

Module 2: Calculate Area Below Cost Threshold

*Monica Moritsch and Alex Waller
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This model calculates area (km²) where seaweed can be farmed at or below two chosen cost thresholds (net cost per ton of carbon dioxide equivalent). This raster should account for the costs associated with farming the seaweed and transporting it to its target destination as well as income received for the seaweed, which may vary depending on the purpose for which it is grown. The target destination may be a port, a sinking location, or a destination further along the supply chain, such as a processing facility. Costs may be framed in units of greenhouse gas reduction from the sinking or end seaweed products (CO₂ equivalent), or they may be framed in terms of dry weight of seaweed harvested.

Any currency may be used. The model uses a raster of net costs and creates a polygon of area meeting the two thresholds. The polygon's attribute table records the area meeting each cost threshold (Table 1, Figure 1). Note that cost thresholds below zero (i.e., negative net cost) represent profit. A threshold of zero represents breaking even (i.e., costs equal to value of the seaweed).

Limitations: This model assumes costs will be the same over entire an grid cell. Coarse input resolutions may omit some nearshore areas. The model does not predict the chances of success or failure for farming seaweed in any given location. It assumes costs of farming are the same over an entire grid cell. Coarse input resolutions may omit some nearshore areas. Output maps do not display uncertainty associated with favorability for seaweed farming. Users are recommended to view maps as a visual guide or to run the tool multiple times for a range of input conditions. Sample data that may accompany this tool are for educational purposes only. Users are responsible for verifying the accuracy, timeliness, and relevance of all input data used in this tool.

Requirements:

- ArcGIS Version 10.2 or higher / ArcGIS Pro 3.2.2 or higher

Notes:

- Cost Threshold 2 should be lower than Cost Threshold 1.
- Before beginning, enable overwriting of results. Open the Geoprocessing menu and select "Geoprocessing Options." Check the box for "Overwrite the outputs of geoprocessing operations" and click OK.
- All files should be loaded from and saved to a physical drive (either the regular hard drive or an external drive). Storing GIS files in the cloud is not recommended. If you are unable to store files on disk long-term, it is recommended to download them for the duration of your work session and upload the outputs to cloud storage at the end of each session.
- Externally linked articles in this user guide provide additional information on how to perform basic operations in ArcMap. They are meant to provide supplemental information in case these operations are new to the user.

Outputs:

- Polygon(s) of where seaweed can be farmed for equal or less than the two cost thresholds when considering the value received for the seaweed at the first point of sale.

Table 1. Description of inputs and outputs for the Area Below Cost Threshold model.

Parameter	Explanation
Output Folder	Folder directory where the output polygon will be saved.
Input Net Cost Raster	Net cost of seaweed farming per metric ton of carbon dioxide equivalent offset (Mg CO ₂ e; includes direct sequestration) or per metric ton dry weight (mg DW) harvested. Any currency may be used. Negative numbers indicate that seaweed can be produced at a net profit.
Cost Threshold 1	Cost threshold 1 (number). Any currency may be used. A negative number indicates that seaweed can be produced at a net profit.
Cost Threshold 2	Cost threshold 2 (number). Any currency may be used. A negative number indicates that seaweed can be produced at a net profit.
Output Polygon (in ArcMap)	Polygon of where seaweed can be farmed for equal or less than the two cost thresholds using the currency of the input raster. The area (km ²) meeting each cost threshold is in the "AREA_GEO" field of the attribute table. The cost thresholds are recorded in the "gridcode" field of the attribute table.
Output Polygon 1 (in ArcGIS Pro)	Polygon of where seaweed can be farmed for equal or less than Cost Threshold 1 using the currency of the input raster. The area (km ²) meeting each cost threshold is in the "AREA_GEO" field of the attribute table. The cost thresholds are recorded in the "gridcode" field of the attribute table.
Output Polygon 2 (in ArcGIS Pro)	Polygon of where seaweed can be farmed for equal or less than Cost Threshold 2 using the currency of the input raster. The area (km ²) meeting each cost threshold is in the "AREA_GEO" field of the attribute table. The cost thresholds are recorded in the "gridcode" field of the attribute table.

Steps:

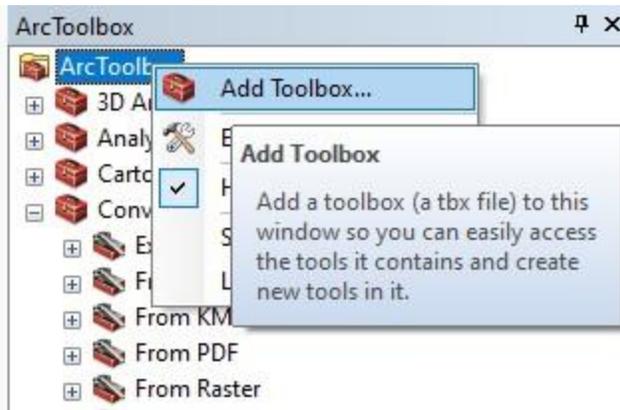
1. **Setting up ArcMap**

- Unzip the zip file containing the toolbox and all input data and move it to the desired folder before opening ArcMap to ensure folder pathways are correctly set.
- [Create a folder connection.](#)

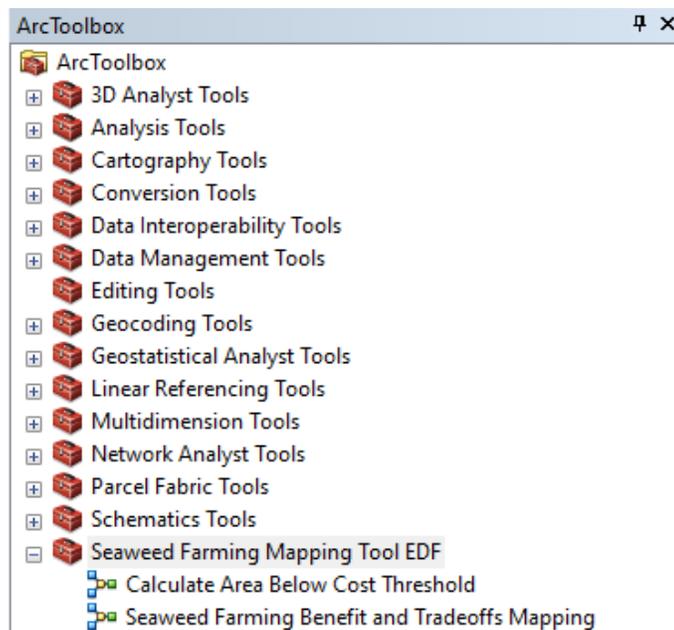
2. **Load the toolbox in ArcMap (for ArcGIS Pro instructions, see Step 3)**

- Open the ArcToolbox pane in ArcMap by clicking the red toolbox button.
- Right-click "ArcToolbox" at the top of the pane and select "Add Toolbox."



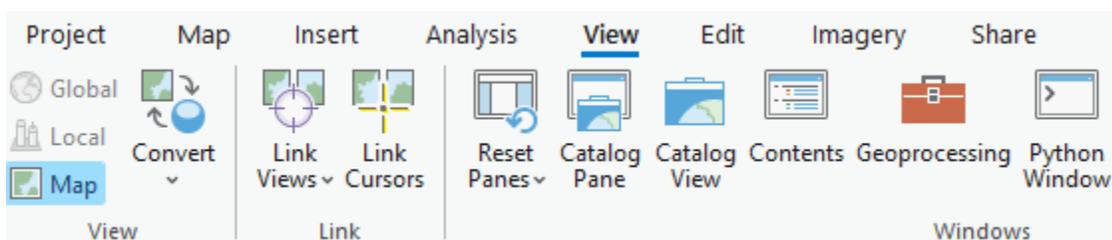


- In the window that opens, navigate to the folder where the toolbox is saved. *Single click* the appropriate .tbx file name and then click “Open.” Do not double click the toolbox name.
- Find the toolbox name in the ArcToolbox pane. Double click on the name to show individual models inside the toolbox. Toolboxes and the models within them appear in alphabetical order.
- Double click on “Calculate Area Below Cost Threshold” to open this module.

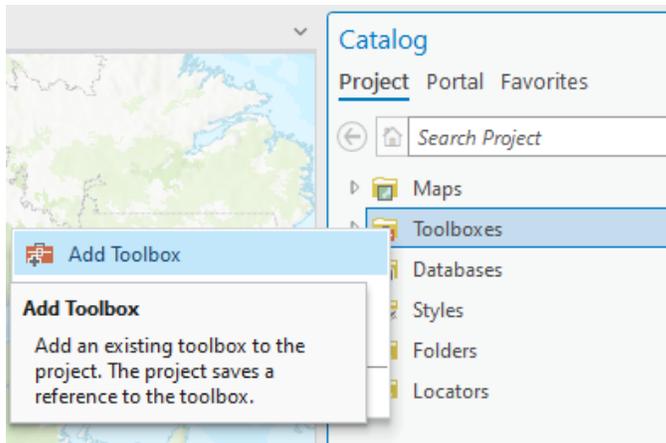


3. Load the toolbox in ArcGIS Pro (for ArcMap instructions, see Step 2)

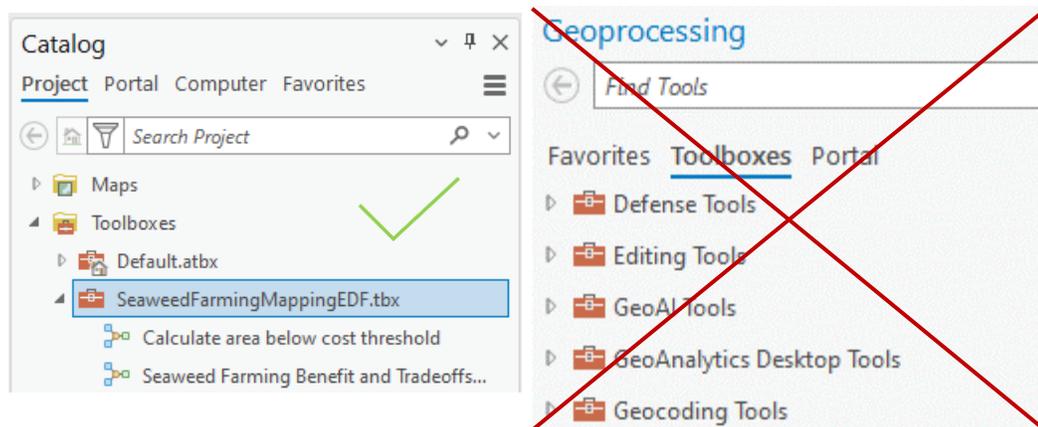
- On the Ribbon, navigate to the View tab and open the Catalog Pane.



- In the pane that opens, right click on “Toolboxes” and select “Add Toolbox.”



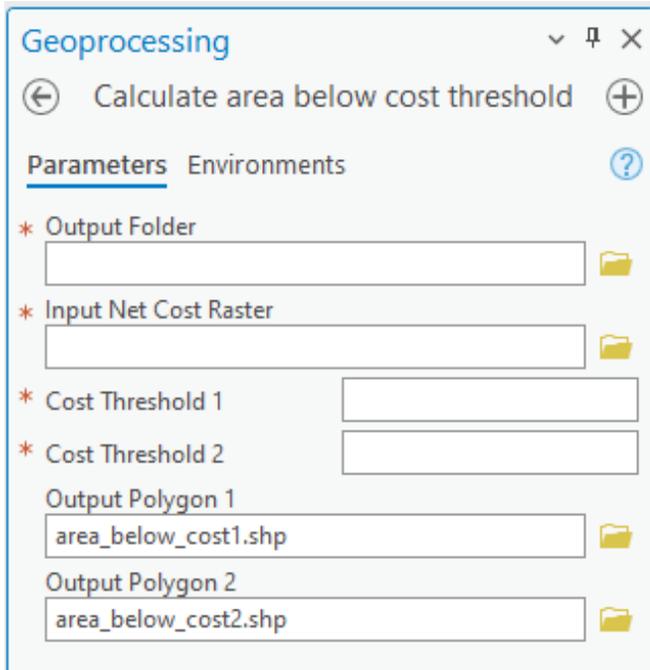
- In the window that opens, navigate to the folder where the toolbox is saved. *Single click* the appropriate .tbx file name and then click “Open.” Do not double click the toolbox name.
- Find the toolbox name in the Catalog Pane. Double click on the name to show individual models inside the toolbox. Toolboxes and the models within them appear in alphabetical order. Note that this imported toolbox will not appear in the regular list of toolboxes in the Geoprocessing Pane.



- Double click on “Calculate Area Below Cost Threshold” to open this module.

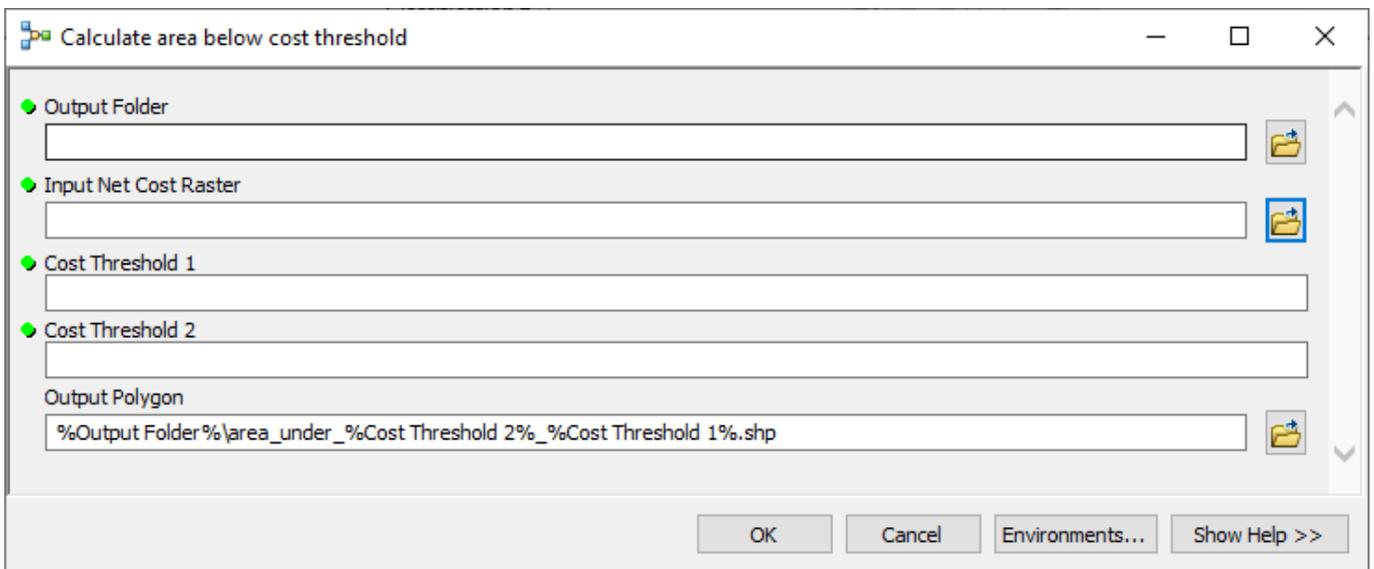
4. Set the location for storing output

- Click the folder browser button  next to line for Output Folder and select the desired folder for where the output file will be saved.
- Alternatively, navigate to the folder in Windows Explorer. Copy and paste the file path into the line for Output Folder.



5. Add inputs

- Click the folder browser button and navigate to the folder with the input data to load the input raster to the line for Input Net Cost Raster. Alternatively, drag and drop the raster file in to this line from Windows Explorer. In the sample data, this file is titled “*CostRaster_products_SA.tif*”.
- Type the desired numbers for the cost thresholds (e.g., Cost Threshold 1 = 1400, Cost Threshold 2 = 0). Note that Cost Threshold 1 must be larger than Cost Threshold 2.
- Leave the Output Polygon name as the default or change it to the desired file name. Note that files ending in “.shp” cannot be saved inside a geodatabase.



- For the ArcMap version: If any negative numbers are used for Cost Thresholds, the default Output Polygon name must be changed because the negative sign cannot be used in files saved inside a geodatabase.

6. Run the tool

- Once the input rasters and cost thresholds have been set click ‘OK’ and the model will run.
- To view the model status click on ‘Geoprocessing pane’ and ‘Results’. Here you can view the status of the model being run with what stage the model is currently processing.
- A spinning globe icon or progress bar indicating percent completion may appear at the bottom right of the window to indicate the model is being processed. There may be a lag between when the model completes and when outputs show up on the map.

7. View the output

- This tool will save one output polygon in the chosen folder.
- The area (km²) in which seaweed can be farmed at costs meeting or below each cost threshold is in the "AREA GEO" field of the attribute table.
- The cost thresholds are recorded in the "gridcode" field of the attribute table.
- Adjust the [symbology to assign colors](#) based on cost thresholds to visualize where seaweed can be farmed at the specified costs.

Supplemental Information

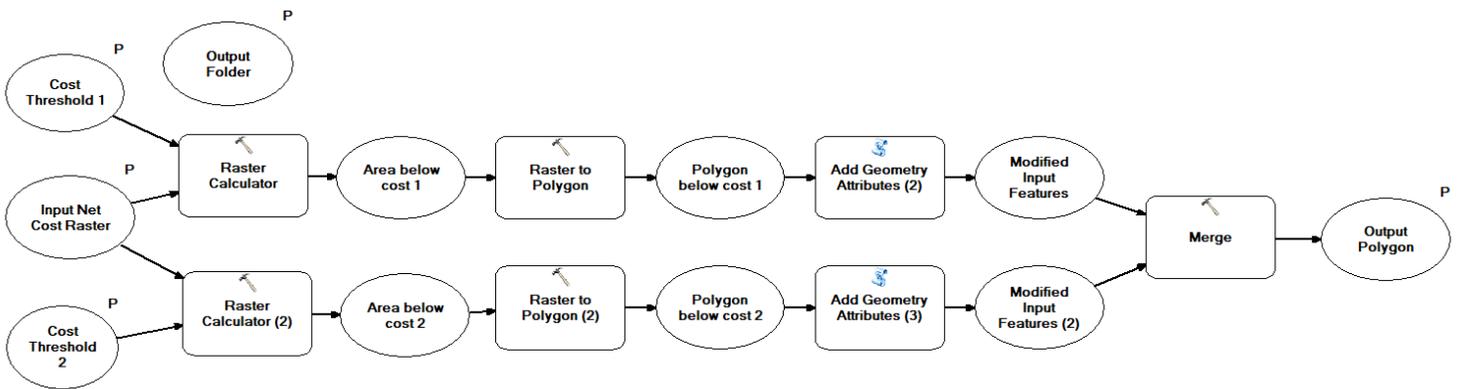


Figure S1. Detailed ArcMap geoprocessing steps for the Area Below Cost Threshold module. “P” indicates “model input” where user designates an input file, number, directory, or file. Note that in ArcGIS Pro 3.0+, the “Add Geometry Attributes” step is renamed as “Calculate Geometry Attributes.”

Sample data

The sample raster “*CostRaster_products_SA.tif*” shows net cost to farm seaweed used for products that reduce greenhouse gas emissions. This input data relies on a global model of average costs to farm seaweed and prices received for that product. The net cost is distributed across the net greenhouse gas reduction for the volume of product made with seaweed harvested from each grid cell (Arzeno-Soltero et al. 2023, DeAngelo et al. 2023). These data are provided “as-is” with no warranty regarding their suitability for use in any given location. Costs of farming and prices for seaweed may vary by location.

References

- Arzeno-Soltero, I.B., B.T. Saenz, C.A. Frieder, M.C. Long, J. DeAngelo, S.J. Davis, and K.A. Davis. 2023. Large global variations in the carbon dioxide removal potential of seaweed farming due to biophysical constraints. *Communications Earth and Environment*, 4: 185. <https://doi.org/10.1038/s43247-023-00833-2>.
- DeAngelo, J. B.T. Saenz, I.B. Arzeno-Soltero, C.A. Frieder, M.C. Long, J. Hamma, K.A. Davis, S.J. Davis. 2023. Economic and biophysical limits to seaweed farming for climate change mitigation. *Nature Plants*, 9: 45-57. <https://doi.org/10.1038/s41477-022-01305-9>.