GOSTEAM Summer School – Workshop II

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

Wednesday 07/07/2021

G STEAM

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

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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): <u>http://www.gosteam.eu/wp-content/uploads/2021/05/GOSTEAM_IO1_A1_final.pdf</u>

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 siteprospecting 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)

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

2. Active investigation (Examples)

1. Wind Farm Deployment Model

Decision Variables

Number of Turbines
 Wind Turbine Size
 Wind Turbine Layout (3 layout cases) Round 3
 Offshore Wind Farm Locations

Round 3 Offshore Locations

- Annual Mean Wind Speed - Distance from ports - Water Depth

LCC Model

1. Wi

Deploy

LCC= CP&C+ CP&A+ CI&C+ CO&M+ CD&D CAPEX= CP&C+ CP&A+ CI&C OPEX= CO&M

Production and Acquisition cost (CP&A)
 Predevelopment and Consenting cost (CP&C)
 Installation and Commissioning cost (CI&C)
 Operation and Maintenance cost (CO&M)
 Decommissioning and Disposal Cost (CD&D)

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Criteria Selection Framework
1. Brainstorm and Mindmap
2. Literature Review
3. Discussion with Experts
4. Preliminary Assessment
5. Values Assignment
6. Decision on an appropriat
MCDM Method

3. Criteria Selection Framework

	LCC C	bjective Functions			
	CAPE	EX			
	1. P	roduction and Acquisition cost (CP&A)			
A. Life Cycle Cost (LCC)	2. P	redevelopment and Consenting cost (C	P&C		
Objective Functions	3. Installation and Commissioning cost (CI&C)				
	OPE	<u>r</u>			
	4.0	peration and Maintenance cost (CO&N	0		
	5. Decommissioning and Disposal Cost (CD&D)				
	-	Other Objective Functions			
		6. Number of Turbines (NWT)			
B. Other Objective Function	ons	7. Total Installed Capacity (TIC)			
		8. Power Extracted (P)			

5. Optimum Location 4. Multi - Criteria Decision Making 4. Multi-Criteria Decision Making Deterministic TOPSIS and Stochastic expansion Criteria Selection 1. Accessibility 2. Operational environmental conditions 3. Environmental Impact 4. Extreme environmental conditions 5. Grid Connection 6. Geotechnical conditions 7. LCOE **MPALISADE** Denisk **Outcome: A list of prioritised locations**

5. Optimum Location

Offshore Wind Farm

Locations Ranking



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



2. Active investigation (Examples)

GOSTEAM

FRAMEWORK FOR CRITERIA SELECTION

1 . Create a min	d map of the idea	
1. BRAINSTORM 2. Brainstorm c	riteria ideas that have impact on the alternatives	
2. PERFORM A LITERATURE RE	Conduct literature review on the idea and discover related studies Confirm or reject ideas from the previous step O Solution 3 Discover new criteria and gaps in literature O Solution 1 Discuss ideas with experts	
3 DISCUSS WITH EXPERTS	2 . Discuss aims and future work	How we select our
S. DISCOSS WITH EXPERTS	3 . Ask experts' opinions and/or data	now we select our
CRITERIA SELECTION	 Identify strengths and weaknesses of the work and criteria Make sure the criteria are clear and precise 	criteria defining the
4. PRELIMINARY ASSESSMENT	3 . Make sure the criteria do not overlap with each other	problem:
	4. Decide the final list of criteria	
	5. Create a clear description for the criteria	
	1 . Create a decision matrix (criteria vs alternatives)	
5 CALCULATE OR ASSIGN VALU	ES 2 . Estimate the criteria/weights	
1.Whi	ich method is best for the study?	
C DECIDE THE METHOD 2. How	v are the criteria presented?	
3. What is a second sec	at are the expectations for the results?	

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



Ready

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)



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.

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Q Reproject Layer	Filter Q 2100	
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Selected features only		
Target CRS		
EPSG:4326 - WGS 84 🔹 🌏		
Advanced Parameters	Predefined Coordinate Reference Systems	Hide deprecated CRSs
Reprojected	Coordinate Reference System	Authority ID
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	GGPS97 / Greek Grid	EDS:G:2100
	OGROST / Greek Ond	₹ 30.2100
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Run as Batch Process	(OK Cancel Help

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)

🔇 Warp (Reproject)		Х
Parameters Log		
Input layer		
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Target CRS [optional]		
EPSG:2100 - GGRS87 / Greek Grid	•	
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✓ Open output file after running algorithm		
GDAL/OGR console call		•
0%	Cancel	
Run as Batch Process	Run Close Help	



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!

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Creation – Part 2 (Select Study Area as Polygon)

- 1. Select a folder to create a new empty polygon shapefile.
- Select the new layer on the Layers menu and click on "Toggle Editing".
 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)



Cancel

Help

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!

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cenarios/Summer_School/Offshore_wind/Results/NATURA_c	dip.shp			
✓ Open output file after running algorithm				

0%

Run

Close

Run as Batch Process..

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)!

Parameters Log			
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Target CRS [optional]			
EPSG:2100 - GGRS87 / Greek Grid		•	۲
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 Keep resolution of input raster 			
Set output file resolution			
X Resolution to output bands [optional]			
0%		Ca	ancel
		_	



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!

- 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!

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



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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)

Run as Batch Process...



Close

Help

Run

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.

Parameters Log Input layer Input layer Input layer Input layer NATURA_clip [EPSG:2100] Image: Selected features only Distance Image: Selected features only 2,000000 Image: Selected features only Selected features only Image: Selected features only Segments Image: Selected features only 30 Image: Selected features only End cap style Image: Selected features only Join style Image: Selected features only New of the selected features only Image: Selected features only Segments Image: Selected features only So Image: Selected features only Indice on the offset on the only	Ruffer	
Input layer Input layer Input layer Input layer Init algorithm computes a buffer area for all the features in an input layer, using a fixed or dynamic distance Interest parameter controls the number of line segments to use to approximate a quarter dired when creating rounded offsets. The segments parameter controls how line endrogs are handled in the buffer. The join style parameter specifies whether round, mitter or beveled joins should be used when offsetting corners in a line. The mitter limit 2,000000 Dissolve result Buffered arios/Summer_School/Offshore_wind/Results/NATURA_buf.shp Conex.output file after running algorithm	Parameters Log	Buffer
	Input layer NATURA_clip [EPSG: 2100] Selected features only Distance 2,00000 Segments 30 End cap style Round Toin style Round Miter limit 2,00000 Dissolve result Buffered tarios/Summer_School/Offshore_wind/Results/NATURA_buf.shp	 This algorithm computes a buffer area for all the features in an input layer, using a fixed or dynamic distance. The segments parameter controls the number of line segments to use to approximate a quarter circle when creating rounded offsets. The end cap style parameter controls how line endings are handled in the buffer. The join style parameter specifies whether round, miter or beveled joins should be used when offsetting corners in a line. The miter limit parameter is only applicable for mite join styles, and controls the maximum distance from the offset curve to use when creating a mitered join.

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.

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6	41,0000000000	GR1270007	5328192,500000	22157,25400000	532,81899999999	SCI	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	AKROTIRIO ELI			
7	42,0000000000	GR1270008	2861098,799999	18385,45100000	286,1100000000	SCI	יייייייי	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	PALIOURI - AKR			
8	43,0000000000	GR1270009	9889620,000000	30180,67199999	988,9619999999	SCI	יייייייי	<u>,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,</u>	PLATANITSI - S			
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10	0	CD4110014	112001102 0000	42422 07500000	11200 11000000	CDA	2 222222	222222				

Creation – Part 3 (NATURA criterion / Union)

Run as Batch Process..



1. Select Vector -> Geoprocessing -> Union.

2. Select NATURA_buffer layer as input and NATURA_clip as overlay

layer.

3. Save as NATURA_union.

	×
Parameters Log Union	
Input layer Input layer NATURA_buf [EPSG:2100] Selected features only Overlay layer [optional] NATURA_clip [EPSG:2100] NATURA_clip [EPSG:2100] Advanced Parameters Union narios/Summer_School/Offshore_wind/Results/NATURA_union.shp Y Open output file after running algorithm	en features parate erlapping e as many re are lap. n which case their overlap eating a layer Input and f the Union m the rlapping poth layers for
0%	Cancel

Close

Help

Run

Creation – Part 3 (NATURA criterion / Union)



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?

Right-click the
 NATURA_union layer and select "Open Attribute
 Table".
 In the line with the "NULL" input, add value

5 at the "score" field

3. Press "Toggle editing"

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0	N	ATURA_union — F	eatures Total: 36, Fil	tered: 36, Selected:	0					-	- 🗆	\times
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31	5	0	GR2420011	393081280,0000	234656,8099999	39308,129999999	SPA	יייייי זייייי	22222	ORI KENTRIKIS		0
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33	5	0	GR1270014	234511664,0000	125018,6399999	23451,16800000	SPA	11111111 11111111	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	CHERSONISOS		0
34	5	107,000000000	GR2420002	12977340,00000	19668,479999999	1297,7339999999	SCI	יייייי זייייי	777777	DIRFYS: DASOS		0
35	5	143,000000000	GR4110001	182316624,0000	81263,85000000	18231,66200000	SCI	?. ??????	??????	LIMNOS: CHOR		0
4												•

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: 241.1611050045360116
 - 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!

Rasterize		;
Parameters Log		
Shapes		-
RATURA_union [EPSG:2100]	- 4	≫,
Selected features only		
Attribute		
123 score_2		•
Output Values		
[2] attribute		-
Method for Multiple Values		
[4] mean		-
Method for Lines		
[1] thick		•
Method for Lines		
[1] cell		-
Preferred Target Grid Type		
[3] Floating Point (4 byte)		-
Output extent [optional]		
426613.9948,688514.9548,4244435.4481,4484873.0698 [EPSG:2100]		
Cellsize		
100,000000		\$
Fit		
[1] cells		
0%		Cancel
Run as Batch Process	Run	Close

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

- 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)!

Q Fill NoData Cells	X	T
Fill NoData Cells Parameters Log Raster input Image: NATURA_union_raster [EPSG:2100] Band Number Band 1 Fill value 10 Image: Ima	Fill NoData cells This algorithm resets the NoData values in the input raster to a chosen value, resulting in a raster data syste with no NoData pixels. This value can be set by the user using the Fill value parameter, the algorithm respects the input raster data type (ega foating point fill value will be truncated when applied to an integer raster).	Processing Toolbox Processing Toolbox Processing Toolbox Processing Toolbox Proc
0%	Cancel	Fill gaps in records
Run as Batch Process	Run Close Help	 Ierrain Analysis - Hydrology Fill sinks Fill sinks (wang & liu)

Creation – Part 3 (NATURA criterion / Rasterize)

- 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



🛿 *Untitled Project — QGIS							
Project <u>E</u> dit <u>V</u> iew <u>L</u> ayer <u>S</u> ettings <u>P</u> lugins Vect <u>o</u> r <u>R</u> aster <u>D</u> at	abase <u>W</u> eb	Mesh Process	ing <u>H</u> elp				
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 Results 	West 42	6614,9548		E	ast 688514,95	48	
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Output raster	Profile [Default				•	
Band 1 (Gray) 10			Nam	ne		Value	
o		Validate	Hel	p			-
■ NATURA_clip ▼ NATURA union raster			✓ Add sav	ved file to map Ok	Ca	ancel Help	



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!

Raster Calcula	ator								>
ter Bands				Result Lay	er				
Bath_fn@1 Bathymetry_clip@1 Bathymetry_proj@1 GRC_elevation_w_bathymetry@1 GRC_wind-speed_10m@1 NATURA_fn@1 NATURA_union_raster@1 Wind_clip@1 Wind_fn@1 Wind_proj@1			Output layer Output format Selected Layer Extent		GeoTIFF				
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<	>	=	!=	<=	>=		AND	OR	
abs	min	max							
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ter Calculat									

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??

▼ ✓ FINAL_Fn Band 1 (Gray) 8,25

0.33

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)



Q Raster Calculator \times Raster Bands Result Laver Bath fn@1 Output layer Bathymetry_clip@1 Bathymetry_proj@1 Output format GeoTIFF Ŧ FINAL_Fn@1 Selected Layer Extent Final areas@1 GRC_elevation_w_bathymetry@1 X max 688514,95479 \$ 426613,99475 \$ X min GRC_wind-speed_10m@1 NATURA fn@1 \$ 4244435,44808 \$ Y max 4484873,06977 Y min NATURA_union_raster@1 Wind_clip@1 \$ \$ Columns 1086 Rows 997 Wind fn@1 Wind_proj@1 -Output CRS EPSG:2100 - GGRS87 / Greek Grid Ŧ test@1 Add result to project Operators * sqrt log10 + COS sin tan ^ acos asin atan In -!= AND OR < > = <= $\geq =$ abs min max Raster Calculator Expression "FINAL Fn@1" >= 7 Expression valid OK Cancel Help

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









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