide students with relevant information and resources and the first cycle of discussion begins:

Available data:

Wind, Elevation and Bathymetry

Land-use, Water, Population

Global spatial data (multiple topics)

National and Global data providers (multiple topics)

Available tools for MCDM:

QGIS

ArcGIS (Schools License)

Need to Learn:

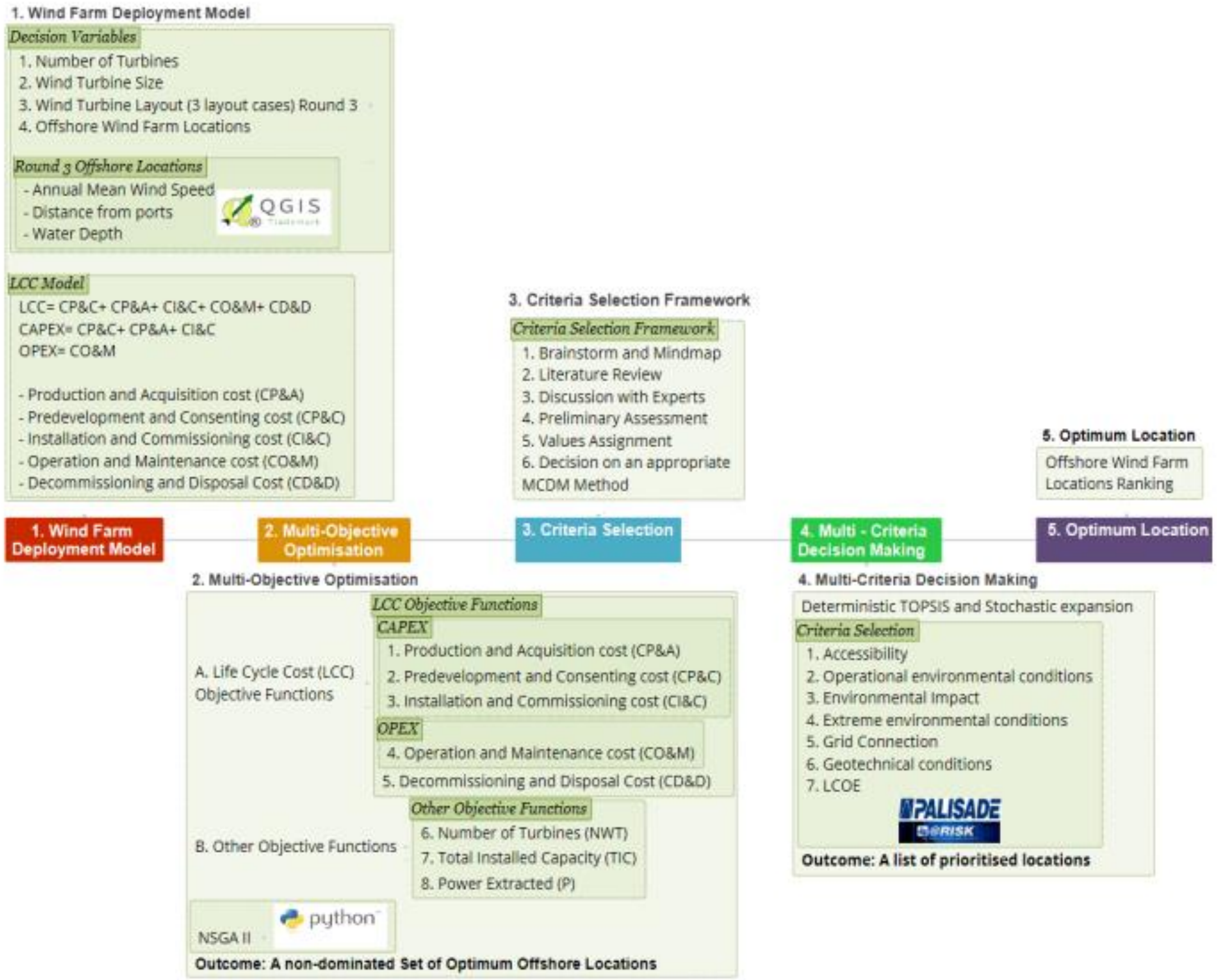
Offshore Wind Farms Multi-Criteria Decision-Making Criteria and Steps (see Figs.1 and 7)

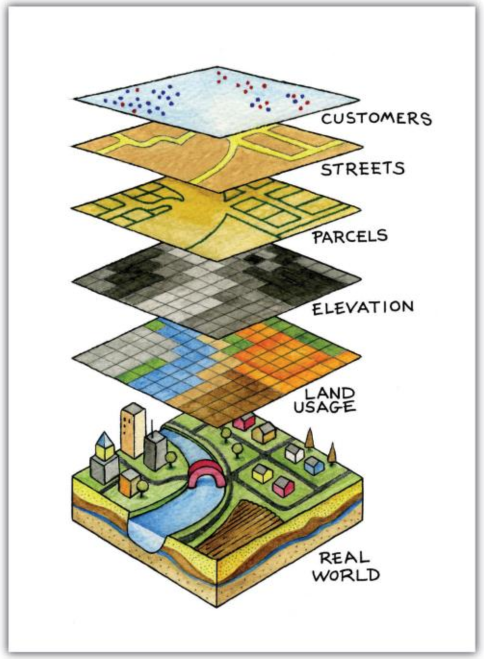
Offshore Wind Farm siting criteria (see Table 1)

Offshore Wind Farm siting criteria (see Section 3 and Tables 1 - 2)

Offshore and Onshore Wind Farm siting criteria review (see Tables 2-3)

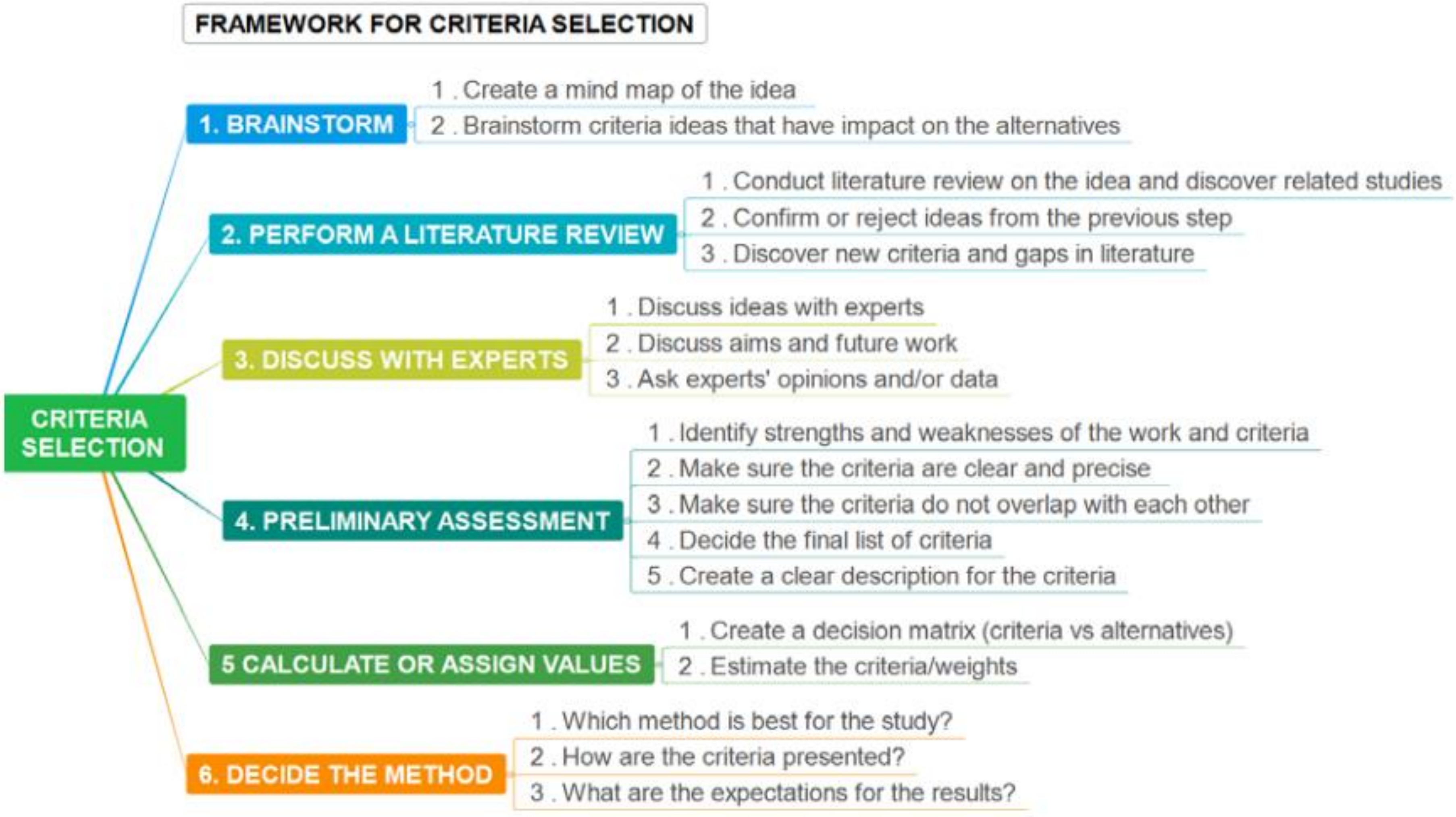
2. Active investigation (Examples)





Models and Digital Apps that are used as also, the logical steps to be followed in order to solve multi-criteria site-prospecting problems.

2. Active investigation (Examples)



How we select our criteria defining the problem?

Chapter Break (Any Questions?)

3. Creation

Gather evidence from observation

It is recommended to introduce group work at this stage. Guide the teachers to divide students in groups, each of which will be facilitated by the teacher to formulate and to evaluate explanations to the scientific questions based on the collected evidence.

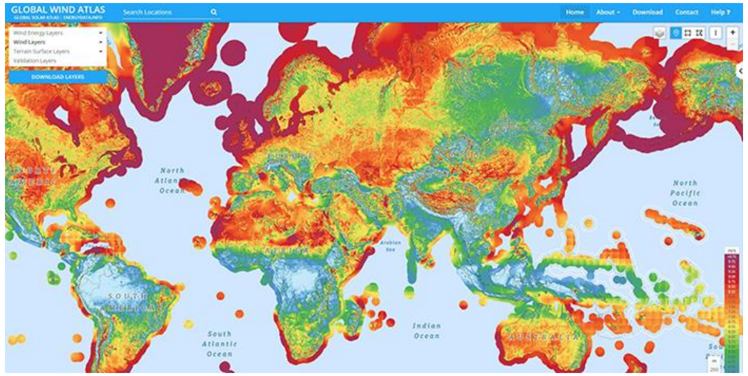
Activity planning

Before the beginning of the activity, student are separated to groups of 2. One of the group members is responsible for the tasks' flowchart implementation, data acquisition and the appropriate steps to be followed during the activity. The second member is responsible for the results validation and communication, including the final report and the maps preparation.

Preparative steps

1. Download QGIS 3.18.1 version

2. Visit Global Wind Atlas website and download wind and elevation/bathymetry data



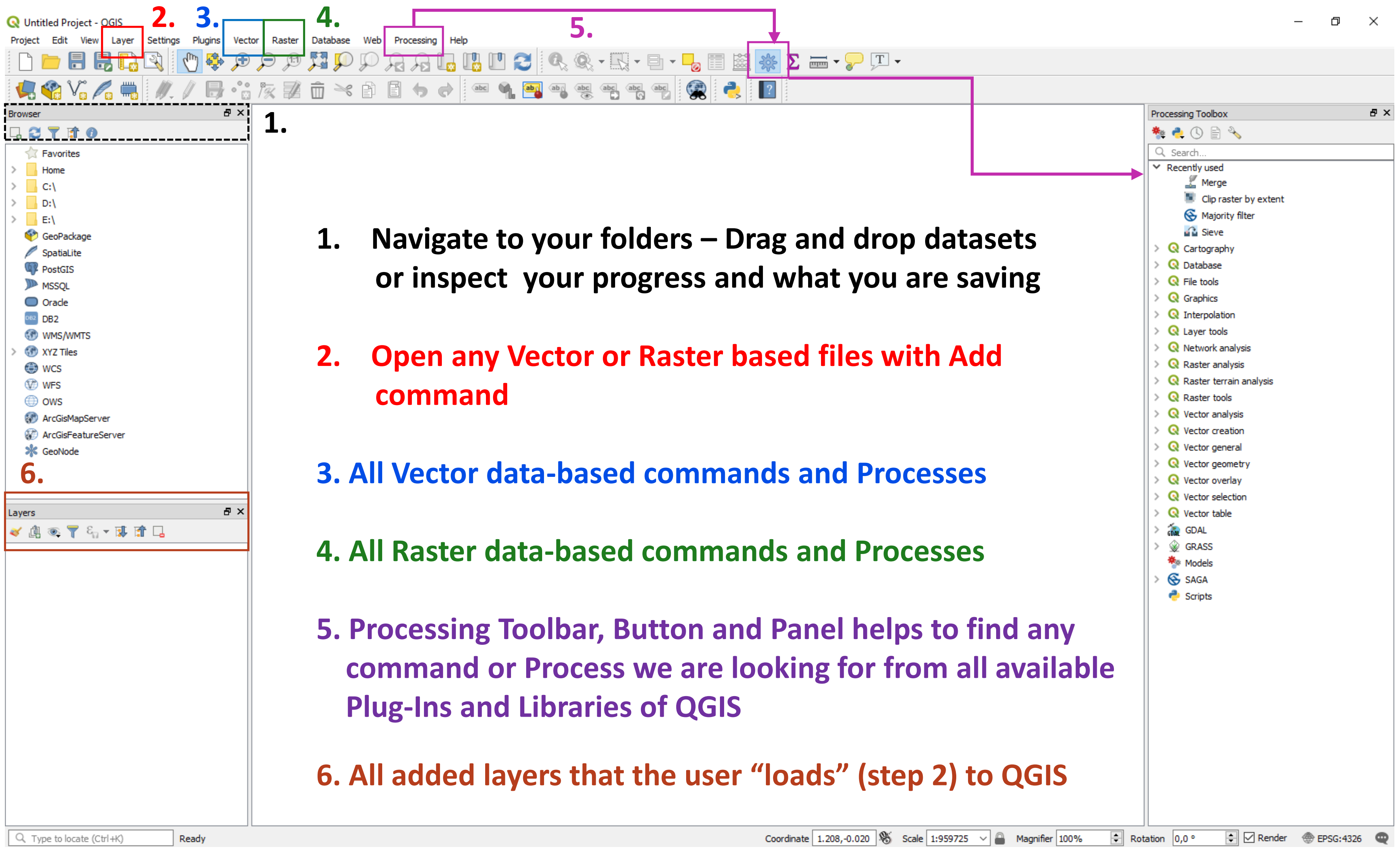
3. Download environmental data (NATURA areas)

Creation – Part 1 (Open QGIS)

QGIS interface

Vector and Raster data:

One key concept that the students must deeply understand is how we “translate” and represent spatial information to spatial data



1. Navigate to your folders – Drag and drop datasets or inspect your progress and what you are saving

2. Open any Vector or Raster based files with Add command

3. All Vector data-based commands and Processes

4. All Raster data-based commands and Processes

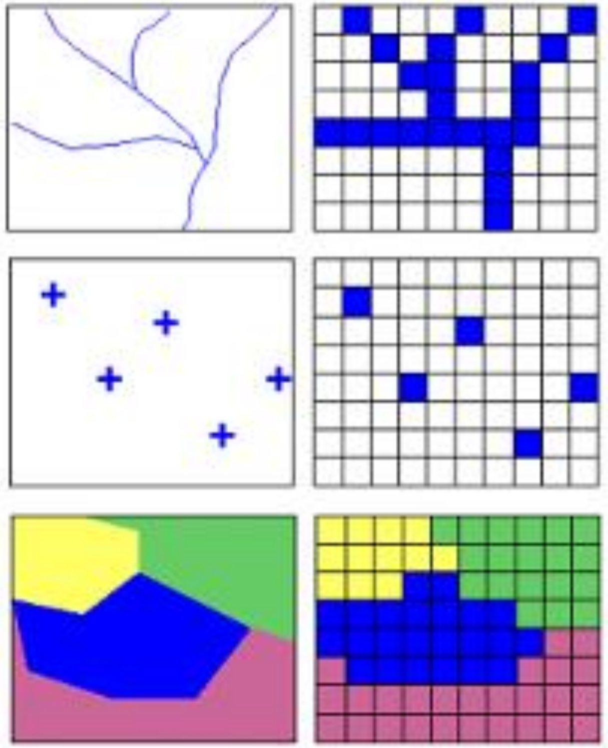
5. Processing Toolbar, Button and Panel helps to find any command or Process we are looking for from all available Plug-Ins and Libraries of QGIS

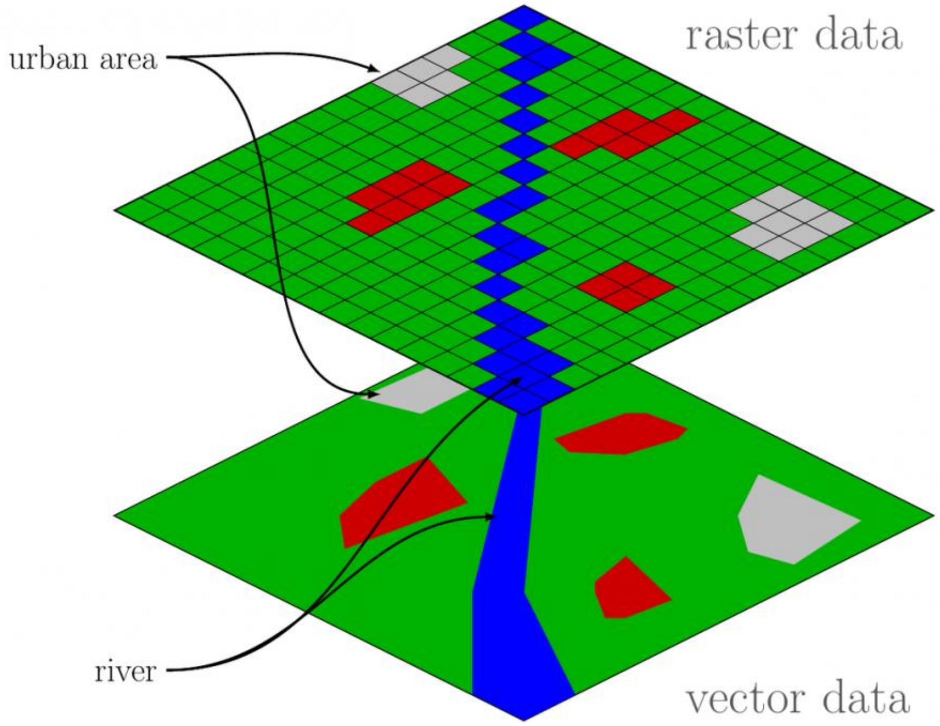
6. All added layers that the user “loads” (step 2) to QGIS

Creation – Part 1 (Open QGIS)

Vector and Raster data:

One key concept that the students must deeply understand is how we "translate" and represent spatial information to spatial data

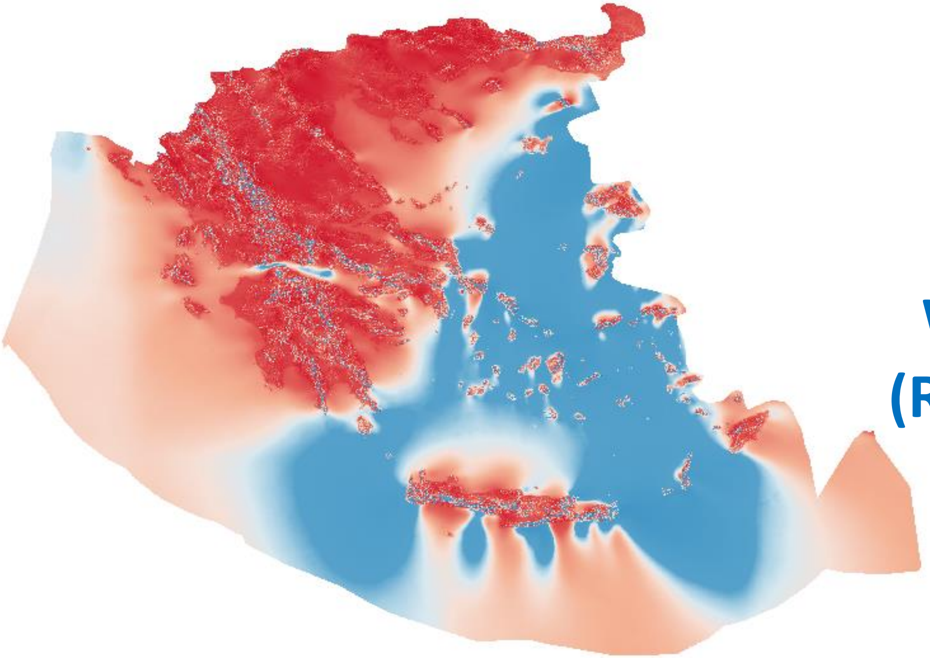




WHY THIS IS IMPORTANT?

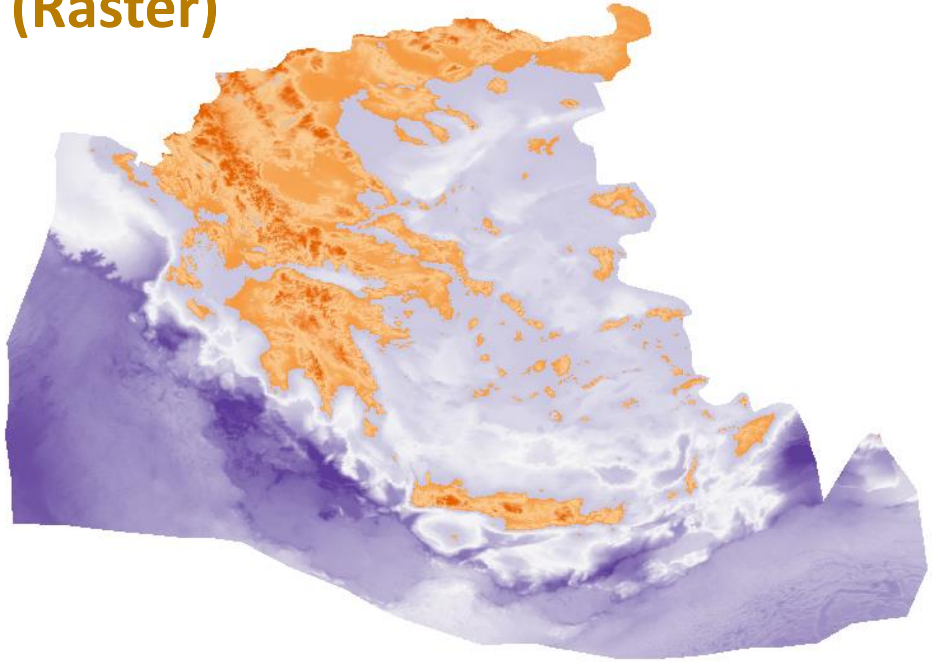
In order to understand spatial data structures, models' data inputs, data volume, spatial resolution, scale, computational efficiency and spatial data, big data manipulation-processing-visualization etc.

Creation – Part 1 (Load data)

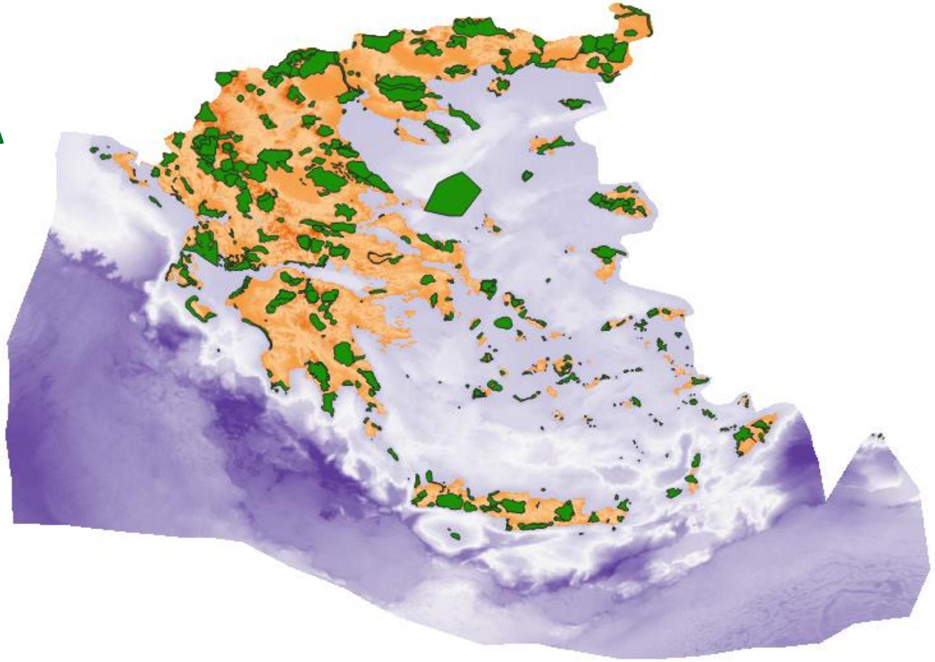


Wind (Raster)

Elevation – Bathymetry (Raster)



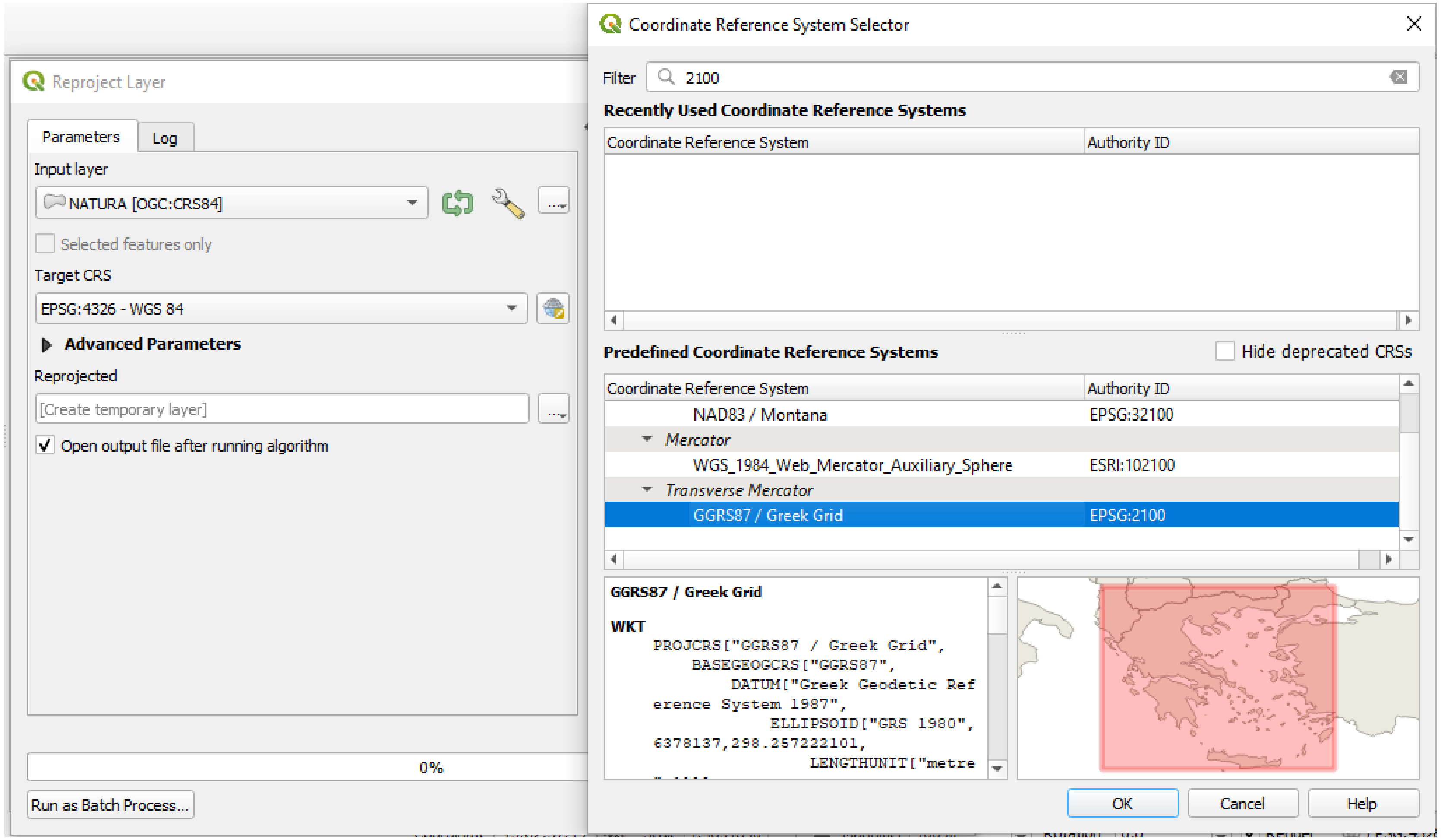
NATURA (Vector)



Creation – Part 1 (Coordinate Systems - Reproject)

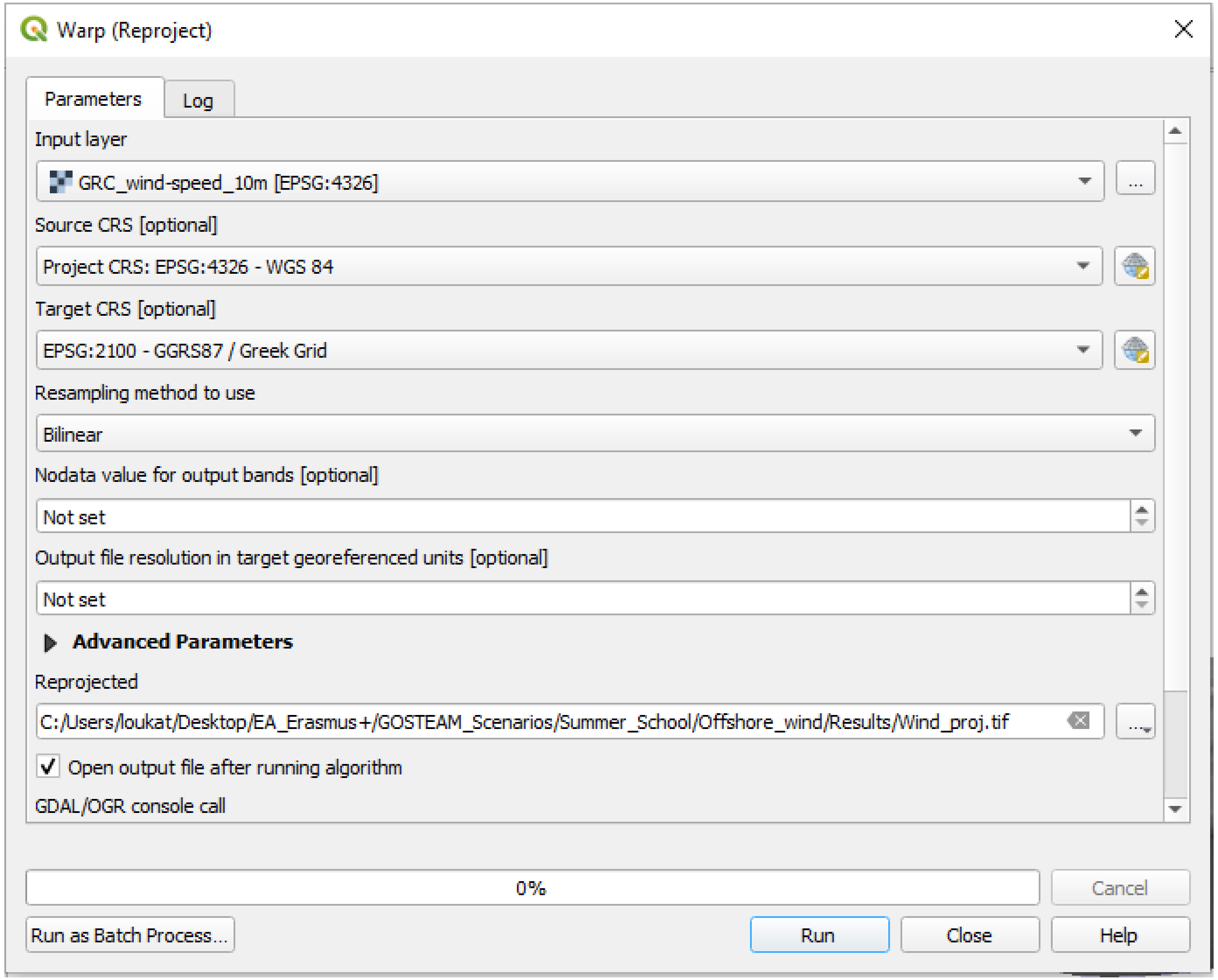
A first discussion may begin focusing on the coordinate systems, geographic transformations and projections! (Geography and Mathematics)

Some of the spatial data acquired may have different coordinate system (Geographic or Projected. But what does it mean?). It is crucial to transform all data to a common coordinate system.



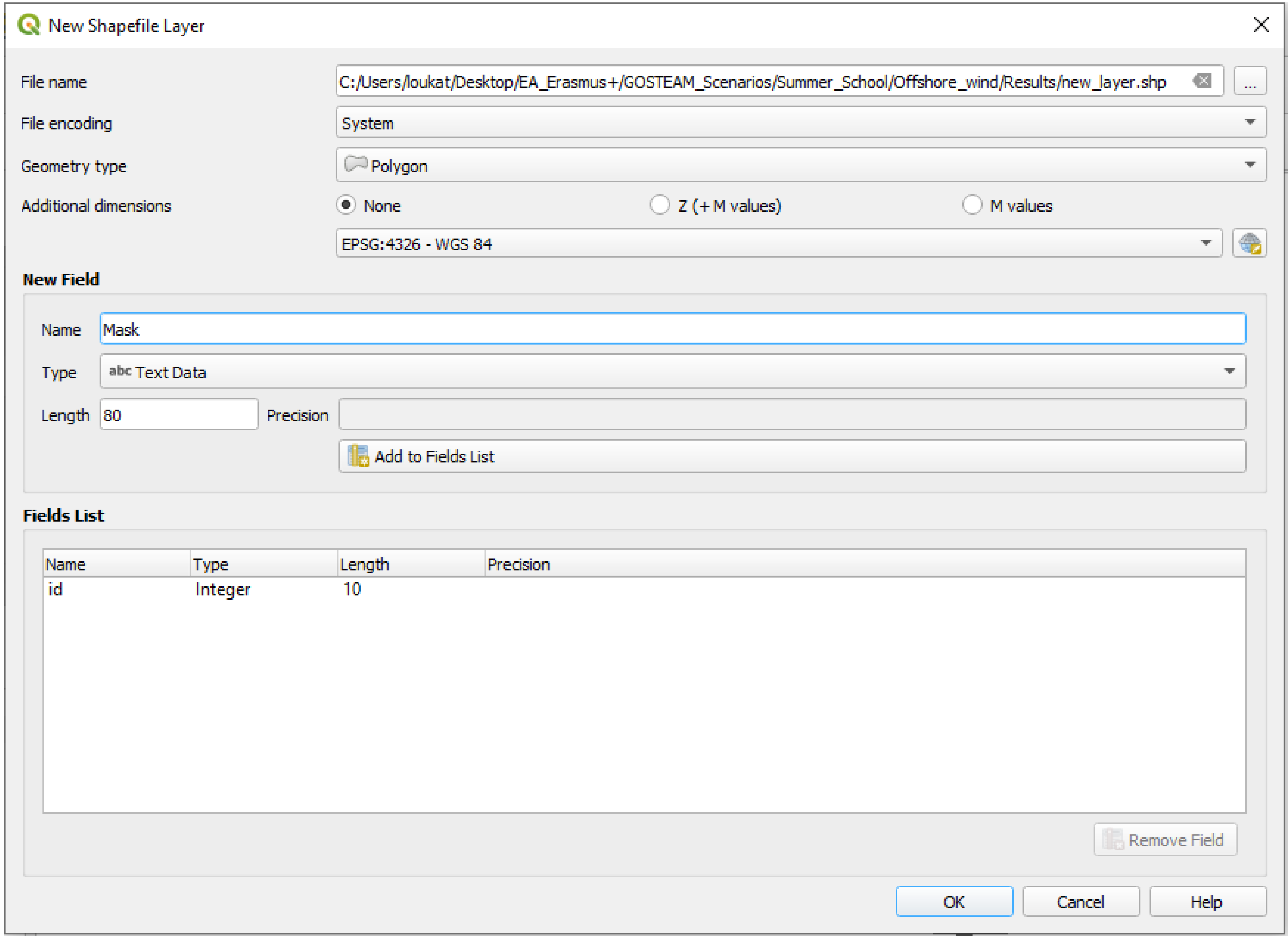
Creation – Part 1 (Coordinate Systems - Reproject)

- Most of the times, we select coordinate systems based on spatial scale we work (i.e. national) and the agent that we will deliver our results (i.e. European Union, Greek Ministry etc.)
- Considering that we work for the Greek Ministry, all available data will be reprojected to the Hellenic Geodetic Reference System (GGRS87 - EPSG:2100)



Creation – Part 2 (Create Mask Layer)

Next step consists of cutting/clipping a specific area of interest; thus, we must create a new empty shapefile layer and create a polygon mask!

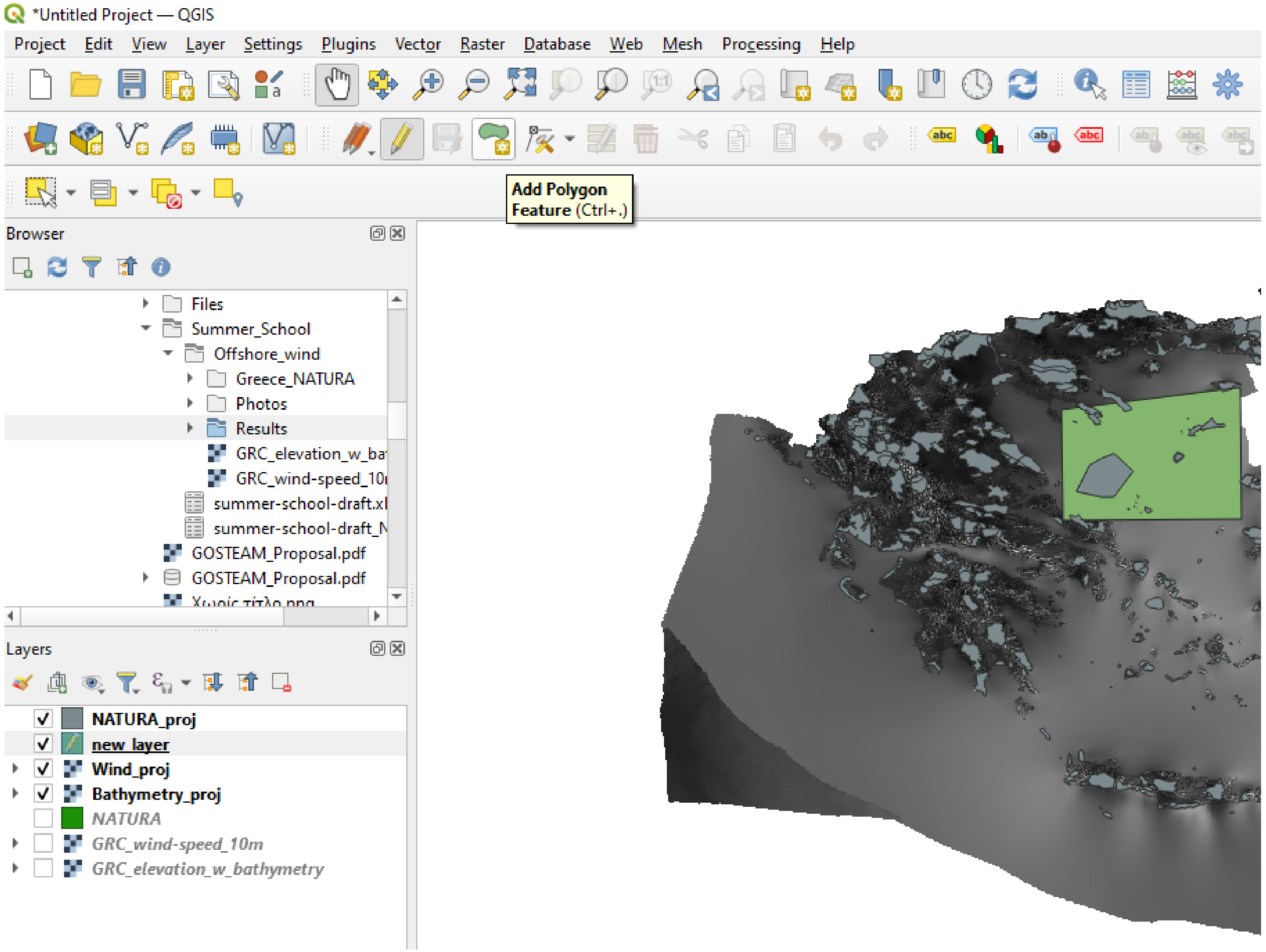


Why? To differentiate students' results and trigger their interest upon different areas!

Creation – Part 2 (Select Study Area as Polygon)

1. Select a folder to create a new empty polygon shapefile.
2. Select the new layer on the Layers menu and click on “Toggle Editing”.
3. Click on “Add Polygon” and draw a Polygon that will be used as a Mask.
4. To the final point we edited, we press right-click by adding number 1 as the Polygon “id”.

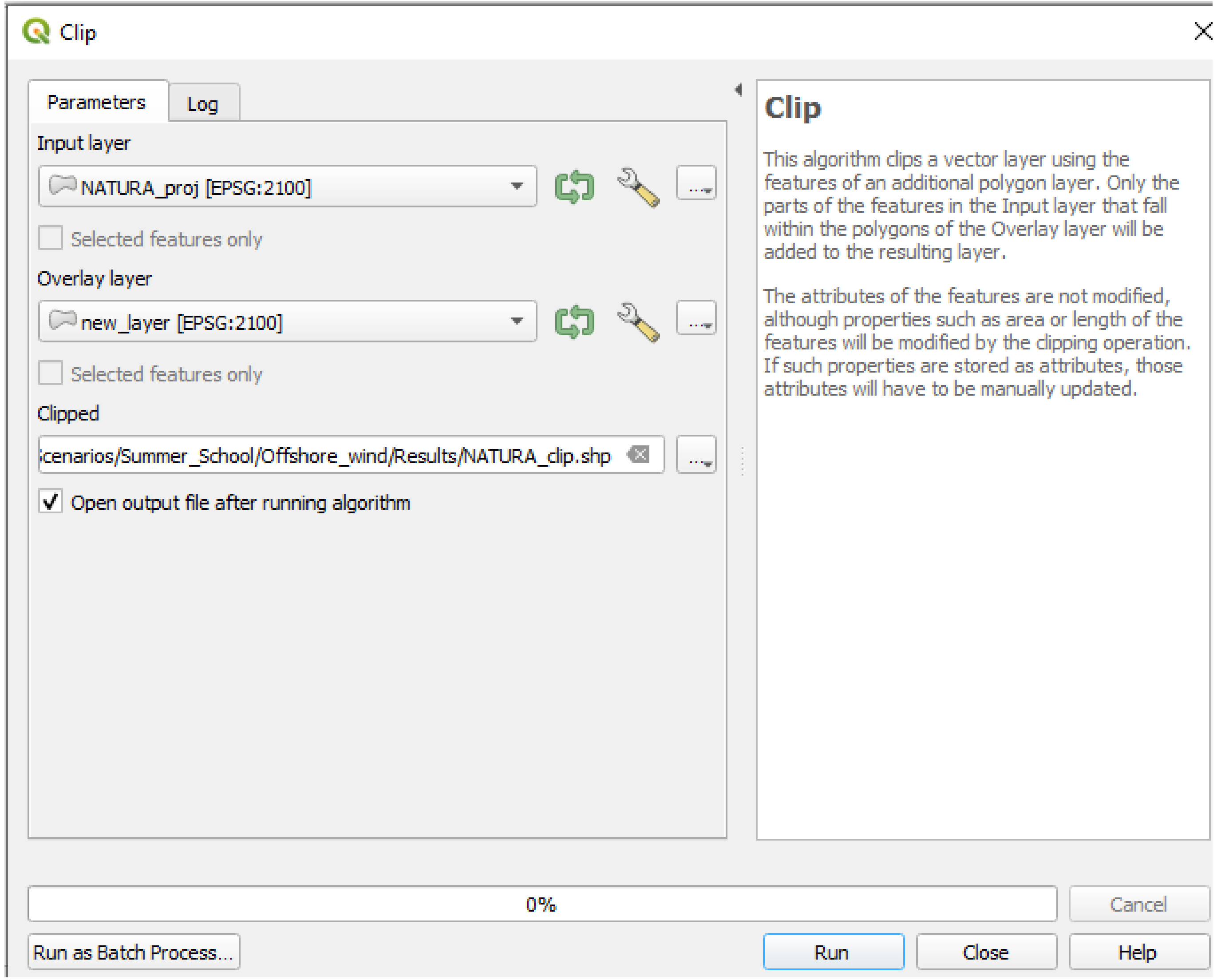
The bigger the Polygon is, the more the processing time increases to the next steps!



Creation – Part 2 (Clip NATURA areas)

1. Select Vector -> Geoprocessing -> Clip.
2. Select NATURA layer as input and the new_layer (Polygon Mask) as overlay layer.
3. Save as NATURA_clip.

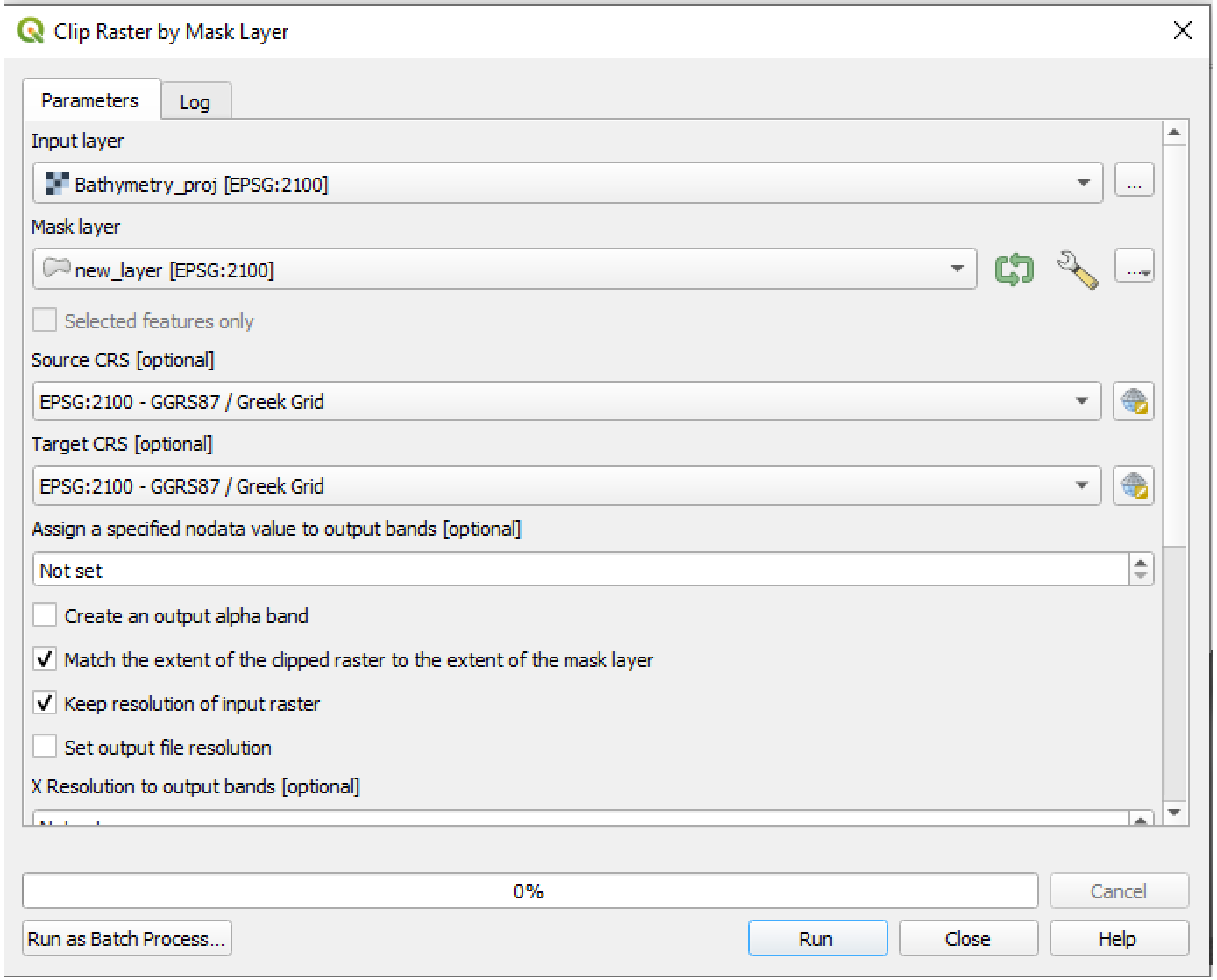
Why we use Vector Toolbar? Because NATURA areas are illustrated as Polygon Features (Vectors) and we want to work only with raster data!



Creation – Part 2 (Clip Wind and Bathymetry rasters)

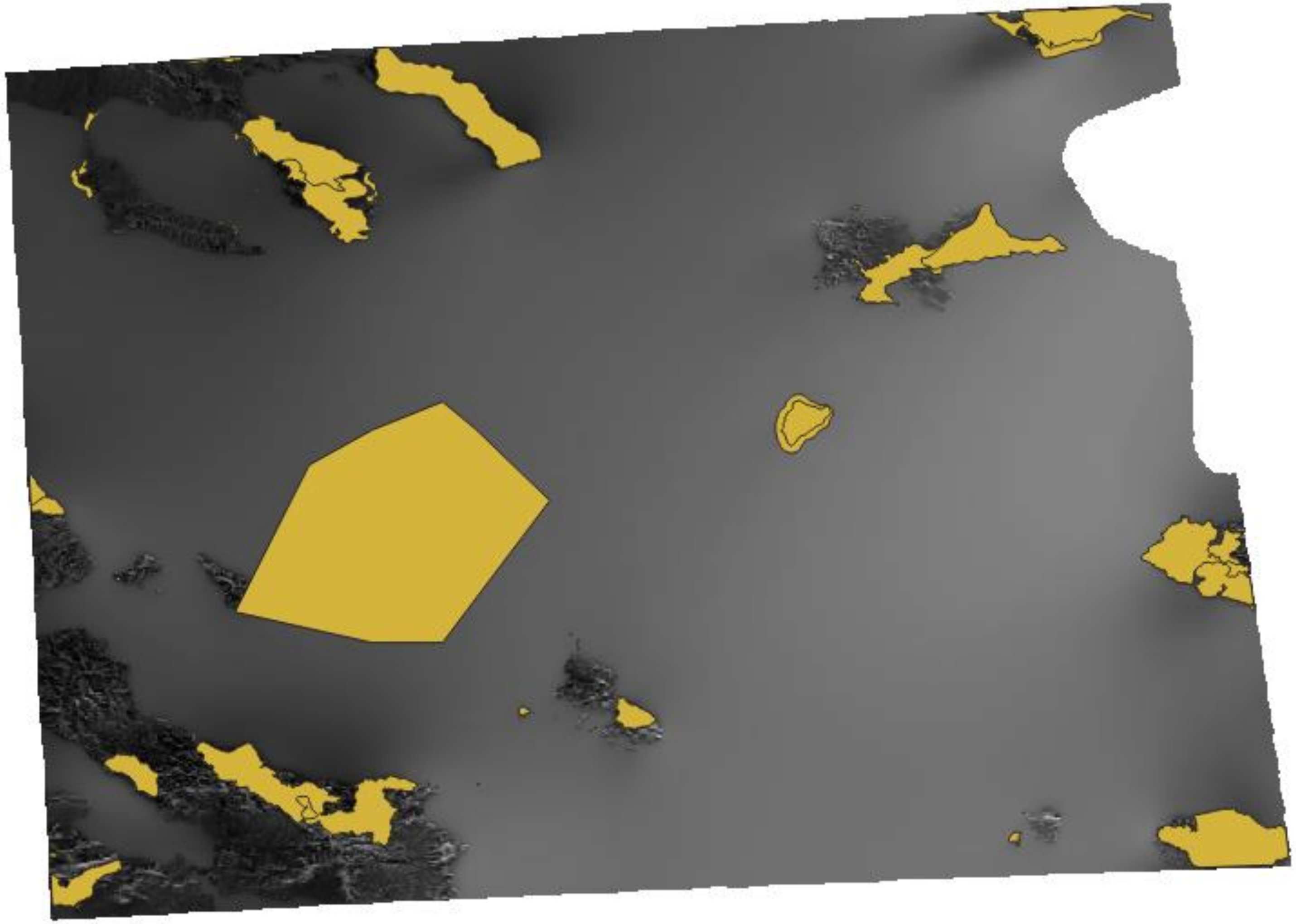
1. Select Raster -> Extraction -> Clip Raster by Mask Layer.
2. Select new_layer (Polygon Mask) as mask layer.
3. Source and Target CRS: 2100
4. Select Keep resolution of input raster and match the extent.
5. Save as Bathymetry_clip.

Why we use Raster Toolbar? Because Wind and Bathymetry data are illustrated as grid entities (georeferenced images)!



Creation – Part 2 (Clip Results)

Clipped data to the Polygon Mask extent!

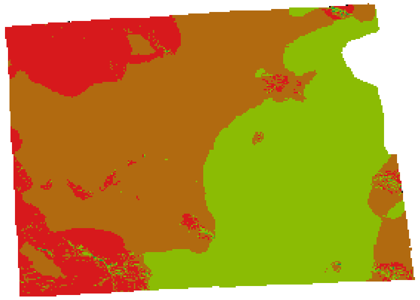


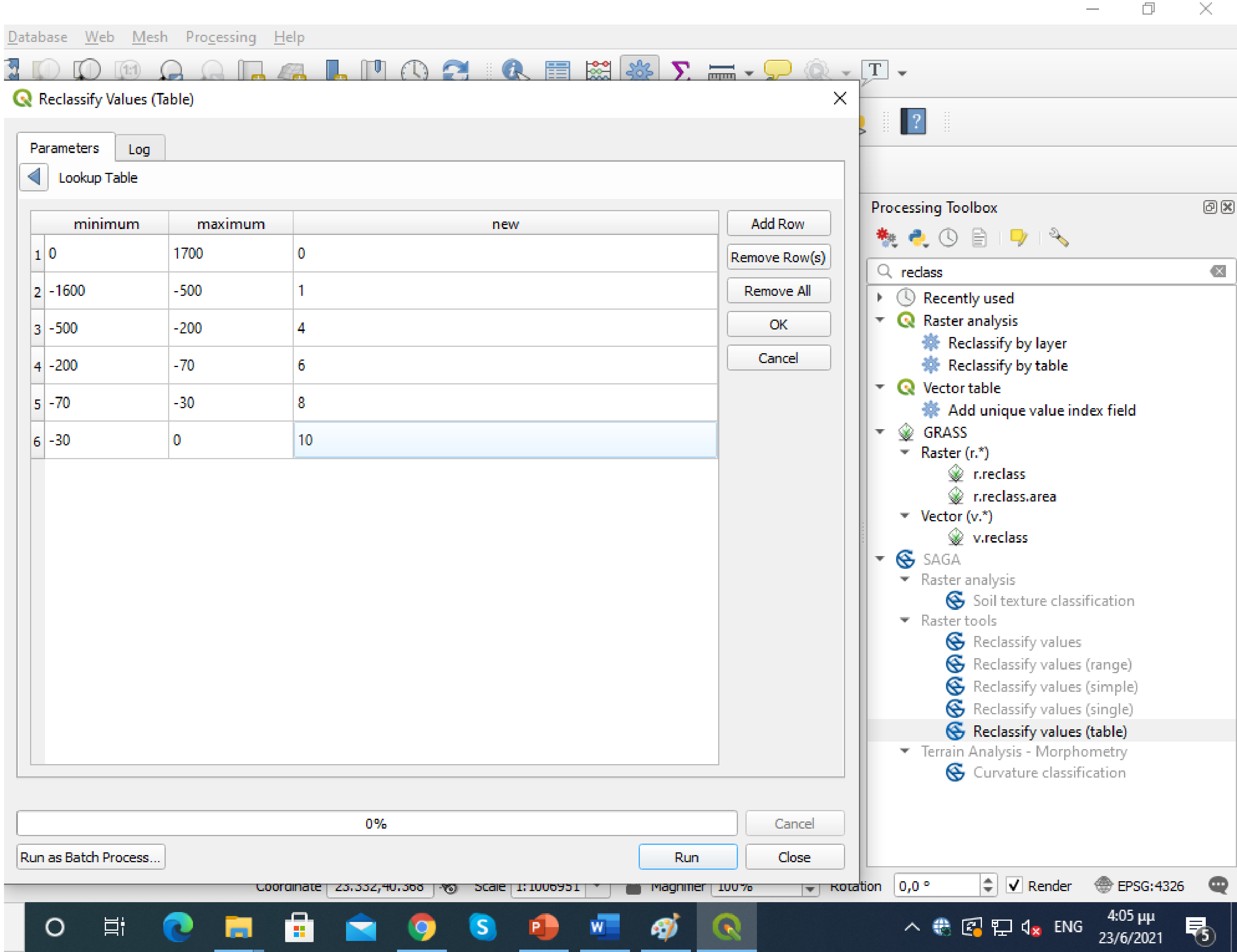
Chapter Break (Any Questions?)

Creation – Part 3 (Bathymetry criterion)

In this step, we want to Reclassify (change) depth values (meters) in score values in the range between 0 and 10!

1. Select Processing -> Toolbox and type to the search area “Reclass”.
2. Select “Reclassify values (Table)”.
3. Grid -> Bathymetry_clip.
4. Operator: [1]
5. Save as “Bathymetry _fn”

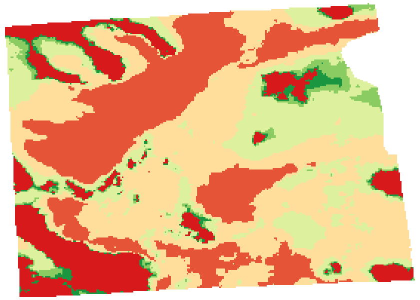


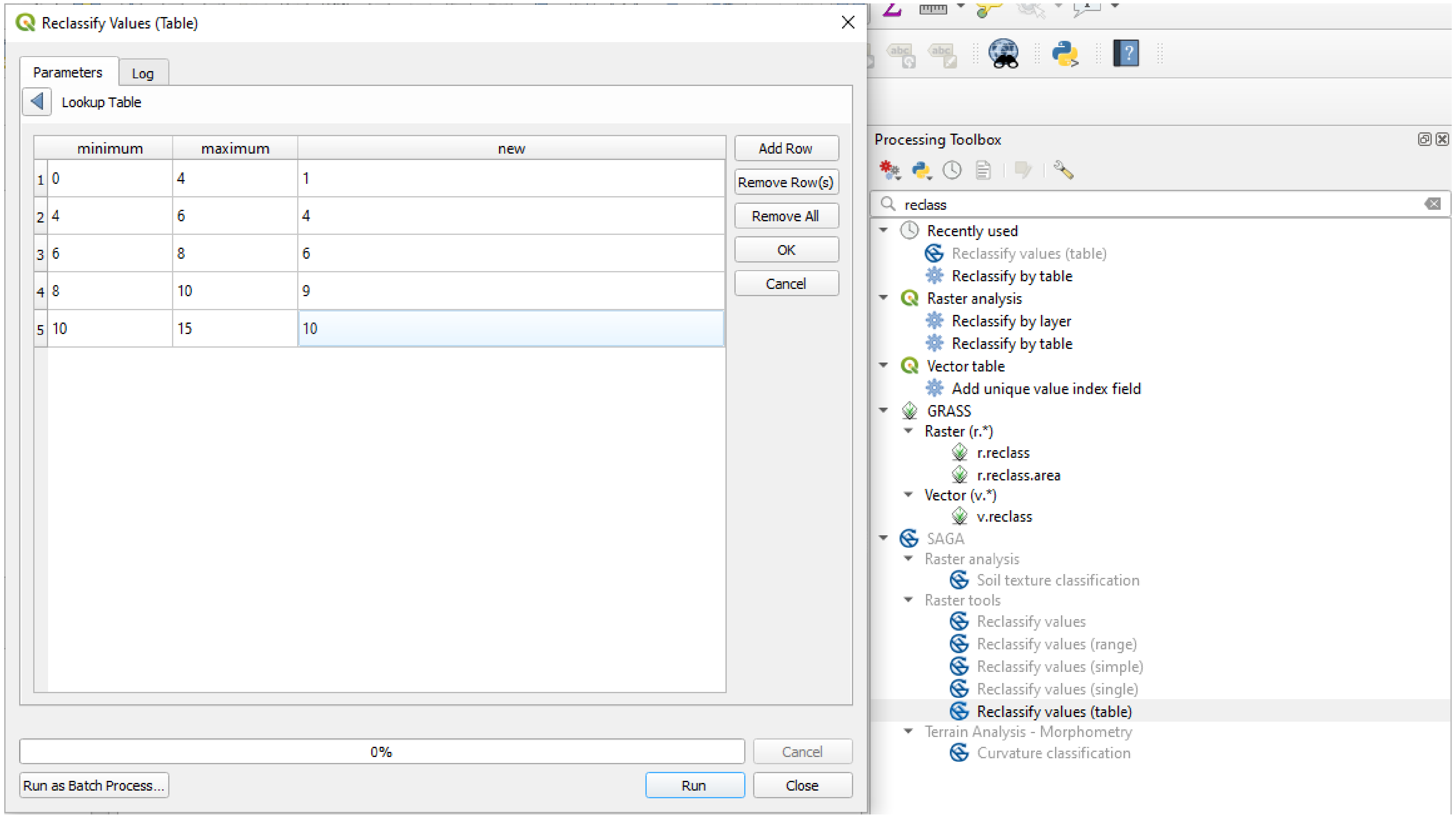


Creation – Part 3 (Wind criterion)

In this step, we want to Reclassify (change) wind speed values (m/s) in score values in the range between 0 and 10!

1. Select Processing -> Toolbox and type to the search area “Reclass”.
2. Select “Reclassify values (Table)”.
3. Grid -> Wind_clip.
4. Operator: [1]
5. Save as “Wind_fn”





Creation – Part 3 (Slope criterion)

Let’s formulate Slopes criterion without any further instructions!

What do we need to estimate Slopes?

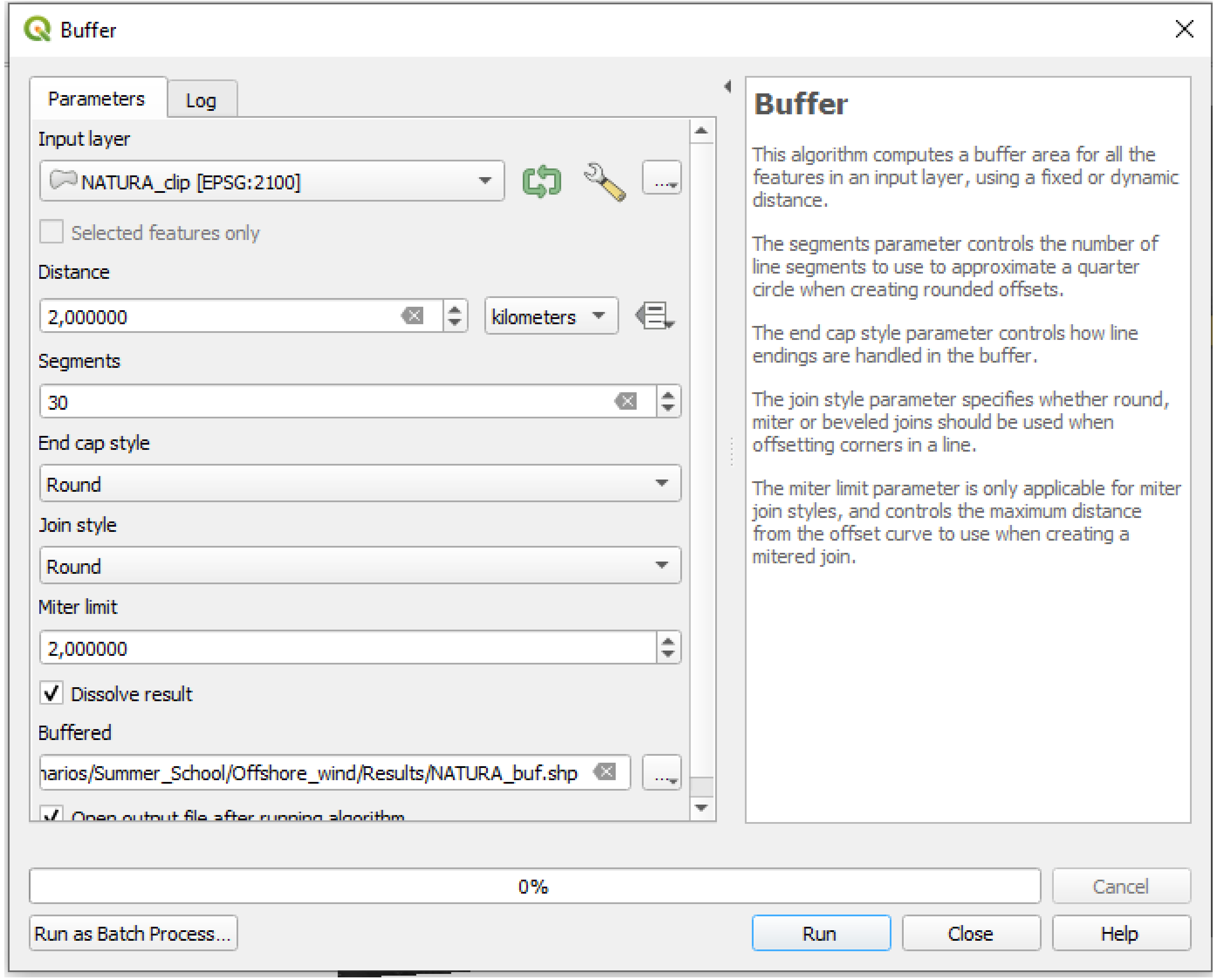
Is a Raster or Vector dataset?

We prefer flat areas or not and why?

Creation – Part 3 (NATURA criterion / Buffer)

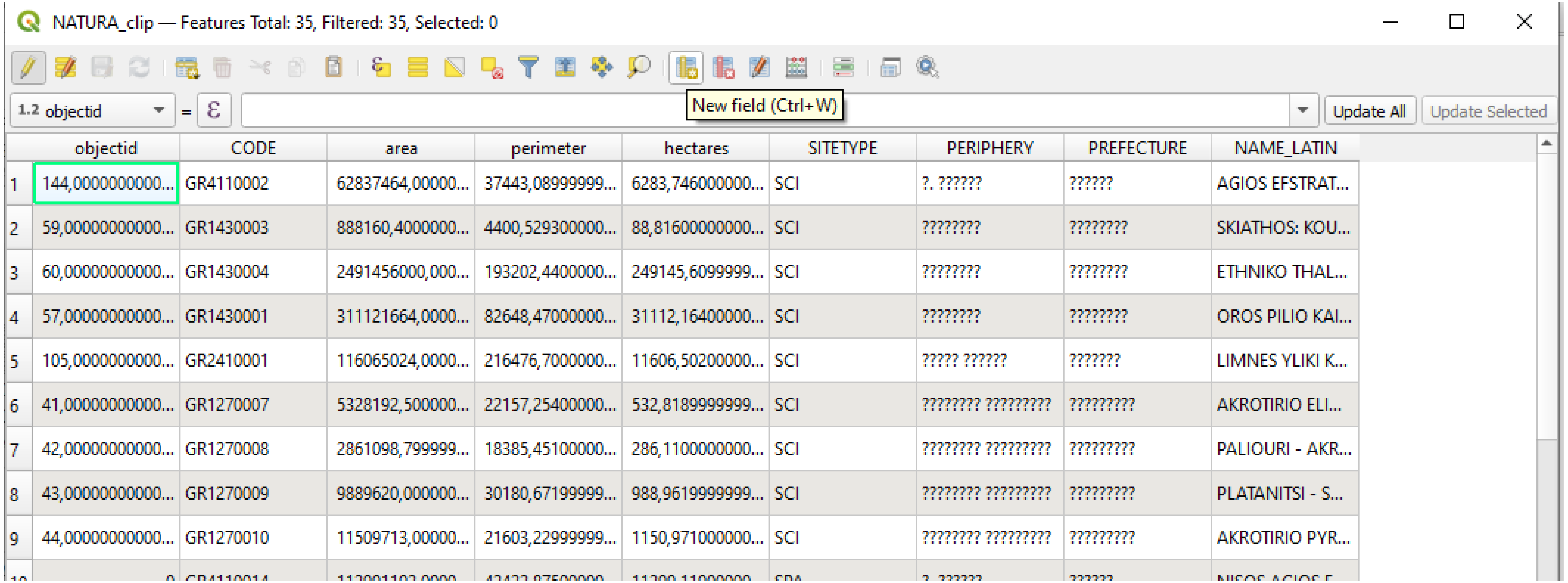
We want to create an exclusion zone (buffer) around all NATURA areas that might be potential sites for OWFs but not optimal.

1. Select Vector -> Geoprocessing -> Buffer.
2. Select NATURA_clip layer as input and Buffer distance 2km by selecting measuring units as “kilometers”.
3. Select 30 segments and tick Dissolve results.
4. Save as NATURA_buffer.



Creation – Part 3 (NATURA criterion / Add score field)

1. Right-click on the NATURA_clip layer (Layers menu) and select “Open attribute Table”.
2. Select the “New field” icon and name it “score”.
3. Select “Open field calculator” -> Update existing field -> score -> type 0 on the blank box and Ok.



	objectid	CODE	area	perimeter	hectares	SITETYPE	PERIPHERY	PREFECTURE	NAME_LATIN
1	144,0000000000...	GR4110002	62837464,00000...	37443,08999999...	6283,746000000...	SCI	?. ??????	??????	AGIOS EFSTRAT...
2	59,00000000000...	GR1430003	888160,4000000...	4400,529300000...	88,81600000000...	SCI	????????	????????	SKIATHOS: KOU...
3	60,00000000000...	GR1430004	2491456000,000...	193202,4400000...	249145,6099999...	SCI	????????	????????	ETHNIKO THAL...
4	57,00000000000...	GR1430001	311121664,0000...	82648,47000000...	31112,16400000...	SCI	????????	????????	OROS PILIO KAI...
5	105,0000000000...	GR2410001	116065024,0000...	216476,7000000...	11606,50200000...	SCI	????? ??????	???????	LIMNES YLIKI K...
6	41,00000000000...	GR1270007	5328192,500000...	22157,25400000...	532,8189999999...	SCI	???????? ?????????	?????????	AKROTIRIO ELI...
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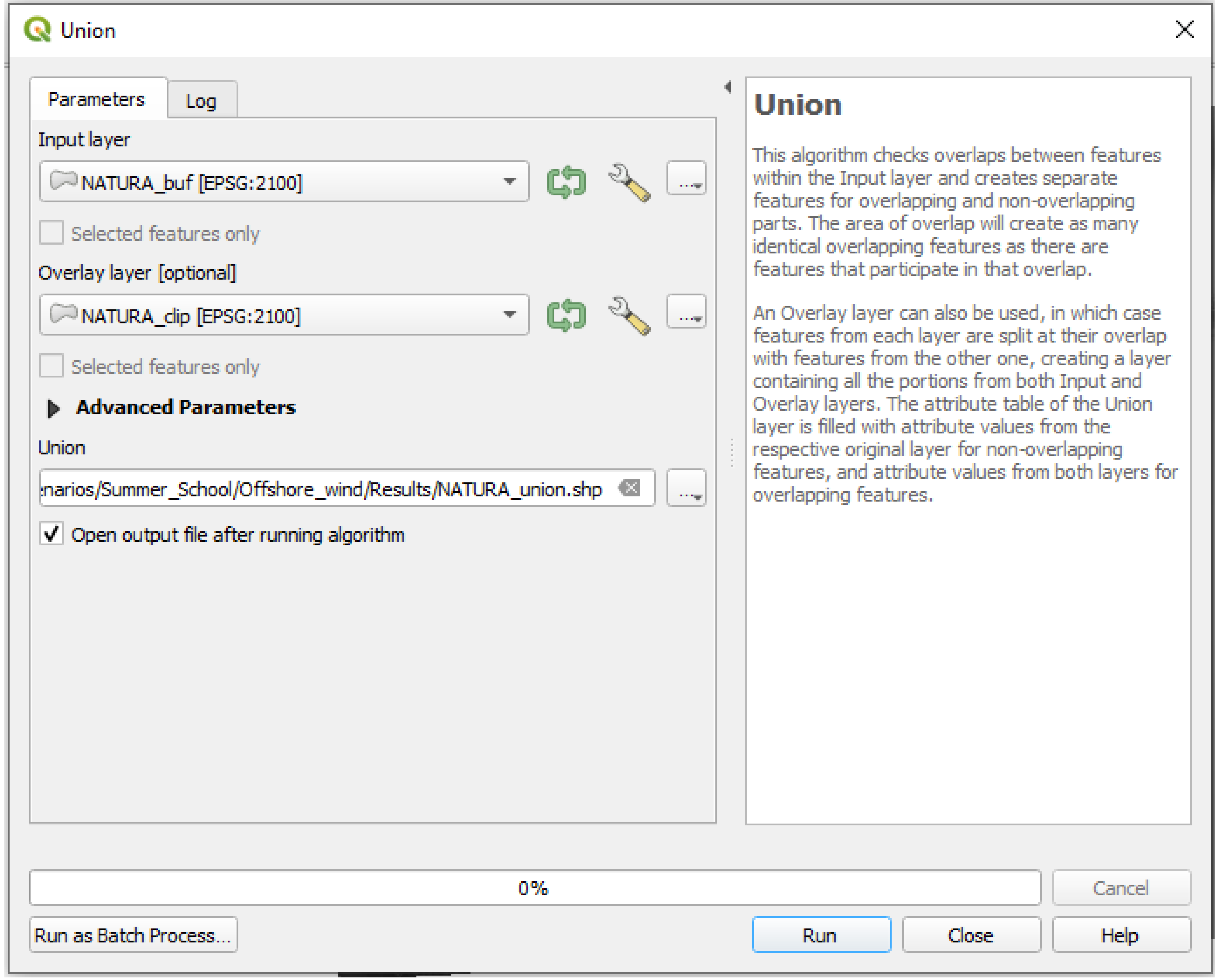
Creation – Part 3 (NATURA criterion / Union)

The scope of the Union tool is to merge the initial NATURA polygons with the Buffer zones created in the previous steps!

1. Select Vector -> Geoprocessing -> Union.
2. Select NATURA_buffer layer as input and NATURA_clip as overlay layer.
3. Save as NATURA_union.

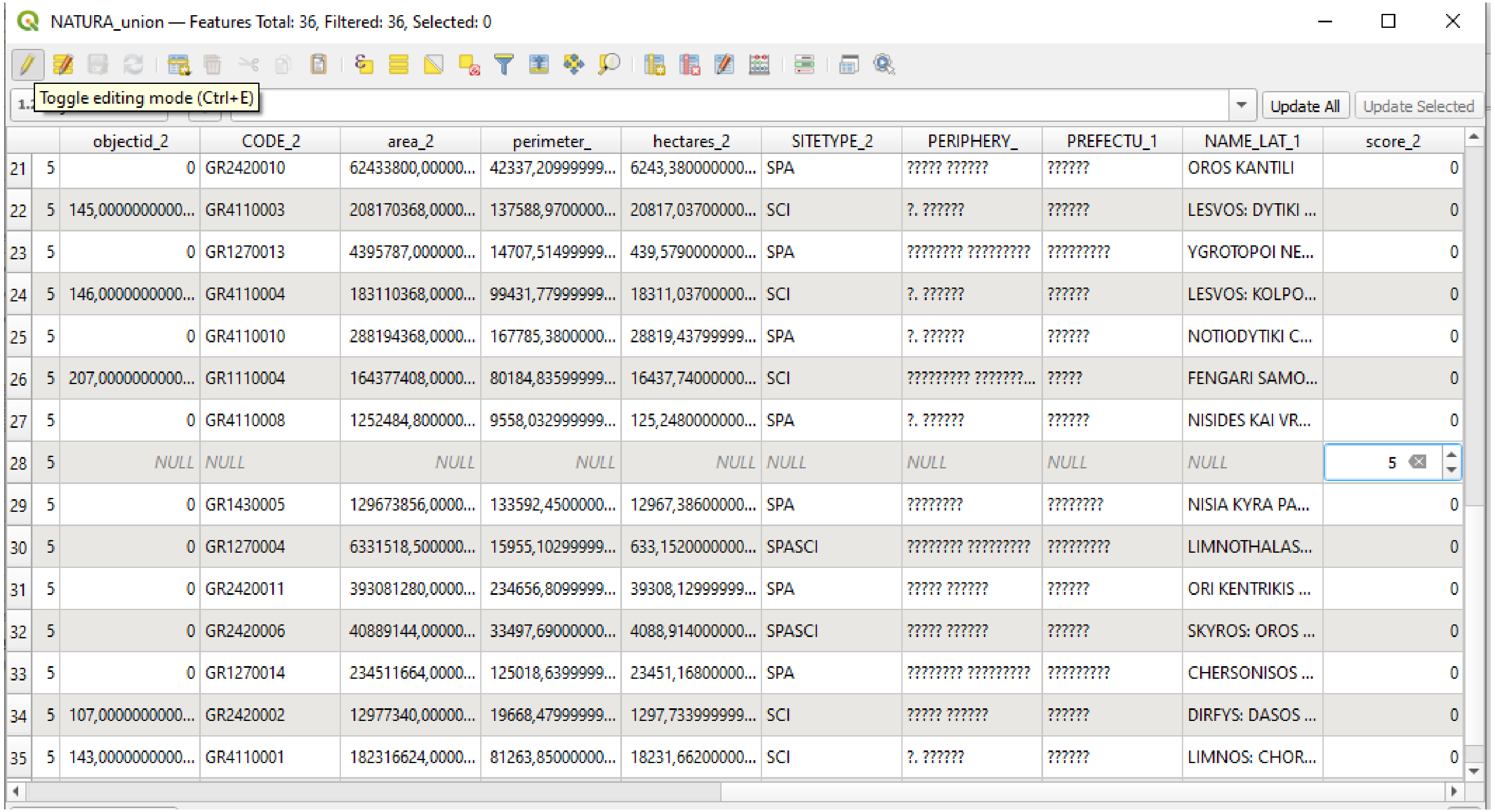


Creation – Part 3 (NATURA criterion / Union)

GOSTEAM

Why we need this procedure? We need to set a low score inside NATURA areas (zero) and a higher score near to the NATURA areas (buffers). But outside these Polygons?

1. Right-click the NATURA_union layer and select "Open Attribute Table".
2. In the line with the "NULL" input, add value 5 at the "score" field
3. Press "Toggle editing" again



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25	5	0	GR4110010	288194368,0000...	167785,3800000...	28819,43799999...	SPA	?. ??????	??????	NOTIODYTIKI C...	0
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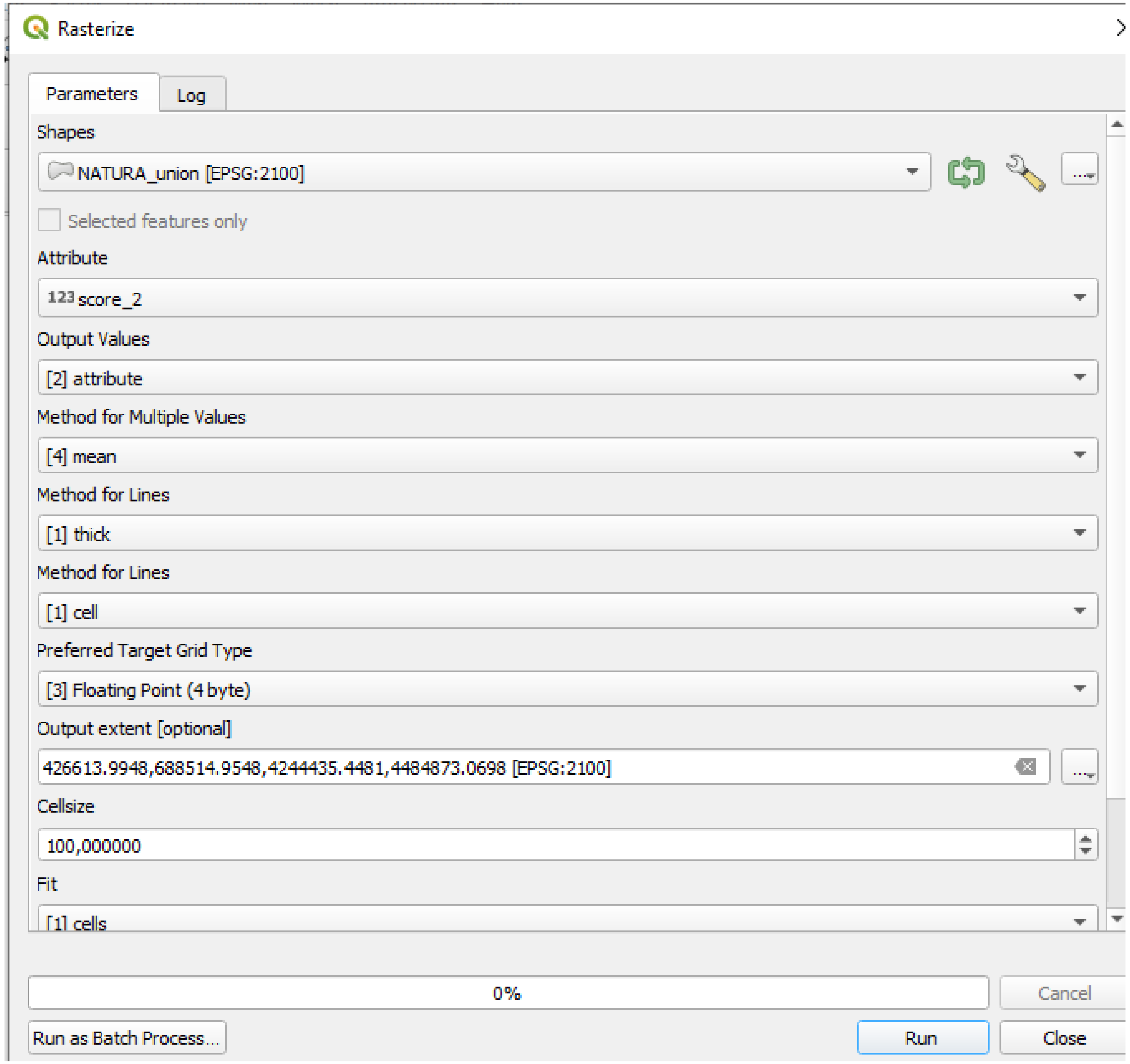
27	5	0	GR4110008	1252484,800000...	9558,032999999...	125,2480000000...	SPA	?. ??????	??????	NISIDES KAI VR...	0
28	5	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	5
29	5	0	GR1430005	129673856,0000...	133592,4500000...	12967,38600000...	SPA	????????	????????	NISIA KYRA PA...	0
30	5	0	GR1270004	6331518,500000...	15955,10299999...	633,1520000000...	SPASCI	???????? ?????????	?????????	LIMNOTHALAS...	0
31	5	0	GR2420011	393081280,0000...	234656,8099999...	39308,12999999...	SPA	????? ??????	??????	ORI KENTRIKIS ...	0
32	5	0	GR2420006	40889144,00000...	33497,69000000...	4088,914000000...	SPASCI	????? ??????	??????	SKYROS: OROS ...	0
33	5	0	GR1270014	234511664,0000...	125018,6399999...	23451,16800000...	SPA	???????? ?????????	?????????	CHERSONISOS ...	0
34	5	107,0000000000...	GR2420002	12977340,00000...	19668,47999999...	1297,733999999...	SCI	????? ??????	??????	DIRFYS: DASOS ...	0
35	5	143,0000000000...	GR4110001	182316624,0000...	81263,85000000...	18231,66200000...	SCI	?. ??????	??????	LIMNOS: CHOR...	0

Creation – Part 3 (NATURA criterion / Rasterize)

1. Select Raster -> Conversion -> Rasterize
2. Select shapes as NATURA_union.
3. Attribute -> score.
4. Ouput extent -> Bathymetry_fn or Wind_fn
5. Cell_size: 241.16110500453601116
6. Save as NATURA_raster

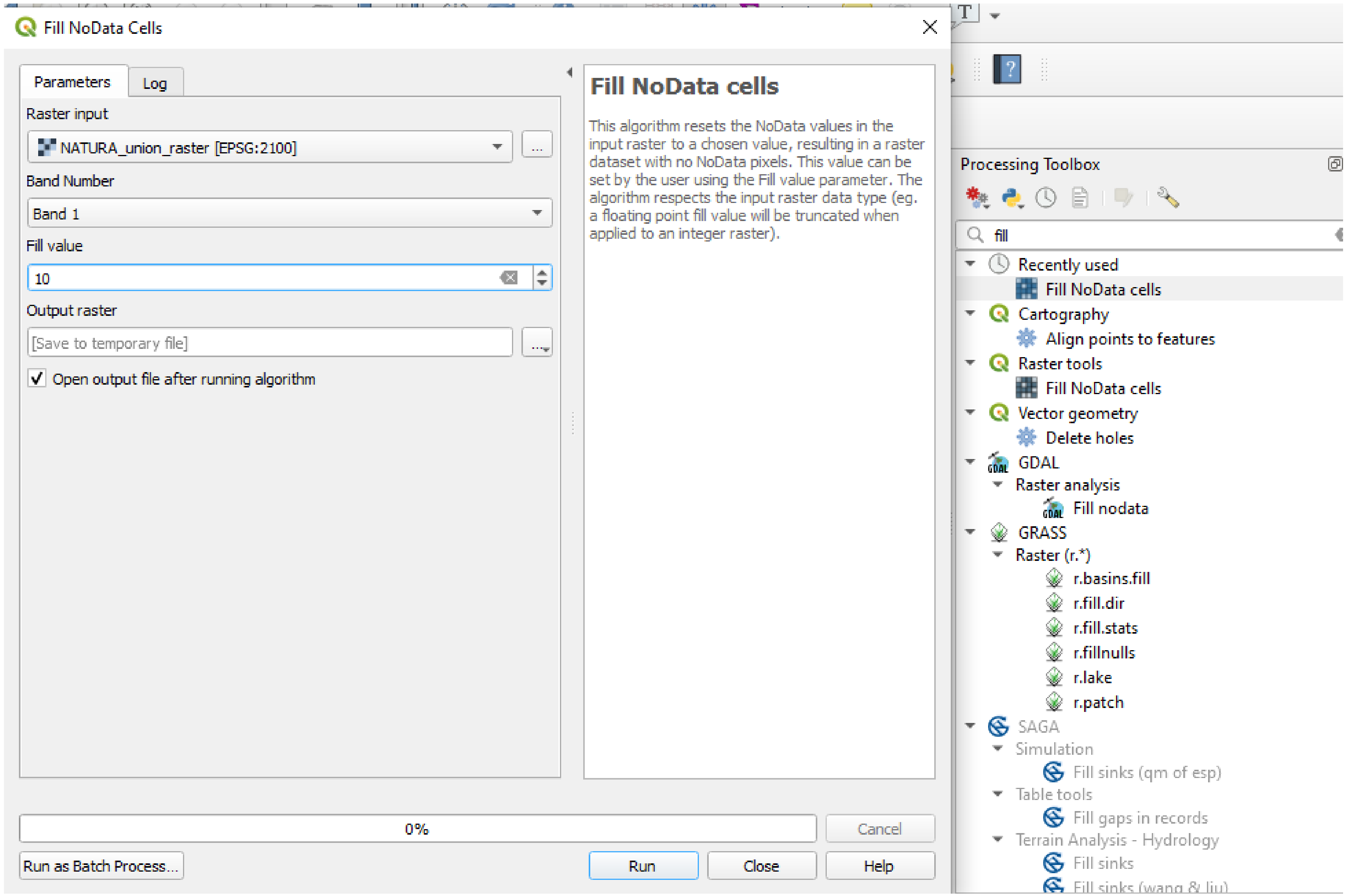


We have to convert NATURA_union from shapefile to raster because Wind and Bathymetry data are also in raster format!

Creation – Part 3 (NATURA criterion / Fill No Data)

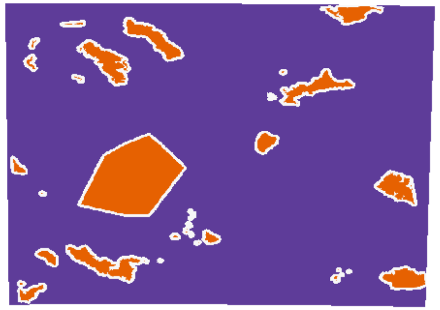
1. Select Processing -> Toolbox and type to the search area “Fill”.
2. Select Fill NoData cells.
3. Raster input -> NATURA_raster.
4. Fill value: 10
5. Do not save output raster, just Run the command (bug issues)

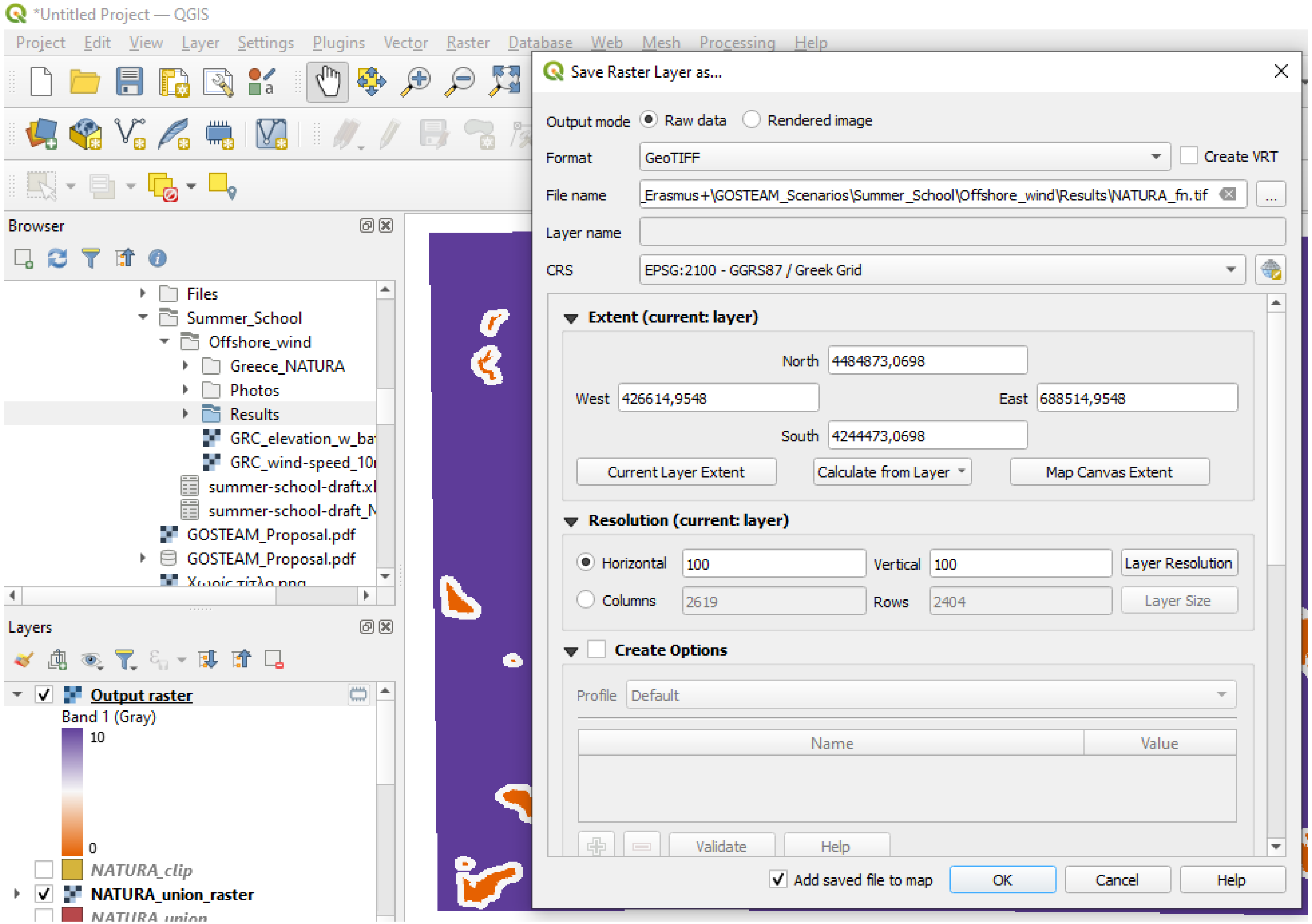
We need to fill all NoData values with the highest score (10)!



Creation – Part 3 (NATURA criterion / Rasterize)

1. Select right-click to the output file -> Save Raster Layer as and name it as “NATURA_fn”.
2. Set CRS:2100
3. Extent -> Calculate from Layer -> Bathymetry_clip.
4. Resolution horizontal and vertical: 241.1611050045360116





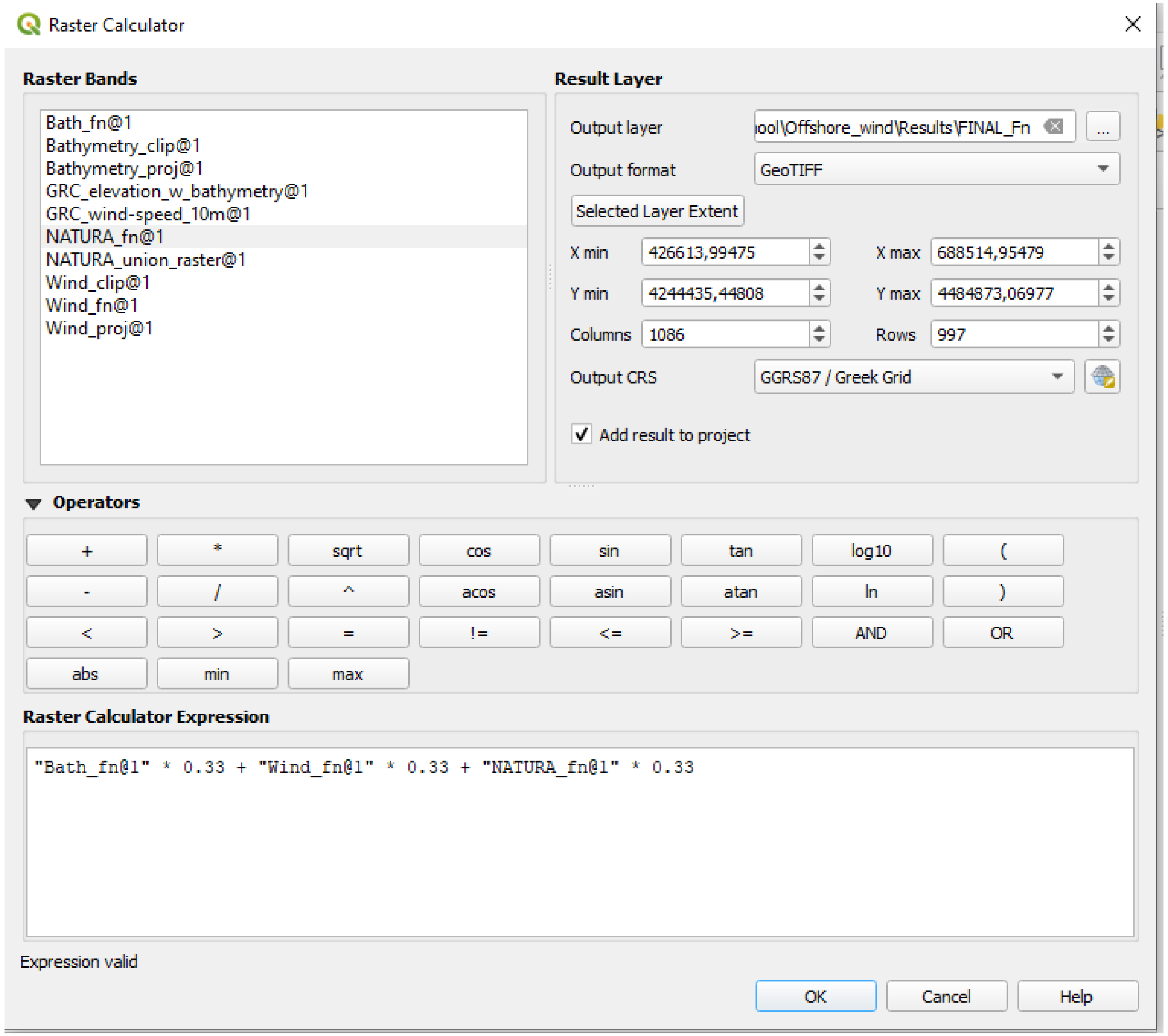
Creation – Part 4 (Weighted Sum and Final Map)

1. Select Raster -> Raster Calculator.
2. Type in the expression box:

"Bathymetry_fn@1" * 0.33 + "Wind_fn@1" * 0.33 + "NATURA_fn@1" * 0.33

3. Save as “Final_fn”

Our goal is to combine each pixel score for each criterion using an analytical expression (i.e. sum). A value of 0.33 is multiplied with each criterion as a weighting factor of “importance”. We may consider different weights for the criteria!
All weights must sum up to 1!



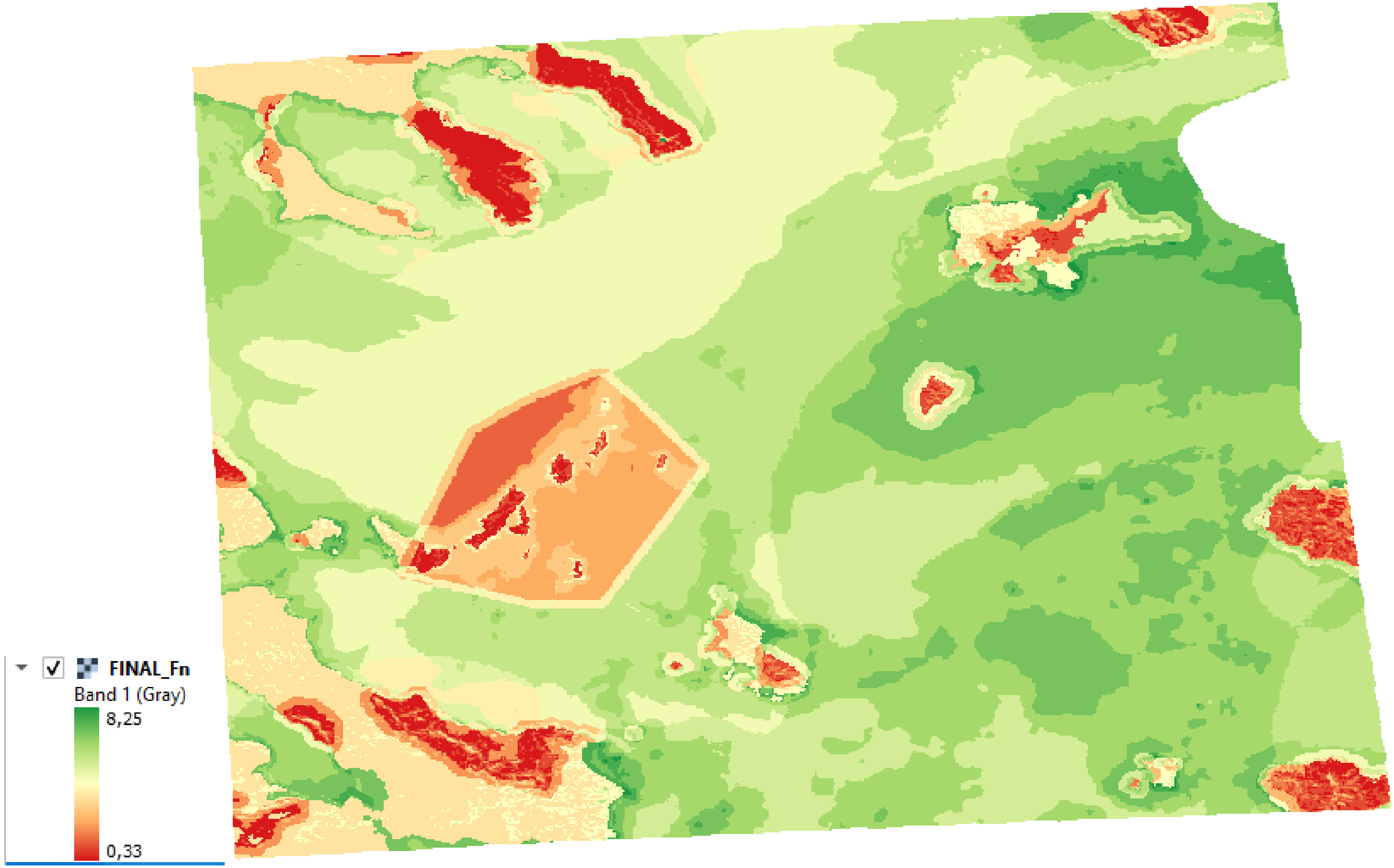
Creation – Part 4 (Final Map)

Final map extraction expressed as the weighted sum of all criteria in the range between 0.33 – 8.25.

These scores depend on the weight of each criterion.

With no weights the scale could be potentially between 0 and 30.

But how can we extract our final most suitable areas??

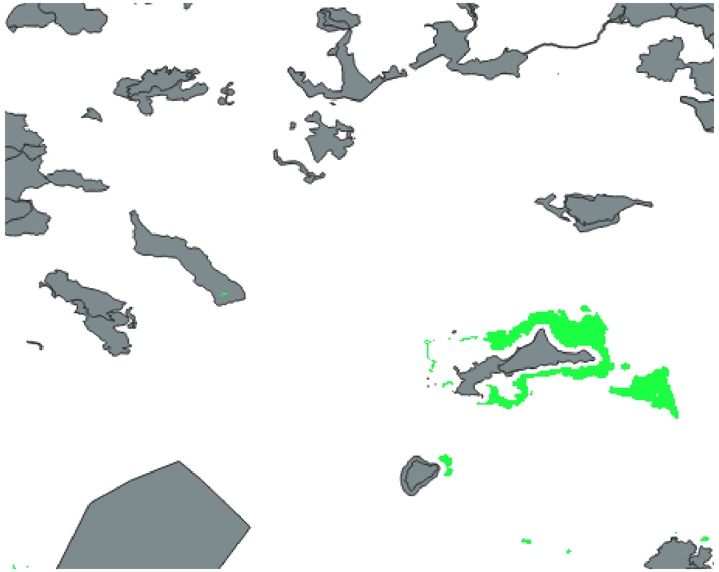


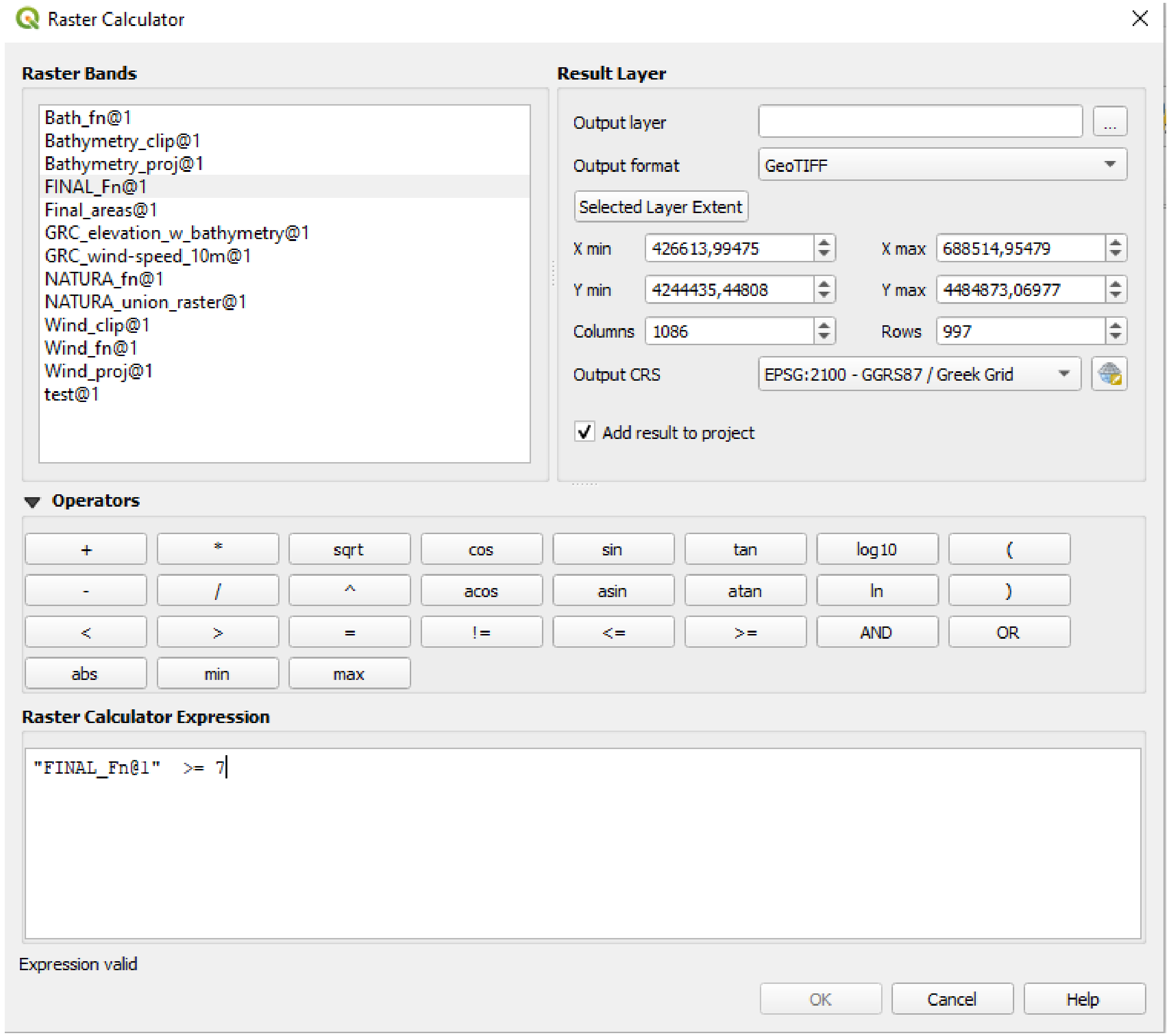
Creation – Part 5 (Screening of optimal areas)

1. Select Raster -> Raster Calculator.

    2. Type in the expression box:

"Final_fn@1" > = 7 (cut-off value)





Chapter Break (Any Questions?)

4. Discussion

Explanation based on evidence

Describe ways and they can use to this end and give them directions how to discover them.

Wind speed and depth importance!

Use the following apps (Wind Power Calculators):

https://rechneronline.de/wind-power/

http://xn--drmstrre-64ad.dk/wp-content/wind/miller/windpower%20web/en/tour/wres/pow/index.htm

https://power-calculation.com/wind-power-energy-calculator.php

Foundations' cost

Consider other explanations

If we change criteria weights, what do you think will happen? (Do the optimal areas change?)

How do we select criteria weights? (i.e., based on the stakeholders, researchers and local communities' preferences)

Can you identify additional criteria that can be incorporated in the analysis? Why do you think they are important?

How we can be sure that the solution we propose is solid? (Sensitivity analysis, run of different scenario by adjusting the scoring and weighting factors)

5. Reflection

Communicate explanation

Provide content which the teacher can use to help the students to get familiarized and to become efficient in scientific writing.

The teacher may ask from the students to prepare a short report in order to demonstrate and discuss their results. Also, students may be guided to follow the appropriate steps in terms of the report outline including:

An introduction and scope of the Activity

The study area and data representation

The Methodology outline

Results and Discussion and finally,

Their conclusions

ELLINOGERMANIKI AGOGI

GOSTEAM

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Thank you for your attention!