

Obtaining Submerged Aquatic Vegetation Coverage from Satellite Imagery and Confusion Matrix Analysis

> Brian Madore April 7, 2015

This document shows the procedure for obtaining a submerged aquatic vegetation (SAV) map using satellite imagery for a shallow coastal environment. The SAV detected in this process is not distinguished between different types or classifications of vegetation. The last part of the procedure documents how to perform a confusion matrix analysis of the SAV detection results. In order to conduct the analysis a reference dataset (or ground truth data) is required.

- A. Obtaining Landsat 8 Imagery
 - A.1. Landsat 8 imagery can be downloaded from <u>http://earthexplorer.usgs.gov/</u>. A login is required, however registration is free and easy to obtain.
 - A.2. Once logged in zoom to the place of interest on the map. Create a polygon around the area of interest by clicking on the map to create the vertices of the polygon.



A.3.If there are any date constraints that need to be used input those under the Search

Criteria tab.

- A.4. Select Data Sets.
- A.5. Open the Landsat Archive section and select L8 OLI/TIRS.



A.6. Open the **Results** tab and search for the image desired for download. Select **Download**

Options on the desired image.

Se	arch Criteria	Data Sets Additional Criteria Results
lf y the		Results d more than one data set to search, use to see the search results for each specific
Sh	ow Result C	ontrols 👻
Da	ta Set	Click here to export your results » 🕑
L8	OLI/TIRS	T
26		Entity ID: LC8013032014228LCNN00 Coordinates: 38.9044773.7764 Acquisition Date: 16-AUG-14 Path: 13 Row: 33
27	Ĵ	Entity ID: LC80140322014219LGN00 Coordinates: 40.33295.74.87253 A equisition Date: 07-AUG-14 Path: 14 Row: 32
28	P	Entity ID: LC801 Download Options Coordinates: 40.33278,-73.32049 Acquisition Date: 31-JUL-14 Path: 13 Row: 32

A.7. Select Level 1 GeoTIFF Data Product for download.

n		Princeton Mariboro Red Bank Township Middletown Township rence Manalaban Colts Neck Long Branch mship East Windoor Township Freehold June Date	
ster hami ove	Download Op		×
E	Download	LandsatLook "Natural Color" Image (5.7 MB)	
	Download	LandsatLook "Thermal" Image (2.0 MB)	
-	Download	LandsatLook "Quality" Image (446.6 KB)	
\ J	Download	LandsatLook images with Geographic Reference (8.1 MB)	
ces	Download	Level 1 GeoTIFF Data Product (897.1 MB)	
		rton State Forest 3 O Stafford Township Long Each Lindu	

- A.8. Once downloaded unzip the file and save the data to a desired folder. It is recommended that the folder the unzip files are saved in be created with the date of the satellite imagery's acquisition date.
- **B.** Creating algorithms to mask deep channels
 - B.1. In ArcMap select Add Data.



B.2. Add bands 2, 3, 4, and 6 to the data frame. If it asks to create pyramids, select yes.

Add Data		×
Look in: 🛅 🛛	Procedural_guide_items	- 🕹 🏠 🗔 🏥 - 🖆 🖆 💱
LC80140322 LC80140322 LC80140322	014219LGN00_B1.TIF 014219LGN00_B10.TIF 014219LGN00_B11.TIF 014219LGN00_B2.TIF	LC80140322014219LGN00_B5.TIF LC80140322014219LGN00_B6.TIF LC80140322014219LGN00_B7.TIF LC80140322014219LGN00_B8.TIF LC80140322014219LGN00_B9.TIF LC80140322014219LGN00_BQA.TIF LC80140322014219LGN00_MTL.txt
	014219LGN00_B3.TIF 014219LGN00_B4.TIF	
, Name: Show of type:		00_B2.TIF; LC80140322014219LGf Add
	Datasets, Layers and Re	esuits Cancel

- B.3. Using band 6, which is the IR band, the threshold between the land and water surfaces will need to be distinguished. Because water absorbs IR radiation this difference in the IR values for land and water surfaces will be used to mask out all of the land features. There are a couple of ways of determining the threshold.
- B.4. If possible, using the 3D analyst tool is the easiest way to determine the value between the land/water threshold. Go to Customize>Toolbars and select the 3D Analyst toolbar. In the toolbar there is a dropdown box which can be used to select different layers. Select the band 6 layer.



B.5. Select Interpolate Line on the toolbar.



B.6. Draw a line that goes over both land and water.



B.7. Select **Profile Graph** on the 3D Analyst toolbar.



B.8. The profile graph will show the values of the IR band over the red line extent. The land IR values will be higher values and the water values will be a consistent lower value. The graph below shows the IR values for this example. All of the water values are below the value of 7000, and the land values are all much higher. Therefore the value of 7000 will be the threshold for this specific image. **Important:** each satellite image, even if collected from the same satellite, will have a different threshold value.



B.9. If the 3D Analyst toolbar cannot be used, the other way to determine the threshold difference is to use the identify tool on the band 6 layer.



- B.10. Select multiple points in the water, on land, and near the water/land boundary to determine what the typical values for the IR band are. A threshold value then should be selected where all values below the threshold value are water and all values above the threshold are land values.
- B.11. In the ArcToolbox select Spatial Analyst Tools>Conditional>Set Null.
- B.12. For the input conditional raster select the Landsat 8 band 6 (IR band). For the Expression use "Value" > (threshold value) OR "Value" = 0

IMPORTANT: Make sure the expression is used correctly, see the below expression as

an example, but make sure to input the correct threshold value for the image being examined, instead of the 7000 which is the value for the image in this procedure. Select the band 2 (blue band) for the **false raster**. Select the folder icon next to **Output Raster** to designate a location to save the layer being created. Name the layer L8_h2o_blue (or similar). This layer being created is using the IR band to mask out all values from the IR band that are considered land by the threshold value on the blue band.

* Set Null	
Input conditional raster LC80140322014219LGN00_B6.TIF	· 🖻
Expression (optional)	
"Value" > 7000 OR "Value" = 0	SQL
Input false raster or constant value	
LC80140322014219LGN00_B2.TIF	- 🖻
Output raster	
V:\Morphology\B_madore_work\Sandy\Landsat_processing\Procedural_guide_items\L8_h2o_blue	
OK Cancel Environments	Show Help >>

- B.13. Repeat step B.11. and B.12. using band 3 as the **false raster** and saving the layer as L8_h2o_green (or similar).
- B.14. Repeat step B.11. and B.12. using band 4 as the false raster and saving the layer as L8_h2o_red (or similar).
- B.15. In the ArcToolbox select Spatial Analyst Tools>Math>Float.
- B.16. For the **input raster** select L8_h2o_blue. Select a destination to save the **output raster** and name the layer L8_float_blue (or something similar).

* Float	_ _ ×	
Input raster or constant value	A	
L8_h2o_blue	- 🖻	
Output raster		
V:\Morphology\B_madore_work\Sandy\Landsat_processing\Procedural_guide_items\8_float_b	lue 🔁	
	-	,
OK Cancel Environments	. Show Help >>	

- B.17. Repeat steps B.15. and B.16. using the L8_h2o_green for the **input raster** and saving the **output raster** as L8_float_green (or similar).
- B.18. Repeat steps B.15. and B.16. using the L8_h2o_red for the **input raster** and saving the **output raster** as L8_float_red (or similar).
- B.19. In the ArcToolbox select Spatial Analyst Tools>Neighborhood>Filter.
- B.20. Select L8_float_blue for the **input raster**. Save the output raster as L8_lpf_blue (or similar). **Filter type** should be set to LOW.

* Filter	- • ×
Input raster 8_float_blue	- <u></u>
Output raster V:\Morphology\B_madore_work\Sandy\Landsat_processing\Procedural_guide_items\L8_lpf_blue Filter type (optional)	
LOW Ignore NoData in calculations (optional)	-
OK Cancel Environments	Show Help >>

- B.21. Repeat steps B.19. and B.20 using L8_float_green for the **input raster** and saving the **output raster** as L8_lpf_green (or similar).
- B.22. Repeat steps B.19. and B.20 using L8_float_red for the **input raster** and saving the **output raster** as L8_lpf_red (or similar).
- B.23. In the ArcToolbox select Spatial Analyst Tools>Map Algebra>Raster Calculator.
- B.24. Input the equation Ln("L8_lpf_blue")/Ln("L8_lpf_green").

See the following figure for reference. Save the **output raster** as L8_blu_grn.

Kaster Calculator	the second se		
Map Algebra expression Layers and variables L8_high_slope I8_bathy_cut 12324_5.KAP	7 8 9 / == != & 4 5 6 * >>= 1 2 3 - <=	Exp10 Exp2 Float Int Ln Log10 Log2 Mod	*
Ln("L8_lpf_blue") / Ln("L8_lpf_grn") Output raster V:\Morphology\B_madore_work\Sandy\Landsat_pr			+
	OK Cancel Environ	Show Help >>	

B.25. Repeat steps B.23. and B.24. using the equation

Ln("L8_lpf_green")/Ln("L8_lpf_red") Save the output raster as L8_grn_red.

NOTE: The naming of the files should be monitored carefully. Since most likely multiple images from different dates will be analyzed and processed, saving the output rasters with the date in the layer name can be useful.

The naming convention for the layers used in this procedure are basic in order to provide structure to the workflow.

C. Extracting the study area

- C.1. A shapefile of the study area will need to be created in order to extract the preceding layers. If a study area shapefile already exists, skip to C.10.
- C.2. Open the **Catalog** by selecting the following icon.



C.3. In the **Catalog** navigate to the folder where the shapefile being created will be saved.

C.4. Right-click the folder and select **New > Shapefile.**



C.5. Name the shapefile SAV_study_area. Select **Polygon** for the feature type. Select **Edit** to choose the correct spatial reference for your shapefile (**NOTE:** This spatial reference is unique to your work and should not be copied from the one in this example, unless the work corresponds to that area). Select **OK**.

Create New Shapefile		x
Name:	SAV_study_area	
Feature Type:	Polygon	-
Spatial Reference		
Description:		
Projected Coordinate Name: WGS_1984		*
Geographic Coordina Name: GCS_WGS		
		Ŧ
	4	
Show Details	Edit	
	ontain M values. Used to store route da ontain Z values. Used to store 3D data.	
	OK	cel

C.6. Right-click on the SAV_study_area shapefile in the table of contents. Select Edit Features > Start Editing.

Table Of Contents	ч ×	N \$/
🏡 🏮 😞 📮 🗉		
🗉 🥩 Layers		Color Color
Error_matrix		
SAV study a		
	<u>Copy</u>	
🗉 🗌 Shapefile_ 🗙	<u>R</u> emove	
	Open Attribute Table	
🗄 🗌 habitat_h2		and the second se
	Joins and Relates	· ·
🕀 🗌 L8_blu_gri 🔍	Zoom To Layer	
⊕ □ 18_lpf_red	Zoom To Make Visible	
⊞ 🔲 l8_lpf_grn	Visible Scale Range	
⊞ 🔲 l8_lpf_blu		
	Us <u>e</u> Symbol Levels	
⊞ 🔲 l8_flt_grn	Selection	
⊞ 🔲 l8_flt_blu	Label Features	
	Edit Features	<u>Start Editing</u>
	Convert Labels to Annotation	Define N
	Convert Features to Graphics	Start Editing
	Convert Symbology to Representation	Start an edit session on the
	Convert symbology to Representation	workspace containing this layer.
	<u>D</u> ata	For example, if you right-click a
	Save As Layer File	layer from a geodatabase and start editing it, you are able to edit all
🕀 🗌 Vegetation		the other layers from that same
🕀 🗌 Post_bath 📦		geodatabase.
🕀 🗌 Channel_r 💊	1 Topertiesin	
E L8_green_rea		

C.7. Open the **Create Features** tool on the **Editor** toolbar.



C.8. Select SAV_study_area in the **Create Features** window. Select **Polygon** to start constructing the shapefile. Create the polygon by clicking to create the vertices of the polygon. Once the polygon is finished double click the last vertex.



C.9. Select Editor > Save Edits. Then select Editor > Stop Editing.



C.10. In the ArcToolbox select Spatial Analyst Tools>Extraction>Extract by Mask.

C.11. Select L8_blu_grn for the **input raster**. Select the SAV_study_area (or other shapefile) for the **feature mask data**. Select a location to save the **output raster** and name the layer SA_blu_grn (or other name).

Input raster	Extract by Mask		x
Input raster or feature mask data SAV_study_area Image: Comparison of the second s	Input raster		1
SAV_study_area Output raster V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\SA_blu_grn	L8_blu_grn	- E	
Output raster V: \Morphology \B_madore_work \Vegetation_barnegat \Processed \Vegetation_Procedure \SA_blu_grn	Input raster or feature mask data		
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\SA_blu_grn	SAV_study_area	- <u></u>	
	Output raster		
OK Cancel Environments Show Help >>	V:\Morphology\B_madore_work\Veget	ation_barnegat\Processed\Vegetation_Procedure\SA_blu_grn	
OK Cancel Environments Show Help >>		_	
OK Cancel Environments Show Help >>			
		OK Cancel Environments Show Help >>	•

- C.12. Repeat C.10 and C.11 using L8_grn_red for the **input raster**. Save the **output raster** as SA_grn_red (or other).
- **D.** Removing the deep channels.
 - D.1. The algorithm layers created in step B are going to be used to mask out deep channels that are located throughout the study area. The reasoning for creating the algorithms are that the deep channels have the same optical signature as vegetation in the green wavelength and would be falsely identified as SAV in the proceeding steps. The algorithms are used to identify only the deep channels in order to remove them before proceeding to the steps that identify SAV. The blue/green algorithm and green/red algorithm were both created because certain satellite images will have a better detection of the deep channels of one or the other. Depending on the study area there may not be any deep channels or other optically similar areas to vegetation that need to be removed using this process.
 - D.2. Determine which algorithm will be used to mask the channels by comparing the deep channel areas with the shallow areas for the SA_blu_grn and SA_grn_red. The deep channels should have a strong signal (either positive or negative) compared to the surrounding areas. It may be essential to examine RGB imagery of the area or to gain an understanding of the study area to in order to know the locations of the deep channels.

Based on these factors, this procedures SA_grn_red layer will be used to mask the deep channels. Note: determining which algorithm layer to use is based on visual inspection, it may be important to change the layers' symbology to get better contrast.

D.3. Once a layer has been chosen the threshold value which separates the deep channel from the non-deep areas must be determined. Using the 3D analyst toolbar is the easiest method. Select the SA_grn_red layer (or other depending on what was chosen) in the 3D analyst toolbar. Select **Interpolate Line** on the toolbar.



D.4. Create a line segment which crosses over at least one deep channel (make sure the line also goes over non-deep areas as well).



D.5. Select **Profile Graph** in the 3D analyst toolbar.



D.6. Determine where the threshold value between deep and non-deep water is by comparing the peaks of the graph for the deep channel areas. The following graph shows the



corresponding deep channels at 800 - 1000 and at 2400 - 2600. In order to get rid of those peaks a threshold value of 1.019 will be used.

D.7.In the ArcToolbox select Spatial Analyst Tools>Conditional>Set Null.

D.8.Select SA_grn_red for the **input conditional raster** (or other). For the **Expression** use "Value" > (**Value determined from step D.6.**) Select SA_grn_red (or other) for the **false raster**. Save the **output raster** as deep_mask. See the following figure to help with the input for the **Expression**.

SA_grn_red	🗾 🖻
Expression (optional)	
"Value" > 1.019	squ
Input false raster or constant value	
inport tobe tobeter of company to tobe	
SA_grn_red	
-	✓ 2010

- D.9. The deep_mask will cover the same area with the deep channels missing. It may be that the threshold value determined in D.6.was slightly off. If that is the case and a different threshold value should be tried then adjust the threshold value slightly in step D.8. until a coverage which eliminates the deep channels correctly is found. Note: Do not be overly strict with the channel removal. It is important to not remove shallow water areas.
- D.10. The following figure shows the SA_grn_red on the left with the deep channels in lighter colors. The figure on the right is the deep_mask with the channels removed.



D.11. In the ArcToolbox select Spatial Analyst Tools>Extraction>Extract by Mask
D.12. Select the green band from the satellite bands (this is band 3 for Landsat 8) for the input raster. Select the deep_mask for the feature mask. Save the output raster as L8_grn_mask (or other name, if desired).

🔨 Extract by Mask	- • ×
Input raster	~
LC80130322014180LGN00_B3.TIF	- 🖻
Input raster or feature mask data	
deep_mask	⊥ 🖻
Output raster V:\Morphology\B madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\L8_grn_mask	
v. vioi phology (p_madore_work (vegetation_bannegat (Processed (vegetation_Procedure (co_grin_mask	
OK Cancel Environments	Show Help >>

E. Determining the Extent of SAV

E.1. With the deep channels removed from the green band, the deep areas with the same optical signal as vegetation have been removed from the green band. Determining the

extent of the SAV is similar to steps D.3. to D.6. where the threshold value between vegetated and non-vegetated needs to be determined.

E.2. Select L8_grn_mask in the **3D analyst toolbar**. Select **interpolate line**.



E.3. Draw a line segment that crosses over areas of vegetation (dark areas of L8_grn_mask) and non-vegetated areas as well. Note: for this particular satellite image the distinction between vegetation and non-vegetated values is very low. Using the symbology tab to adjust the visual properties is helpful in distinguishing visually the vegetated areas.



E.4. Select Profile Graph in the 3D analyst toolbar.



E.5. Examine the graph to find a threshold value that distinguishes vegetated regions from non-vegetated areas. For this graph the vegetated areas were determined to be at areas



from 1300 - 1600 and 2200 - 2300. Based on these areas the vegetated areas are found at regions below a value of 8400.

- E.6. In the ArcToolbox select Spatial Analyst Tools>Conditional>Set Null.
- E.7. For the input raster select L8_grn_mask. For the Expression use "Value" > (value determined in E.5.) For the false raster input 1. Save the output raster as SAV_area. See the following figure for help inputting the expression correctly.

, Set Null	
Input conditional raster	
L8_grn_mask	I 🖻
Expression (optional)	
"Value" > 8400	SQL
Input false raster or constant value	
1	– 🔁
Output raster	
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\SAV_area	
	_
OK Cancel Environments	Show Help >>

- E.8. If the resulting SAV region needs to be adjusted try changing the threshold value in small amounts.
- E.9. The SAV regions have now been determined. The figure on the left is L8_lpf_green and the figure on the right is L8_lpf_green with SAV_area (in green) covering it.



F. Confusion Matrix

F.1. The confusion matrix is a technique used to statistically analyze the results of certain datasets. For the SAV datasets the confusion matrix is going to be used to compare the regions that were determined to be SAV (SAV_area layer created in step E.8.) with a

dataset collected by Rutgers Universisty at the Grant F. Walton Center for Remote Sensing and Spatial Analysis. This dataset is from 2009 and gives SAV coverage over Barnegat Bay, NJ and will be the actual dataset (called reference dataset in this guide, as well), whereas the SAV_area will be the predicted dataset. The confusion matrix is going to compare vegetation and non-vegetated regions for the predicted and actual datasets. NOTE: Raster calculator is going to be used to determine the values for the confusion matrix, therefore some layers are going to be converted from shapefile/polygon to rasters.

The following table is how the confusion matrix is set up. The values representing when each case is correct will be explained as the procedure continues.

N=?	Predicted: Vegetated	Predicted: Non-vegetated
Actual/Reference: Vegetated	When value = 11	When value = 21
Reference: Non-vegetated	When value = 10	When value = 20

- F.2. Since the SAV_area has only values for vegetated areas, a background needs to be added for all areas that are non-vegetated. In the ArcToolbox select Conversion Tools>To
 Raster>Polygon to Raster.
- F.3. Select the SAV_study_area for the input features. Save the output raster as study_raster. Select 30 for the cellsize (this is because the Landsat 8 satellite imagery is at 30 meter resolution. If another imagery type was used to create the SAV_area use the corresponding cellsize and not 30). IMPORTANT: Make sure study_raster has only values of 0 when created.

N Polygon to Raster	
Input Features	
SAV_study_area	I 🖆 🛛
Value field	
FID	-
Output Raster Dataset	
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\study_raster	2
Cell assignment type (optional)	
CELL_CENTER	-
Priority field (optional)	
NONE	-
Cellsize (optional)	
30	
	~
OK Cancel Environments	Show Help >>

- F.4. In the ArcToolbox select Data Management Tools>Raster>Raster Dataset>Mosaic To New Raster.
- F.5. For the input rasters add SAV_area and study_raster. Set the output location to the folder where the raster will be saved. Use Raster dataset name with extension to name the raster as SAV_area_mos. Set number of bands to 1. Set Mosaic Operator to MAXIMUM. The resulting raster will contain values of 1 for SAV areas and a value of 0 for non-vegetated areas.

Mosaic To New Raster		_ 0 ×
Input Rasters		
		-
1		
♦ SAV_area		+
♦ study_raster		
		×
		➡
Output Location		
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation	Procedure	
Raster Dataset Name with Extension		
SAV_area_mos		
Spatial Reference for Raster (optional)		
		P
Pixel Type (optional)		
8_BIT_UNSIGNED		•
Cellsize (optional)		
Number of Bands		
		1
Mosaic Operator (optional) MAXIMUM		
		•
Mosaic Colormap Mode (optional)		
FIRST		•
		ohann Uala a s
	OK Cancel Environments	Show Help >>



- F.6. In the ArcToolbox select Spatial Analyst Tools>Conditional>Con.
- F.7. For the input raster select SAV_area_mos. Set the Expression to: "Value" > 0 Set the input true raster to 10. Set the false raster to 20. Save the output raster as SAV_predicted. This step makes the SAV areas have a value of 10 and the nonvegetated areas have a value of 20.

Con			
Input conditional raster			*
SAV_area_mos	-	2	
Expression (optional)			
"Value" > 0		SQL	
Input true raster or constant value			
10	•	2	
Input false raster or constant value (optional)		_	
20	•	2	
Output raster		_	
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\SAV_predicted		2	
			Ŧ
OK Cancel Environments	Show H	lelp >>	

F.8. The resulting SAV_predicted will have two values. 10 for vegetated regions determined from the SAV_area from step E in this guide and value 20 for all other areas covering the study area.



- F.9. The next steps are used to change the Rutgers dataset for SAV to a raster file. If the dataset being used to compare your SAV_area is not a raster file and is a shapefile, follow these steps to convert it into a raster layer.
- F.10. In the ArcToolbox select Analysis Tools>Extract>Clip.
- F.11. For the **input feature** select the reference dataset you are utilizing. For the **clip features** select SAV_study_area. Save the **output feature class** as reference_cut.

Clip	
Input Features	*
Vegetation_Rutgers_SAV\bbleh_sav09	- 🖻
Clip Features	
SAV_study_area	I 🖻
Output Feature Class	
V: \Morphology \B_madore_work \Vegetation_barnegat \Processed \Vegetation_Procedure \reference_cut.shp	
XY Tolerance (optional)	
Mete	s ▼]
	Ŧ
OK Cancel Environmen	s Show Help >>

- F.12. In the ArcToolbox select Conversion Tools>To Raster>Polygon to Raster.
- F.13. For the input feature select reference_cut. The value field is going to be dependent on how the shapefile is set up, but FID should be acceptable as long as the reference dataset is of only SAV regions, otherwise this may need to change. Select output raster and name it reference_ras. Set the cellsize to the same value as being used in step F.3. (Reminder: this depends on the satellite imagery used to create the predicted SAV_area).

Polygon to Raster	
Input Features	
reference_cut	
Value field	
FID	•
Output Raster Dataset	
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\Reference_ras	2
Cell assignment type (optional)	
CELL_CENTER	-
Priority field (optional)	
NONE	-
Cellsize (optional)	
30	6
OK Cancel Environments	s Show Help >>

F.14. In the ArcToolbox select Spatial Analyst Tools>Conditional>Con.

F.15. For the **input raster** select Reference_ras. For the **Expression** use:

"Value" >= 0

Set the **true raster** value to 1 and leave the **false raster** blank. Save the raster as Reference_con.

Input conditional raster Reference_ras Expression (optional) "Value" >= 0 Input true raster or constant value 1 Input false raster or constant value (optional) Input false raster or constant value (optional) Input false raster or constant value (optional) V: \Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure \Reference_con	🔨 Con	
Expression (optional) "Value" >= 0 Input true raster or constant value 1 Input false raster or constant value (optional) Output raster V: \Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\Reference_con	Input conditional raster	^
"Value" >= 0 Input true raster or constant value 1 Input false raster or constant value (optional) Imput false raster or constant value (optional) Imput raster Output raster V: Morphology \B_madore_work \Wegetation_barnegat \Processed \Wegetation_Procedure \Reference_con	Reference_ras	- 🖆
Input true raster or constant value 1 Input false raster or constant value (optional) Input false raster or constant value (optional) Imput false raster Output raster Imput false raster or constant value (optional) V: \Morphology \B_madore_work \Vegetation_barnegat \Processed \Vegetation_Procedure \Reference_con Imput false	Expression (optional)	
1 Input false raster or constant value (optional) ✓ ✓ Output raster V: \Morphology \B_madore_work\Wegetation_barnegat\Processed\Wegetation_Procedure\Reference_con	"Value" >= 0	SQL
input false raster or constant value (optional) Input false raster or constant value (optional) Output raster V: \Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\Reference_con	Input true raster or constant value	
	1	- 2
Output raster V: \Morphology \B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\Reference_con	Input false raster or constant value (optional)	_
V: Worphology \B_madore_work \Vegetation_barnegat \Processed \Vegetation_Procedure \Reference_con		- 🖆
	Output raster	
	V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\Reference_con	6
· · · · · · · · · · · · · · · · · · ·		_
		-
OK Cancel Environments Show Help >>	OK Cancel Environments Sh	ow Help >>

F.16. In the ArcToolbox select Data Management Tools>Raster>Raster Dataset>Mosaic To New Raster.

F.17. Add Reference_con and study_raster for the input rasters. Select the folder to save the raster in the output location. Name the raster as SAV_reference in Raster dataset name with extension. Set number of bands to 1. For the Mosaic operator choose MAXIMUM.

Mosaic To New Raster		
Input Rasters		_
		- 🖻
, 		
Reference_con		-
study_raster		
		×
		►
		_
Output Location		
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Veget	ation Procedure	
Raster Dataset Name with Extension		
SAV_reference		
Spatial Reference for Raster (optional)		
Pixel Type (optional)		
8_BIT_UNSIGNED		-
Cellsize (optional)		
Number of Bands		
		1
Mosaic Operator (optional)		-
MAXIMUM		-
Mosaic Colormap Mode (optional)		
FIRST		
11/01		•
	OK Cancel Environments Sho	ow Help >>

F.18. The resulting raster file for SAV_reference should have values of 1 for SAV regions and values of 0 for the non-vegetated areas.



F.19. In the ArcToolbox select Spatial Analyst Tools>Map Algebra>Raster Calculator.

F.20. For the expression use:

"SAV_reference" + "SAV_predicted"

Save the **output raster** as Matrix_result.

Layers and variables Frror_matrix\Final_products\Worth_Sedge_Area Error_matrix\Final_products\Worth_Sedge_Area	a\07aug2014_sedge a\31jul2014_sedge a\22jul2014_sedge a\22jul2014_sedge a\29jun2014_sedge a\10apr2014_sedge ▼ }	7 8 9 4 5 6 1 2 3 0 .		Conditi Con Pick SetNull Math Abs Exp Even10	-	
V:\Morphology\B_madore_work\Vegetation_barneg	at Processed Vegetatio	on_Procedure (Matrix	k_result			

F.21. The resulting layer will have 4 unique values: 10, 11, 20, and 21. Each of these values corresponds to a different cell in the confusion matrix. The following table shows the corresponding results.

Value	Predicted Layer	Reference Layer
10	Vegetated Cell	Non-Vegetated Cell
11	Vegetated Cell	Vegetated Cell
20	Non-Vegetated Cell	Non-Vegetated Cell
21	Non-Vegetated Cell	Vegetated Cell

F.22. The amount of cells for each value, which can be translated to area, can be obtained by right-clicking on the Matrix_result layer in the table of contents and selecting **Open Attribute Table.**



F.23. The table shows the Value and the corresponding count which is the number of cells with that value. Using the cell size (which is 30 meter by 30 meter for this procedure) the area corresponding to each cell size can be obtained by multiplying COUNT by the cell size.

Tał	ble			□ ×	
0	- B	- 🍡 🧏	y 🖸 🕀	×	
Ma	trix_result	t		×	
	Rowid	VALUE	COUNT		
Þ	0	10	1004		
	1	11	5801		
	2	20	62426		
	3	21	8844		
	I ← 1 → → I I I ← (0 out of 4 Selected) Matrix_result				

F.24. Computing the accuracy of the confusion matrix can be done by adding the COUNT for the VALUE 11 with VALUE 20, and then dividing that by the total count.

(5801 + 62426)/(1004 + 5801 + 62426 + 8844) = .8739

G. Supplemental Confusion Matrix notes.

- G.1. The confusion matrix example provided for this procedure in part F focused on comparing vegetation detection versus non-vegetated areas. With different imagery datasets the confusion matrix can be modified to include more fields. This include specific types of vegetation, density of vegetation, or various other detections/predictions that statistics want to be calculated for.
- G.2. The changes that would be made to the datasets would involve creating rasters that have more values than the binary components created above. In order to do this slight changes to the procedure need to be made.
- G.3. Adding fields to the prediction layer (beyond 2)
 - G.3.1. In part F the prediction layer was created by first mosaicing the two different datasets, then using the conditional tool to change the values to the confusion matrix values. For more than 2 different components in the prediction layer each raster will first be changed to its appropriate confusion matrix value then all the rasters will be mosaiced together.
 - G.3.2. For the values to be used for the prediction layer of the confusion matrix it is important to use values of 10. Therefore this example with 3 different density type

predictions of SAV the following values will be used. **NOTE:** If there are more components of the prediction layer being examined simply add more components. As long as the numeric value is a factor of 10 the confusion matrix process will work correctly.

Numeric Value	Prediction Layer Description of SAV
10	Dense Vegetation
20	Moderate Vegetation
30	Sparse Vegetation
40	Non-Vegetated Region

- G.3.3. If the individual layers are still in shapefiles use the following steps. This will convert the values during the raster making process to the appropriate prediction layer value. This example will show the conversion of the dense vegetation prediction layer shapefile.
 - G.3.3.1. Right-click the shapefile layer (Dense_prediction for this example) in the table of contents and select **Open Attribute Table.**
 - G.3.3.2. In the table options select **Add Field**.

Table	•						
:	🖶 - 🖳 🌄 🖾 🐗 🗙						
M	Find and Replace						
5	Select By Attributes						
M	Clear Selection						
2	Switch Selection						
	Select All						
	Add Field						
• **** • ***	Turn Augen Line Add Field	٦.					
~	Show						
	Adds a new field to the table.						
	Restore Default Column Widths						
	Restore Default Field Order						
	Joins and Relates						
	Related Tables						
dh	Create Graph						
	Add Table to Layout						
з	Reload Cache						
۵	Print						
	Reports +						
	Export						
	Appearance						
_							

G.3.3.3. Name the field dense_val (or whatever is appropriate for the dataset being studied). Set the type as short integer, select OK.

Add Field	×
<u>N</u> ame:	dense_val
<u>T</u> ype:	Short Integer
Field Prope	erties
Precision	n [0
	OK Cancel

G.3.3.4. Since this polygon covers only the dense predictions, all of the components to shapefile need to have the dense_val field changed to the appropriate value for the dense vegetation for the confusion matrix. This value

is 10 as shown in the table at G.3.2. Right-click the dense_val header in the attribute table and select **Field Calculator**.

Tal	ble						
0	🖾 • 🖶 • 🖫 🕅 🔯 🗸						
De	Dense_prediction						
	FID	Shape *	ld	dense	val		
	0	Polygon	0		1	Sort <u>A</u> scending	
	1	Polygon	0		7	Sort Descending	
	2	Polygon	0			Advanced Sorting	
	3	Polygon	0				
	4	Polygon Polygon	0			<u>S</u> ummarize	
Н		Polygon	0		Σ	S <u>t</u> atistics	
	0	Polygon	U		×	Field Calculator Calcu Turn Populate or update the values of this field by specifying a calculation expression. If any of the records in the table are currently selected, only the values of the selected records will be calculated.	

G.3.3.5. Input the value 10 into the dense_val expression window and select OK.

Field Calculator		
Parser VB Script Python Fields:	Type: Functions:	
FID Shape Id dense_val	▼ ● Number Abs () Atn () Cos () Exp () ○ String Cos () Exp () ○ Date Fix () Int () Log () Sin () Sqr () Tan ()	
Show Codeblock	* / & + - =]
10	•	
About calculating fields	<u>C</u> lear <u>L</u> oad <u>S</u> ave]
	OK Cancel]

- G.3.3.6. Repeat steps G.3.3.1 to G.3.3.5 for each different component of the prediction layer that is a shapefile, giving the appropriate value in step G.3.3.5 that corresponds to the confusion matrix in step G.3.2 (or the confusion matrix values chosen for the specific project at hand). For this example a moderate_prediction and sparse_prediction shapefile have also been processed.
- G.3.3.7. To create the background layer (aka the non-vegetated layer) repeat steps G.3.3.1 to G.3.3.5 with the SAV_study_area shapefile created in part C (this shapefile will be used to cover the study site and represent the background for all non-vegetated areas) and give it a value of 40 (or the appropriate value based on your data/confusion matrix).
- G.3.3.8. In the ArcToolbox select ConversionTools>To Raster>Polygon to Raster for converting the shapefiles into rasters.
- G.3.3.9. Input the dense_prediction shapefile (or other). Set the value field to dense_val (or the name of the field created which corresponds to the layers confusion matrix value). Save the dataset as dense_predict and set the cellsize to 30 (or to the appropriate value based on your datasets. This uses 30 meter cellsize as Landsat 8 is in 30 meter resolution).

🔨 Polygon to Raster	
Input Features	
Dense_prediction	- 🔁
Value field	_
dense_val	•
Output Raster Dataset	
$\label{eq:processed} V: \cite{there} V: \cit$	
Cell assignment type (optional)	_
CELL_CENTER	•
Priority field (optional)	
NONE	•
Cellsize (optional)	
30	
	_
OK Cancel Environ	Show Help >>

- G.3.3.10. Repeat step G.3.3.9. for each part of the prediction layer of the confusion matrix. For this example that includes the moderate prediction layer, spare layer, and the SAV_study_area (which is the non-vegetated layer).
- G.3.3.11. In the ArcToolbox select **Data Management Tools>Raster>Raster Dataset>Mosaic To New Raster**.
- G.3.3.12. Add all the rasters created in step G.3.3.9 and G.3.3.10 for the prediction part of the confusion matrix. Select the output location for which folder the file will be saved in. Set the name of the layer being created under Raster Dataset name with extension. Set the number of bands as 1. For the Mosaic Operator set the value based on how your datasets are set up. For overlapping components of this example a higher density layer will take priority (therefore if a cell contains both dense and moderate as a value the dense layer will take

priority) (ALSO since the non_veg layer have the highest value in this set up, it should have least priority, feel free to use the LAST and FIRST decisions to customize which layers have priority when mosaicing the multiple rasters together). This example will use minimum for the operator.

Mosaic To New Raster		
Click error and warning icons for more information		×
Input Rasters		
dense_predict		+
mod_predict		
sparse_predct		×
onveg_predct		
Output Location		
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vege Raster Dataset Name with Extension		
Matrix_predct		
Spatial Reference for Raster (optional)		
Pixel Type (optional)		
8_BIT_UNSIGNED		•
Cellsize (optional)		
Number of Bands		
		1
Mosaic Operator (optional)		
MINIMUM		-
Mosaic Colormap Mode (optional)		
FIRST		•
	OK Cancel Env	ironments Show Help >>

G.3.4. If the prediction layers are already individual rasters but with the incorrect values the Con tool will be used to change the values then the layers will be mosaiced together. It may be helpful to still read section G.3.3 entirely through to understand the process.

G.3.4.1. In the ArcToolbox select Spatial Analyst Tools>Conditional>Con.

G.3.4.2. For the **input** select the prediction layer that is having its value changed (for this example it is the dense vegetation area which is being changed to have

the correct raster values associated with the table at G.3.2.). Set the **Expression** to encompass all values of the raster being changed, for this example the following is used: "Value" ≥ 0

Set the **true raster** value corresponding to the confusion matrix table for the association prediction layer. Save the **output raster** as a name fit for the layer being changed.

Input conditional raster dense_area	Con		• • •	3
Expression (optional) "Value" >= 0 Input true raster or constant value 10 Input false raster or constant value (optional) Output raster V: \Morphology \B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\dense_ras	Input conditional raster			*
"Value" >= 0 Input true raster or constant value 10 Input false raster or constant value (optional) ✓ Output raster V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\dense_ras	dense_area	-	2	
Input true raster or constant value 10 Input false raster or constant value (optional) Input false raster or constant value (optional) Output raster V: \Morphology \B_madore_work\\Vegetation_barnegat\Processed\\Vegetation_Procedure\dense_ras	Expression (optional)			
10 ▼ Input false raster or constant value (optional) ▼ Output raster ▼ V: \Morphology \B_madore_work\\Vegetation_barnegat\Processed\Wegetation_Procedure\dense_ras ▼	"Value" >= 0		SQL	
Input false raster or constant value (optional)	Input true raster or constant value			
Output raster V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\dense_ras	10	-	2	
Output raster V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\dense_ras	Input false raster or constant value (optional)			
V: \Morphology \B_madore_work \Vegetation_barnegat \Processed \Vegetation_Procedure \dense_ras		•	2	
	Output raster			
OK Cancel Environments Show Help >>	V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\dense_ras		2	
OK Cancel Environments Show Help >>			_	
OK Cancel Environments Show Help >>				Ŧ
	OK Cancel Environments	Show H	ielp >>	

- G.3.4.3. Repeat step G.3.4.1 to G.3.4.2 for each raster that needs to have its values changed to the appropriate confusion matrix table value.
- G.3.4.4. In the ArcToolbox select **Data Management Tools>Raster>Raster Dataset>Mosaic To New Raster**.
- G.3.4.5. Add all the rasters created in step G.3.4.3 and others (if applicable) for the prediction part of the confusion matrix. Select the **output location** for which folder the file will be saved in. Set the name of the layer being created under **Raster Dataset name with extension**. Set the **number of bands** as 1. For the **Mosaic Operator** set the value based on how your datasets are set up. For overlapping components of this example a higher density layer will take priority (therefore if a cell contains both dense and moderate as a value the dense layer will take priority) (ALSO since the non_veg layer have the highest value in this set up, it should have least priority, feel free to use the LAST and

FIRST decisions to customize which layers have priority when mosaicing the multiple rasters together). This example will use minimum for the operator.

Mosaic To New Raster	- D - X
Click error and warning icons for more information	××
Input Rasters	
	🖃 🖻
♦ dense_predict	+
→mod_predict	
♦ sparse_predct	×
onnveg_predct	
Output Location	
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure	
Raster Dataset Name with Extension	
Matrix_predct	
Spatial Reference for Raster (optional)	
Pixel Type (optional)	
8_BIT_UNSIGNED	•
Cellsize (optional)	
Number of Bands	
	1
Mosaic Operator (optional)	
MINIMUM	•
Mosaic Colormap Mode (optional)	
FIRST	-
	-
OK Cancel Environments	Show Help >>

- G.4. Creating the actual (will be called reference in this procedure as well) layer for the confusion matrix may follow some steps described in G.3. but most likely the reference dataset will come from an outside data source and therefore will not be created by the user. Therefore only modifications to the layer will need to be made.
 - G.4.1. The most important thing about the reference layer is the value scheme that it will use for the confusion matrix. Whereas the prediction layer used factors of 10, the actual layer will use single digit values. Therefore for this example where dense, moderate, sparse, and non vegetated areas are being compared the following values

Numeric Value	Reference Layer Description of SAV
0	Non-Vegetated
1	Dense
2	Moderate
3	Sparse

will be used. **NOTE:** if your work requires or has more components simply add another digit value for each layer. However, this will only work for values up to 9.

- G.4.2. This example for the procedure will assume a shapefile containing the appropriate SAV files was given to the user to compare against their own work. Therefore the changes that need to be changed are giving the shapefile the appropriate values for the correct description of SAV, convert the shapefile to a raster, and mosaic a non_vegetated background layer to the raster. **NOTE**: This assumes the shapefile has been clipped to the study area as described in F.10
 - G.4.2.1. Right-click the reference shapefile containing the data in the table of contents and select **Open Attribute Table**.
 - G.4.2.2. Examine the shapefile and its description. For example this shapefile gives the descriptions of Dense, Moderate, and Sparse. Each of these components will need to be given the appropriate value as shown in the table of G.4.1.
 - G.4.2.3. Select table options and select Add Field.

Table	:		
:= -	🖥 - 🖫 🎦 🖉 🗶		
<i>P</i> 1	Fin <u>d</u> and Replace		
	Select <u>By</u> Attributes	JM	CLASSDESC
M	Clear Selection	1	SAV: Dense (80-100% cover)
		1	SAV: Dense (80-100% cover)
	-	1	SAV: Dense (80-100% cover) SAV: Dense (80-100% cover)
	Select <u>A</u> ll	H	SAV: Dense (80-100% cover)
	Add <u>F</u> ield	1	SAV: Dense (80-100% cover)
	Turp All Cialda On	1	SAV: Dense (80-100% cover)
	Add Field	1	SAV: Dense (80-100% cover)
~	Sho Adds a new field to the table.	1	SAV: Dense (80-100% cover)
	Arra	1	SAV: Dense (80-100% cover)
		1	SAV: Dense (80-100% cover)
	Restore Defa <u>u</u> lt Column Widths	1	SAV: Dense (80-100% cover)
	Restore Default Field Order	1	SAV: Dense (80-100% cover)
	lains and Palatas	1	SAV: Dense (80-100% cover)
	Joins and Relates	2	SAV: Moderate (40-80% cover)
	Related Tables	2	SAV: Moderate (40-80% cover)
		2	SAV: Moderate (40-80% cover)

G.4.2.4. Name the field matrix_val. Set the type as short integer.

Add Field	×
<u>N</u> ame:	matrix_val
<u>T</u> ype:	Short Integer
- Field Prope	erties
Precision	n 0
	OK Cancel

G.4.2.5. For this example, since the shapefile contains multiple components and these components have different values associated with the confusion matrix the values will need to be input manually. Keep the attribute table open, but go to the table of contents and right-click the reference shapefile and select Edit Features then Start Editing.



G.4.2.6. The values in the attribute table opened before can now be edited. For the matrix_val field begin to input the associated reference table value based on the information given in the table. Once all the values of have been input, select **editor** in the **editor toolbar** and choose **save edits.** Then select **editor** then **stop editing**. **NOTE:** There are other methods of adding values to the matrix_val component. If the reference shapefile contains so many components that manual input is unrealistic, using tools in the toolbox such as Split may be useful to separate the individual fields. These can then have their values changed separately before being mosaiced together again in then (this would be similar to the processes described in G.3.3.).

Edito Edito	r•I►N/ZZQ+米INH中×QI	(<i>28</i> 3	able		• ⊻	12	A			
	Save Edits	re	ference							
$ \rightarrow \frac{\pi}{2}$	Save all edits made since the last	' I-	FID	Shape *	OBJECTID	CLASSNUM		SHAPE_LENG		matrix_val
	save. After saving, you cannot	۵ <u>–</u>	0		14	1	SAV: Dense (80-100% cover)	20	14	1
57	undo previous editing operations.	d He	1	Polygon	15	1	SAV: Dense (80-100% cover)	14	8	1
	Merge	11-			16	1	SAV: Dense (80-100% cover)	10	4	1
		i –	3		17	1	SAV: Dense (80-100% cover)	38	30	1
1	Buffer	UH-	4	Polygon	18	1	SAV: Dense (80-100% cover)	4	1	1
	Union		5		19	1	SAV: Dense (80-100% cover)	4	1	1
	Clip		6	Polygon	20	1	SAV: Dense (80-100% cover)	4	1	1
	Clip		7	Polygon	21	1	SAV: Dense (80-100% cover)	4	1	1
2	Validate Features		8		22	1	SAV: Dense (80-100% cover)	13576	632803	1
*	000000		9	Polygon	23	1	SAV: Dense (80-100% cover)	4	1	1
	Snapping		10	Polygon	24	1	SAV: Dense (80-100% cover)	4	1	1
	More Editing Tools		11	Polygon	25	1	SAV: Dense (80-100% cover)	6	2	1
			12	Polygon	26	1	SAV: Dense (80-100% cover)	14	9	1
	Editing Windows			Polygon	27	1	SAV: Dense (80-100% cover)	8694	357921	1
	Options			Polygon	312	2	SAV: Moderate (40-80% cover)	10	5	2
_	options.		15	Polygon	313	2	SAV: Moderate (40-80% cover)	26	17	2

G.4.2.7. In the ArcToolbox select ConversionTools>To Raster>Polygon to Raster to convert the shapefile into a raster.

G.4.2.8. Input the shapefile from the previous steps. For the value field select the field created in G.4.2.4. Select a location and name to save the layer. For the cellsize use an appropriate value based on the datasets being examined. For this example 30 meters is used because that is the resolution of Landsat 8.

Polygon to Raster	
Input Features	A
reference_cut	- 🖻
Value field	
matrix_val	-
Output Raster Dataset	_
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation_Procedure\SAV_ref_ras	
Cell assignment type (optional) CELL_CENTER	
Priority field (optional)	
Cellsize (optional)	
30	6
	+
OK Cancel Environments	. Show Help >>

- G.4.2.9. In the ArcToolbox select Data Management Tools>Raster>Raster Dataset>Mosaic To New Raster for adding the non_vegetated raster background to the data (see step F.3 for more information on the background raster).
- G.4.2.10. Add the reference raster from G.4.2.8. and the study_raster (from F.3).
 Select the output location for which folder the file will be saved in. Set the name of the layer being created under Raster Dataset name with extension.
 Set the number of bands as 1. For the Mosaic Operator set the value based on how your datasets are set up. For overlapping components of this example a higher density layer will take priority (therefore if a cell contains both dense and moderate as a value the dense layer will take priority)(For this example and process the background raster of non-vegetated areas (that is the study_raster layer) has values of 0 therefore the maximum value will be used for the operator). Other operators can be used, but make sure they go correctly with the input of rasters and how your data was entered.

Mosaic To New Raster	et 1995			x
Input Rasters				^
			- 🖻	
SAV_ref_ras			+	
oprocedure \study_raster				
			×	
Output Location				
V:\Morphology\B_madore_work\Vegetation_barnegat\Processed\Vegetation	on_Procedure			
Raster Dataset Name with Extension			_	
Matrix_ref				
Spatial Reference for Raster (optional)			_	
Pixel Type (optional)				
8_BIT_UNSIGNED			•	
Cellsize (optional)				
Number of Bands				
			1	
Mosaic Operator (optional) MAXIMUM			-	
Mosaic Colormap Mode (optional)			•	
FIRST			•	
	ОК	Cancel Environmen	nts Show Help >>	,

G.5. Once the predicted layer and reference layers have been created with the multiple components the two datasets can be added together.

G.6. In the ArcToolbox select Spatial Analyst Tools>Map Algebra>Raster Calculator.

G.7.For the expression select the predicted layer created in G.3 and add to it the reference layer created in G.4.

Map Algebra expression Layers and variables Matrix_ref study_raster study_raster SAV_ref_ras dense_area dense_area a a
OK Cancel Environments Show Help >>

G.8. The resulting raster will now have up to 16 possible unique values based on the 4 possible prediction values and the 4 possible reference values. The table below shows the values and their explanations (for this example).

Numeric Value	Predicted Layer SAV description	Reference Layer SAV description
10	Dense Vegetation	No Vegetation
11	Dense Vegetation	Dense Vegetation
12	Dense Vegetation	Moderate Vegetation
13	Dense Vegetation	Sparse Vegetation
20	Moderate Vegetation	No Vegetation
21	Moderate Vegetation	Dense Vegetation
22	Moderate Vegetation	Moderate Vegetation
23	Moderate Vegetation	Sparse Vegetation
30	Sparse Vegetation	No Vegetation
31	Sparse Vegetation	Dense Vegetation
32	Sparse Vegetation	Moderate Vegetation
33	Sparse Vegetation	Sparse Vegetation
40	No Vegetation	No Vegetation
41	No Vegetation	Dense Vegetation

42	No Vegetation	Moderate Vegetation
43	No Vegetation	Sparse Vegetation

G.9. Opening the **Attribute Table** of the final raster will provide the number of cells (which can then be calculated into area) for each of the unique values. Calculating the accuracy can be accomplished by adding all of the matching cell values (that is, when predicted = reference, for example 11 is when predicted has dense vegetation and the reference layer has dense vegetation) and then dividing by the total number of cells. More information on confusion matrix and what can be calculated from the results can be found online.

Ta	ble			$\square \times$							
0	🗄 • 🖶 • 🏪 🌄 🖄 🐗 💥										
Ma	Matrix_fin ×										
	Rowid	VALUE	COUNT								
F	0	10	99								
	1	11	682								
	2	12	795								
	3	13	172								
	4	20	1023								
	5	21	150								
	6	22	3221								
	7	23	1373								
	8	30	2328								
	9	31	39								
	10	32	267								
	11	33	1798								
	12	40	59980								
	13	41	247								
	14	42	2303								
	15	43	3598								
ŀ	• •	1	► •I								
	(0 out of 16 Selected)										
M	Matrix_fin										

The table below uses values from the attribute table located above with the description of the values shown in step G.8.

Example of 4X4 vegetation	Predicted	Predicted	Predicted	Predicted	Total
confusion matrix	(Dense)	(Moderate)	(Sparse)	(No-SAV)	
Actual (Dense)	682	150	39	247	1118
Actual (Mod)	795	3221	267	2303	6586
Actual (Sparse)	172	1373	1798	3598	6941
Actual (No-SAV)	99	1023	2328	59980	63430
Total	1748	5767	4432	66128	78075

For the accuracy of the above table the gold shaded regions would be added together and then divided by the absolute total, represented in the green shaded cell. This value would be .841 (for the hypothetical example).

G.10.