FEDERATED STATES OF MICRONESIA
OFFICE OF ENVIRONMENT & EMERGENCY MANAGEMENT (OEEM)

Vegetation and Land Cover Vulnerability Geospatial Analyses due to Sea Level Rise Modeling

Final Report

Kosrae State ⬩⬩⬩ Chuuk State ⬩⬩⬩ Yap State ⬩⬩⬩ Pohnpei State

Snyther Biza
College of Micronesia - FSM

March 18 to 22, 2013

TABLE OF CONTENTS

Background:

"Pacific Adaptation Strategy Assistance Program"

Food security situations are determined by locally diverse conditions, such as soil qualities, crop varieties and market conditions, and by common regional issues such as climate change, trade policies and natural disasters. Adaptation responses therefore need to be local in nature, and address pressures at the regional level.

In 2008, the FAO declared that climate change was the single most important factor affecting the stability of food supplies. Given the likely impacts of climate change, compounded by instability caused by natural variability and human pressures on natural resources, there is a need to strengthen household and local resilience. This can be achieved by building on existing local mechanisms for resilience: by appropriate investment projects and by support to on-going research and piloting work in the development of adjustment strategies for food production and food security.

The Plan of Action for Food Security in FSM (draft) acknowledges that 'long term food security requires establishing food supply systems that can mitigate risk and cope with stress.' It recognizes that 'there is a need to create more resilient food systems in the FSM that are capable of adapting to shifts at both the macro and local levels and absorb disturbances resulting from the volatility of the global economic market and environmental changes'.

This project aims to identify how climate change will affect food security in FSM, and what responses are appropriate. In FSM, the priority of food security has been identified for a country-led activity under the Pacific Adaptation Strategy Assistance Program (PASAP) in consultations starting in March 2009 and more recently in March and August 2010.

In FSM, the PASAP will establish a partnership between the FSM Office of Environment and Emergency Management (OEEM) Project Office, the SPC North Pacific Regional Office (SPC NPRO) and the National College of Micronesia FSM Cooperative Research and Extension (COM FSM CRE) Office in Pohnpei to analyse the impacts of climate change on the four pillars of food security in FSM, and identify what adaptation measures can enhance the resilience of food systems.

Objectives:

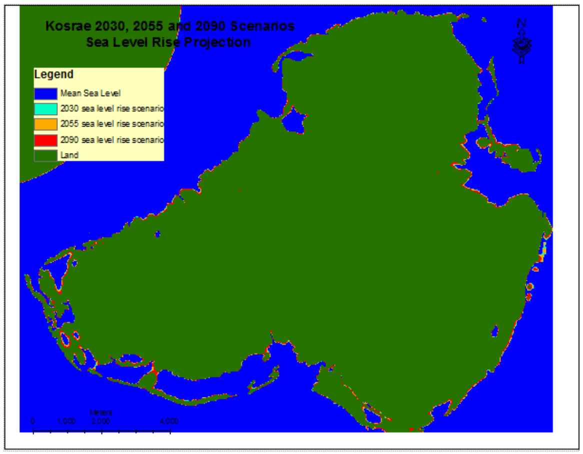
1. Build a predicted sea level rise model for the 3 states, Chuuk, Yap and Kosrae
2. To visualized the impact on PASAP pilot site
3. Analyze the predicted sea level rise projections and create vegetation & land-cover vulnerability maps of high vulnerable zone, medium vulnerable zone and low vulnerable zone for each state.

This report focuses on objective #3, where the analyses and the creation of the vegetation and land-cover vulnerability maps for the FSM States were made.

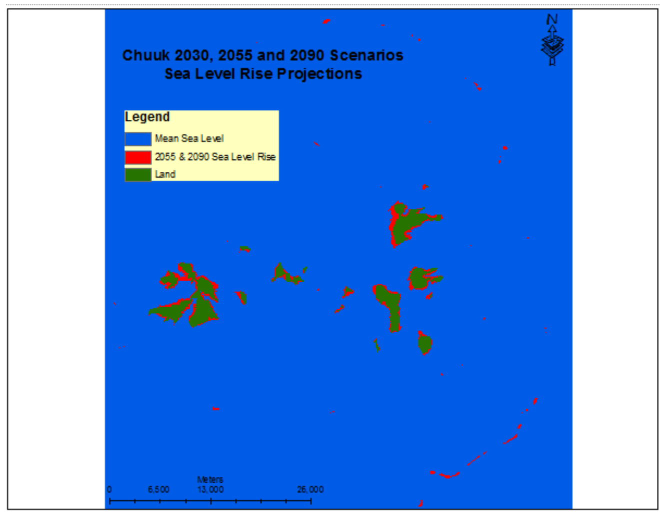
ERDAS Imagine – Sea Level Rise Projection Results from the 3 Scenarios:

Below are the results of the 3 scenarios for each state's sea level rise projections using the ERDAS Imagine. From the projections, Kosrae state has sea level rise effects in all 3 scenarios (2030, 2055 & 2090), Chuuk state has sea level rise effects in only the 2055 and 2090 scenarios but not in the 2030 scenario, Yap state also has sea level rise effects in both 2055 and 2090 but not in the 2030 scenario, and Pohnpei state also has sea level rise effects in 2055 and 2090 scenarios but none in the 2030 scenario.

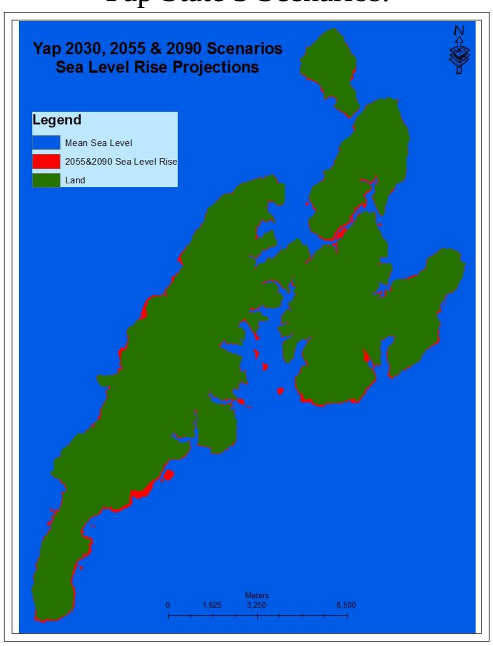
Kosrae State 3 Scenarios:



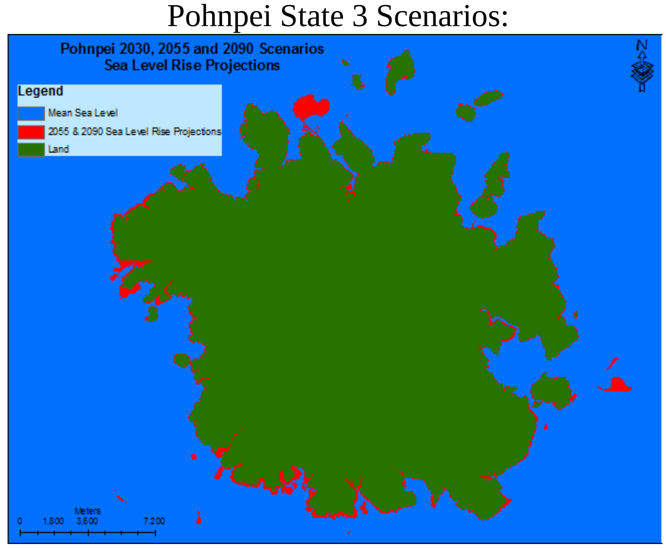
Chuuk State 3 Scenarios:



Yap State 3 Scenarios:



Pohnpei State 3 Scenarios:



Geospatial Analysis Procedures:

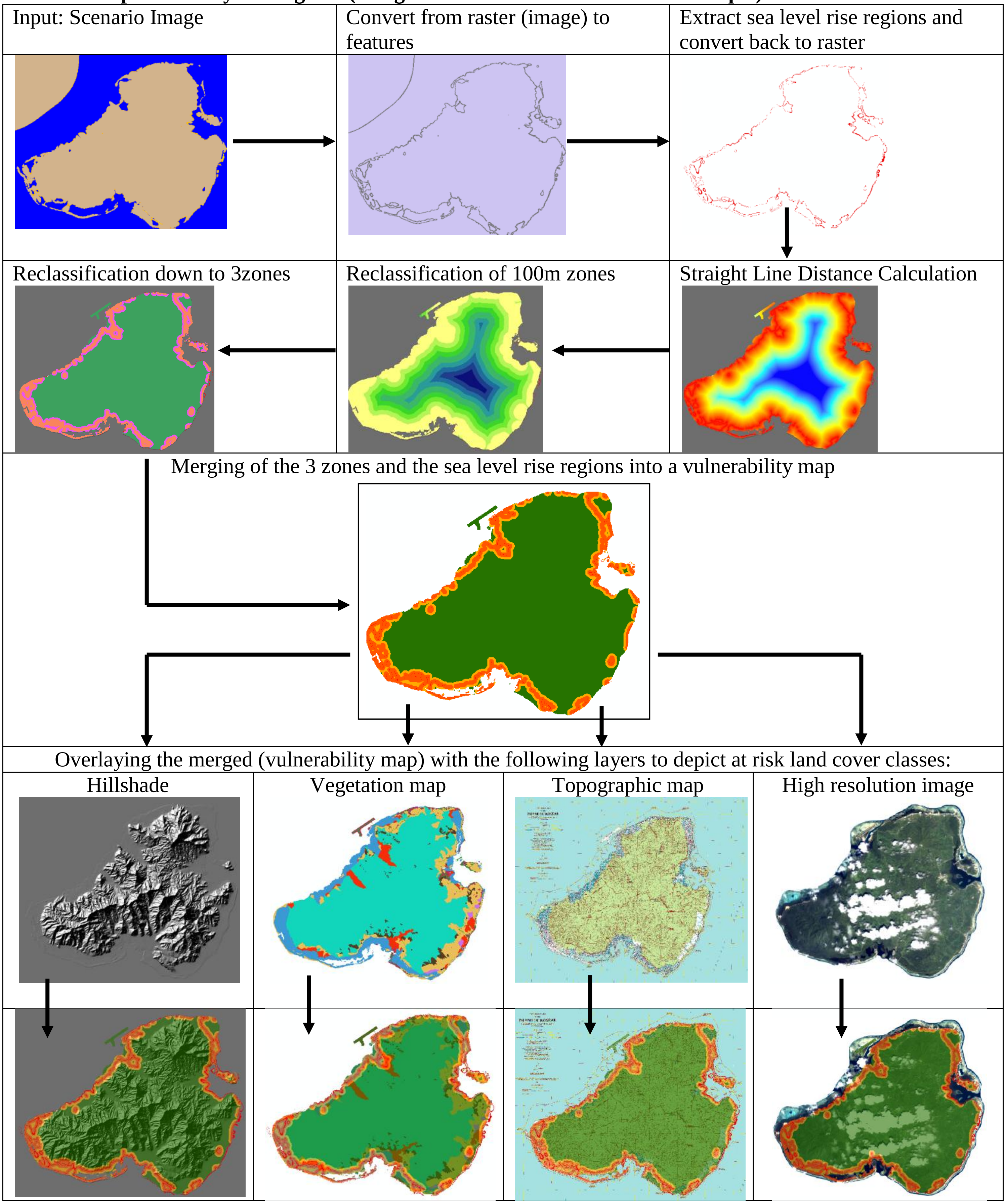
To analyze the vegetation and land cover impacts from the 3 sea level rise projection scenarios for each state, a vegetation and land-cover vulnerability zone map from each scenario was created. The vulnerability map is made up of 3 vulnerability zones, namely the 'high vulnerable zone', 'medium vulnerable zone', and 'low vulnerable zone', including the affected areas for each scenario. The distance zones that are closer to the affected areas due to sea level rise projection for each scenario is considered the 'high vulnerable zone'. The farther away zones from the affected areas are considered 'medium and low vulnerable zones' respectively. The impacts of vegetation classes and land-cover classes due to sea level rise projection of each scenario were analyzed by overlaying the vulnerability map with the vegetation map(s) and the high resolution images. The vegetation and land cover analyses were accomplished using the ArcGIS software spatial analyst tools.

The ***general procedures*** for the creation and overlay analyses of the vegetation & land-cover vulnerability maps are as follows:

1. **Launch** or open *ArcMap* and **enable** the *Spatial Analyst Toolbar,*
2. **Add-in** the input layers that will be used for the analyses,
3. **Set** the *working environment* and the *analysis parameters,*
4. **Convert** the sea level rise model results for each scenario *from raster to features,*
5. **Extract** the sea level rise projection areas for each scenario *into a layer (feature file),*
6. **Convert** the feature layer (from step 5) *back to raster,*
7. **Create** a 100 meters <u>straight line distance</u> zones layer from the sea level rise areas for each scenario using the *ArcGIS Spatial Analyst Toolbar's straight line distance tool,*
8. **Reclassify** the distance zones down into *three zones* namely
   a. '2' – High Vulnerable,
   b. '1' – Medium Vulnerable, and
   c. '0' – Low Vulnerable
9. **Merge** the sea level rise projection layer and the 3 zones reclassified layer into a *vulnerability or risk map,*
10. **Calculate** the *total acreages* for the sea level rise projection areas and the three vulnerability zones of the vulnerability or risk map for each scenario,
11. And, **Overlay** the vulnerability map (from step 9) of each scenario with the vegetation map, and the land cover maps, such as topographic map and high resolution image(s), to *depict* vegetation class(s) and land covers that will be affected by the sea level rise projection for each scenario.

The ***specific procedures*** for this analyses using Kosrae's 2030 scenario is attached to this report as attachment.

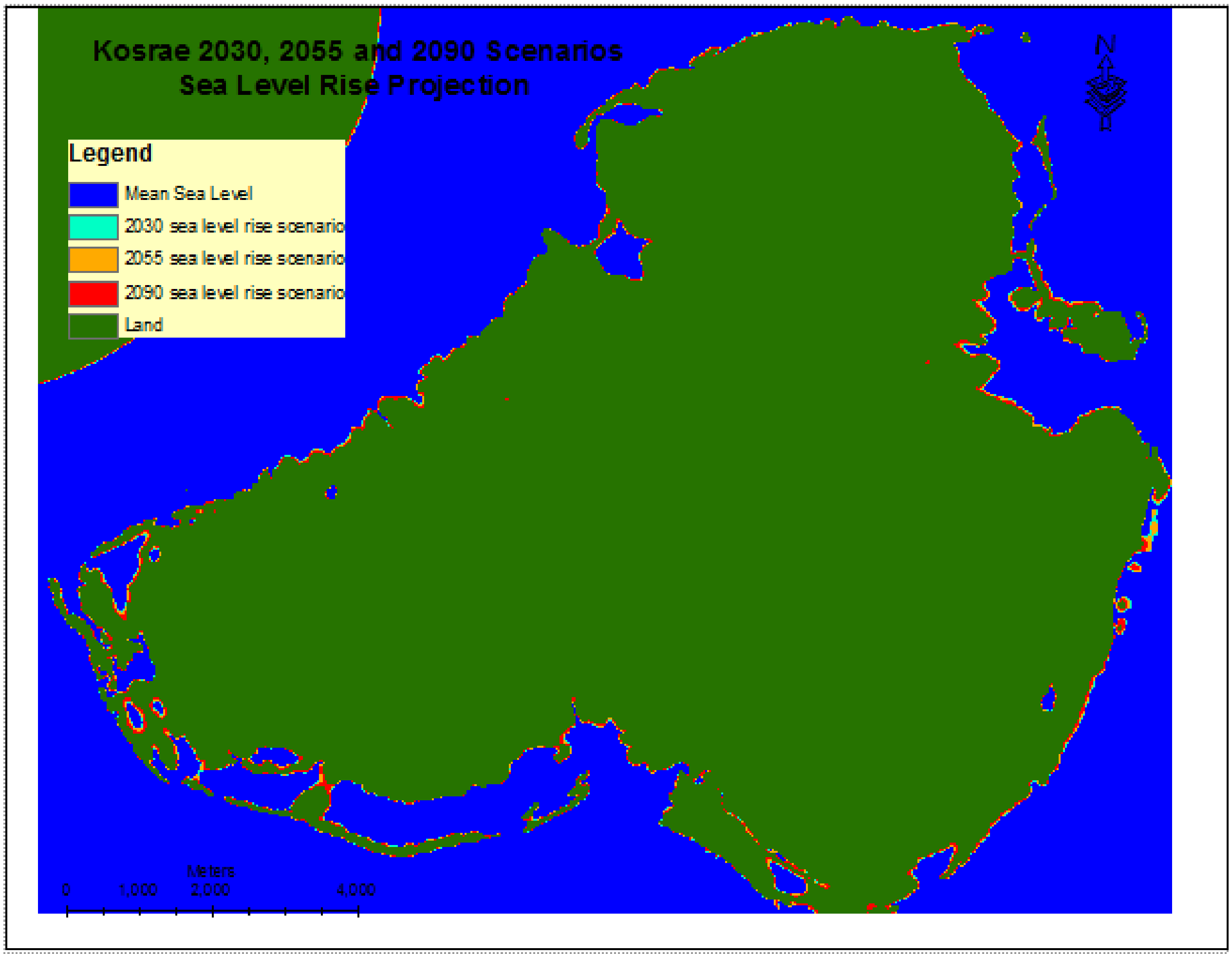
Geospatial Analysis Diagram (using Kosrae's 2030 scenario as an example):



KOSRAE STATE SCENARIOS

The image below presents the 3 scenarios of the sea level rise projections in year 2030, 2055 and 2090 for Kosrae State. The image shows that there are effects of sea level rise in Kosrae in all three scenarios (**2030, 2055 and 2090**).

<u>Kosrae 3 Scenarios</u>

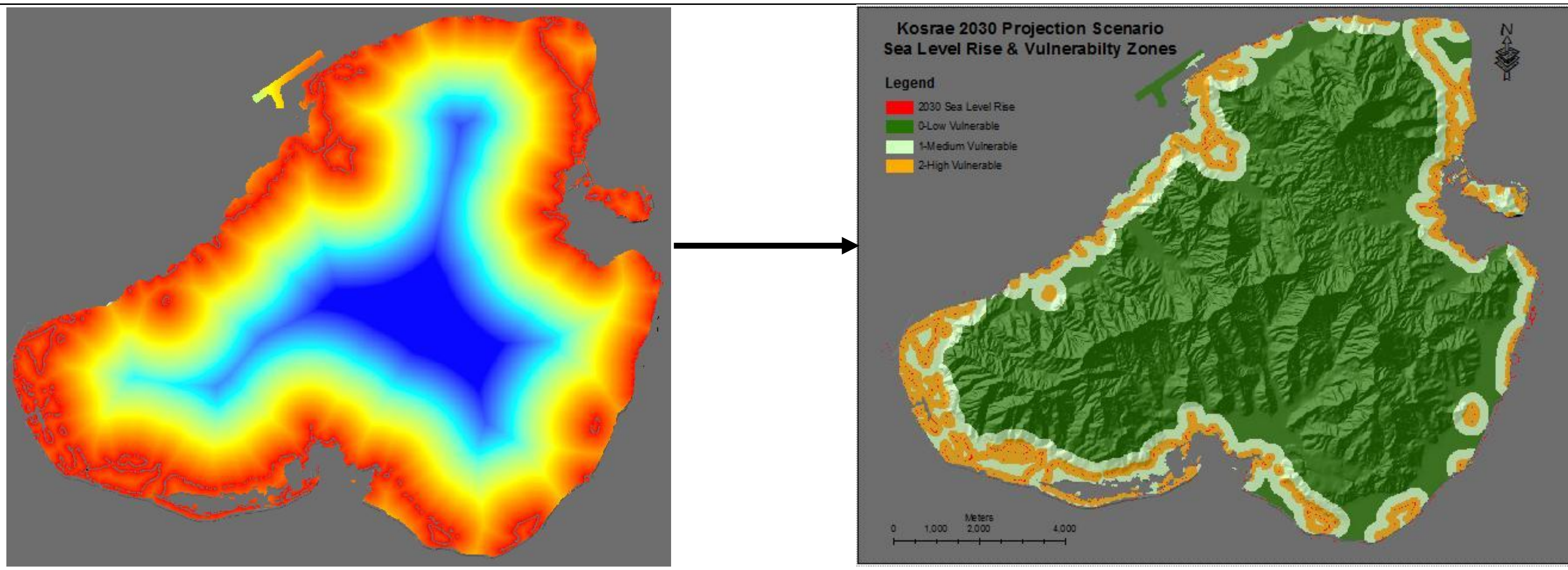


Since the effects of sea level rise projections occur in all three scenarios, there are 3 vegetation overlay analyses done for Kosrae State. The analyses and the results for each scenario are presented in the following pages.

Kosrae 2030 Scenario Analyses

The two images below portray the straight line distance zone calculation and the reclassification of the **2030** scenario. The reclassification of the zones indicates the vulnerability zones for the **2030** scenario. As shown in the attributes for the **2030** vulnerability map:

1. The Sea Level Rise areas cover at approximately 134.74 acres of land along the coastline of Kosrae
2. The High Vulnerable Zone covers at approximately 3177.51 acres of land mostly along the coastline of Kosrae
3. The Medium Vulnerable Zone covers at approximately 3827.18 acres of land
4. The Low Vulnerable Zone covers at approximately 20,346.24 acres of land.



Attributes of Export_Output_2

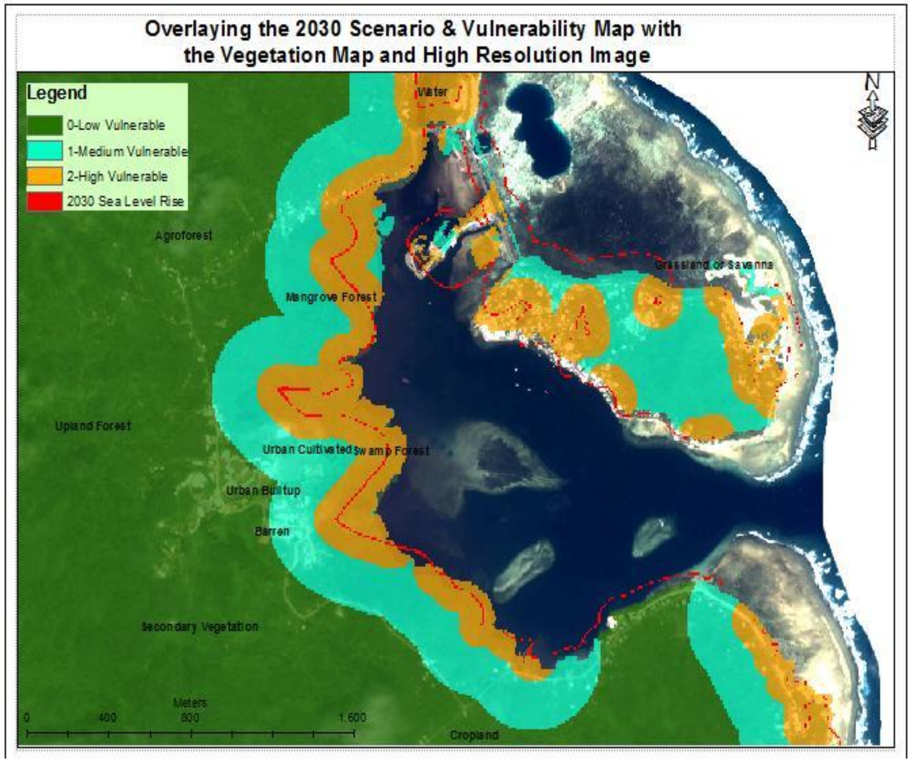
ObjectID	Value	Count	Zone	Acres
0	2	5453	Sea Level Rise	134.74363

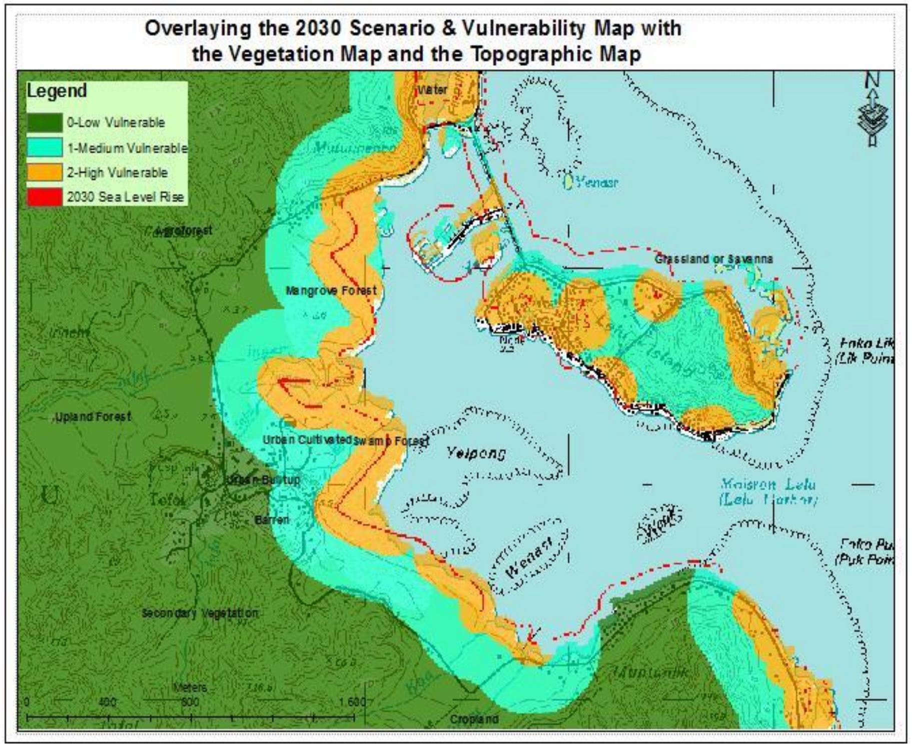
Attributes of Export_Output

ObjectID	Value	Count	Zone	Acres
0	0	823401	Low Vulnerable	20346.2387
1	1	154884	Medium Vulnerable	3827.18364
2	2	128592	High Vulnerable	3177.50832

Record: 1 Show: All Selected Records (0 out of 3

The images below are the results of overlaying the vulnerability map of **2030** scenario with the vegetation classes map and land cover images (high resolution and the topographic) to portray the vegetation and land cover classes that will be affected in **2030** for Kosrae State.

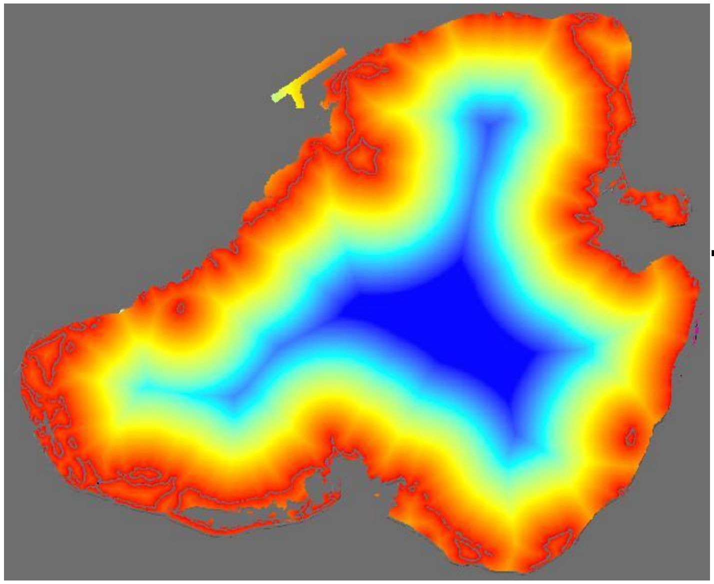


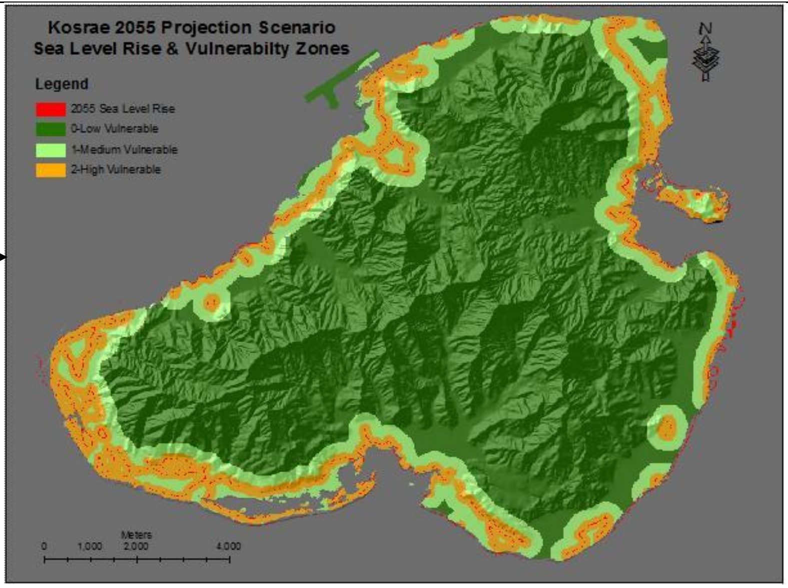


Kosrae 2055 Scenario Analyses

The two images below portray the straight line distance zone calculation and the reclassification of the **2055** scenario. The reclassification of the zones indicates the vulnerability zones for the scenario. As shown in the attributes for the **2055** vulnerability map:

1. The Sea Level Rise areas cover at approximately 240.13 acres of land along the coastline of Kosrae
2. The High Vulnerable Zone covers at approximately 3573.12 acres of land mostly along the coastline of Kosrae
3. The Medium Vulnerable Zone covers at approximately 3925.06 acres of land
4. The Low Vulnerable Zone covers at approximately 19,852.76 acres of land





Attributes of Export_Output_3

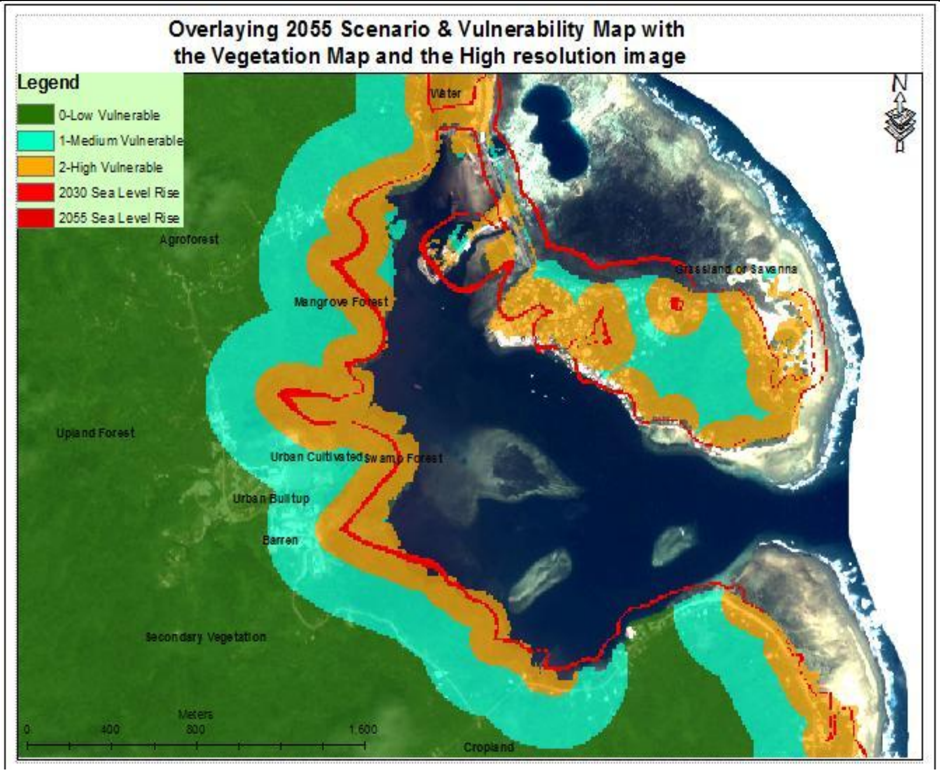
Value	Count	Zone	Acres
3	9718	Sea Level Rise	240.13178

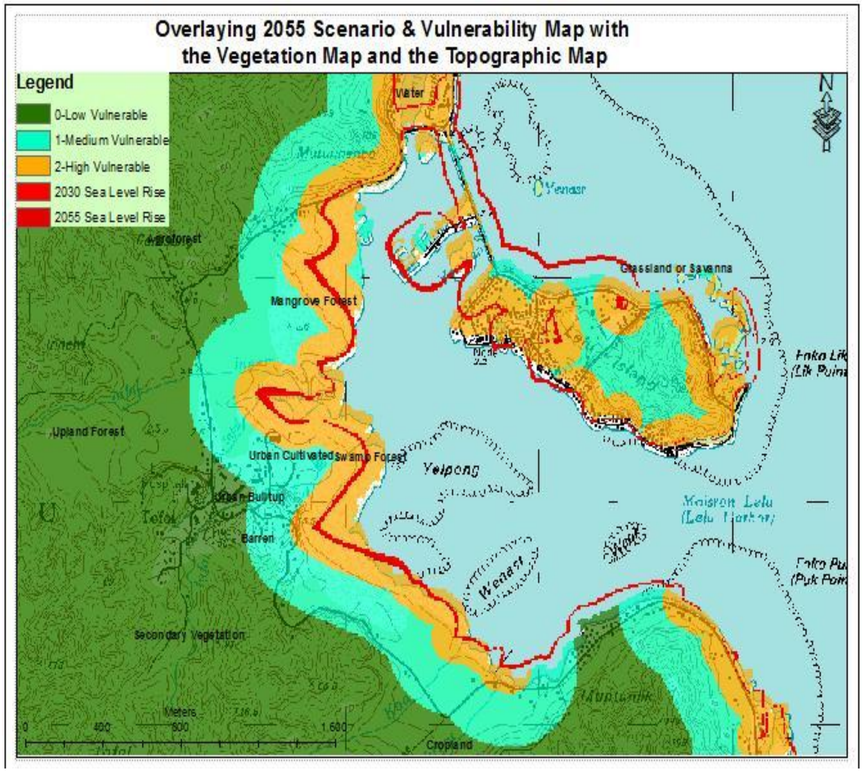
Attributes of Export_Output_4

Value	Count	Zone	Acres
0	803430	Low Vulnerable	19852.7553
1	158845	Medium Vulnerable	3925.05995
2	144602	High Vulnerable	3573.11542

Record: 0 Show: All Selected Records (0 out of

The images below are the results of overlaying the vulnerability map of **2055** scenario with the vegetation classes map and land cover images (high resolution and the topographic) to portray the vegetation and land cover classes that will be affected in **2055**.

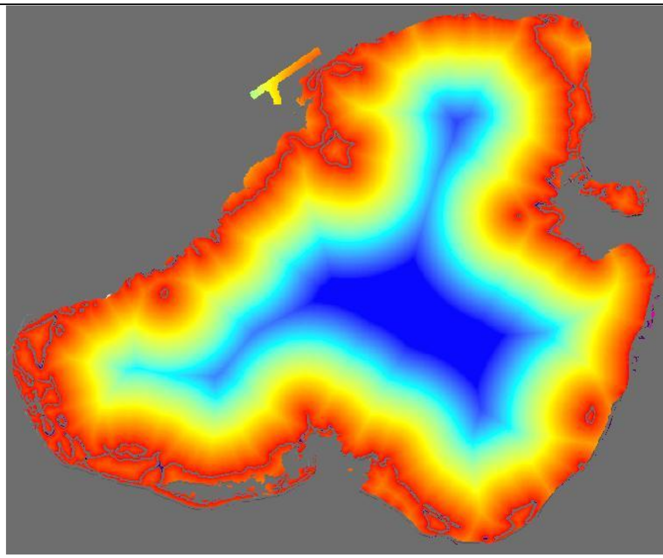


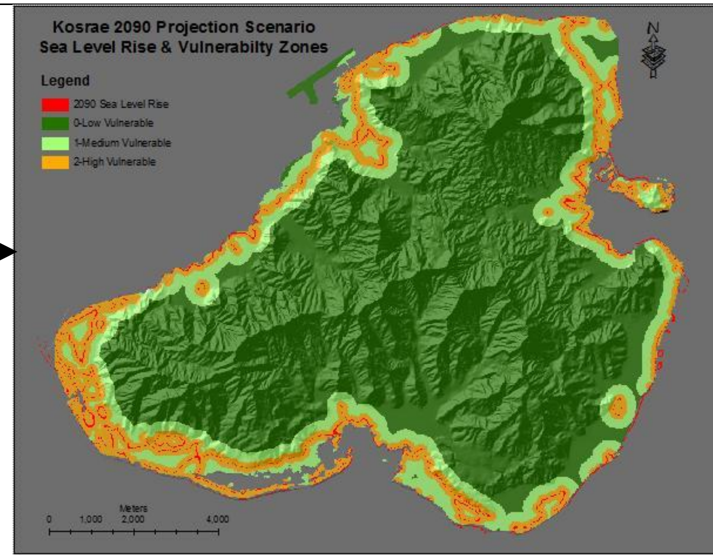


Kosrae 2090 Scenario Analyses

The two images below portray the straight line distance zone calculation and the reclassification of the **2090** scenario. The reclassification of the zones indicates the vulnerability zones for the scenario. As shown in the attributes for the **2090** vulnerability map:

1. The Sea Level Rise areas cover at approximately 347.50 acres of land along the coastline of Kosrae
2. The High Vulnerable Zone covers at approximately 3741.88 acres of land mostly along the coastline of Kosrae
3. The Medium Vulnerable Zone covers at approximately 3908.97 acres of land
4. The Low Vulnerable Zone covers at approximately 19,700.07 acres of land





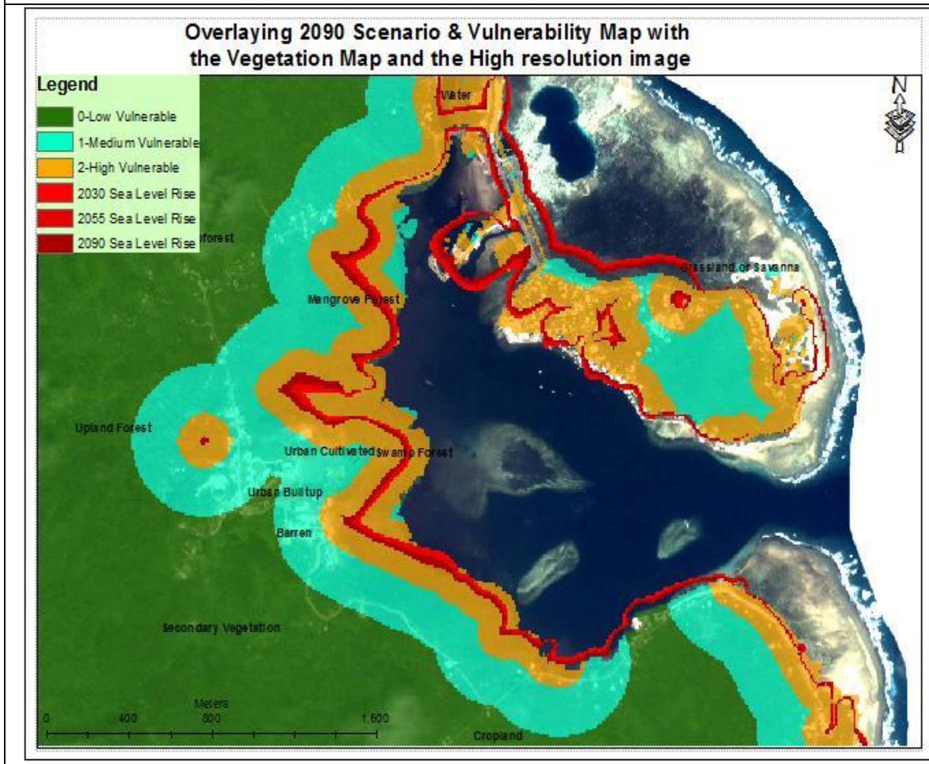
Attributes of Export_Output_5

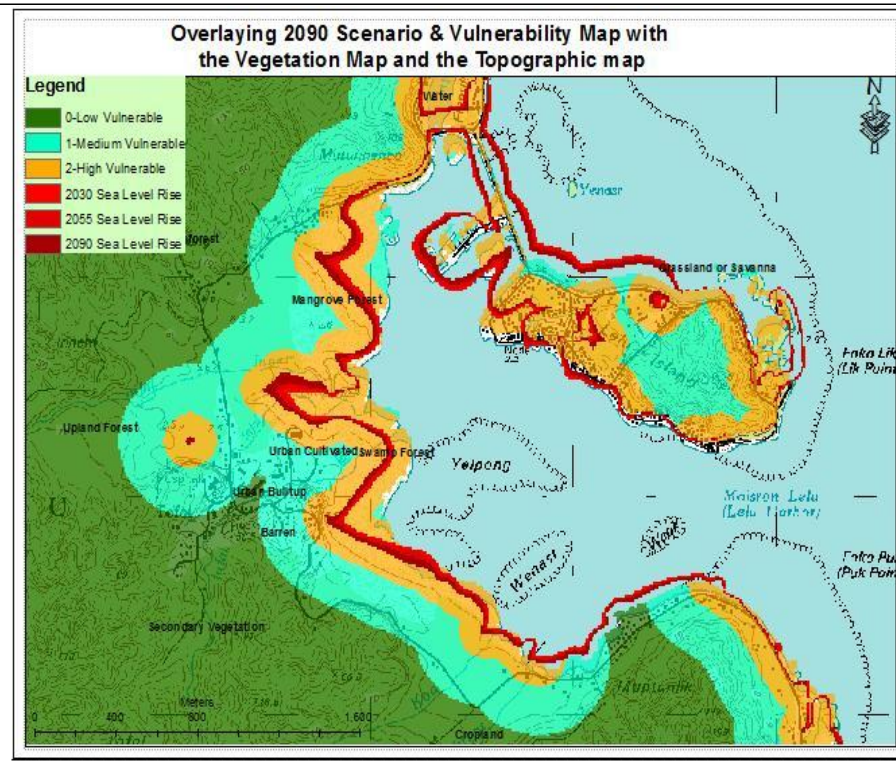
Value	Count	Zone	Acres
4	14063	Sea Level Rise	347.49673

Attributes of Export_Output_6

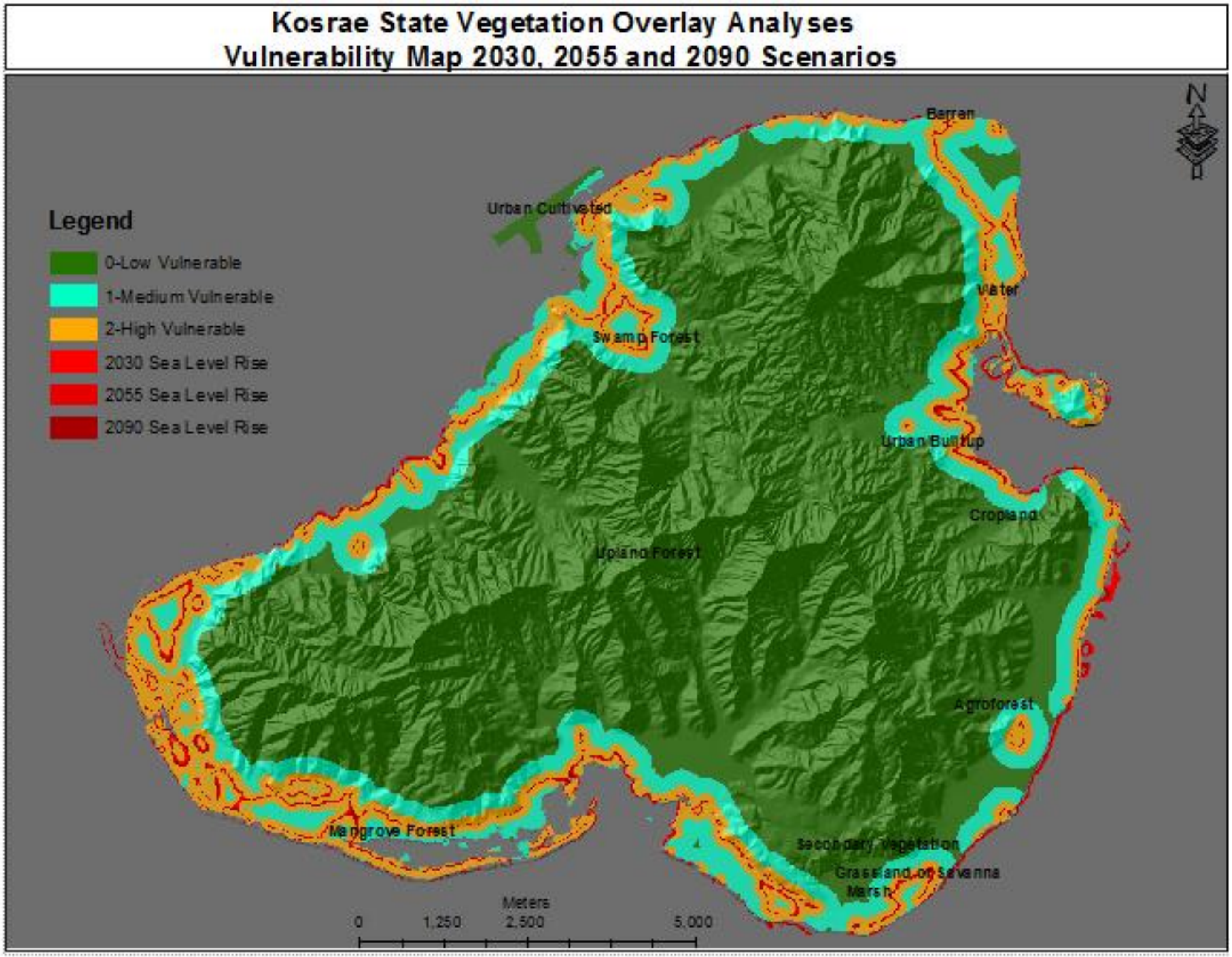
Value	Count	Zone	Acres
0	797251	Low Vulnerable	19700.07221
1	158194	Medium Vulnerable	3908.97374
2	151432	High Vulnerable	3741.88472

The images below are the results of overlaying the vulnerability map of **2090** scenario with the vegetation classes map and land cover images (high resolution and the topographic) to portray the vegetation and land cover classes that will be affected in **2090**. The overlay indicated that most of the urban built-ups and urban cultivated along the coastline of Kosrae are in high risk zones due to sea level rise in **2090**. The Lelu island will be greatly impacted by this projection.





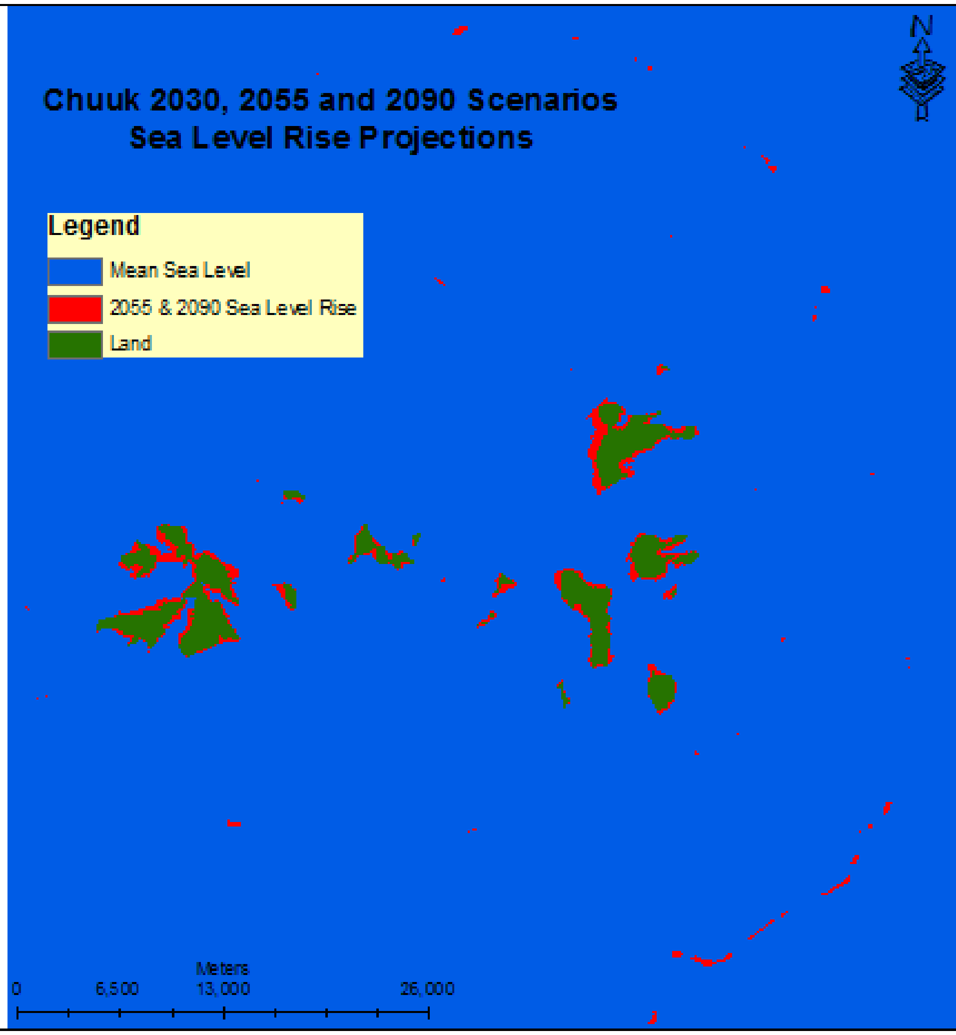
Kosrae 2030, 2055 & 2090 Sea Level Rise and Vulnerability Map:



CHUUK STATE SCENARIOS

The image below portrays the 3 scenarios of the sea level rise projections in year 2030, 2055 and 2090 for Chuuk State. The image shows that the effects of sea level rise for Chuuk only occur in the **2055** and **2090** scenarios and the effects are same. There is no effect of sea level rise in **2030** scenario.

Chuuk 3 Scenarios

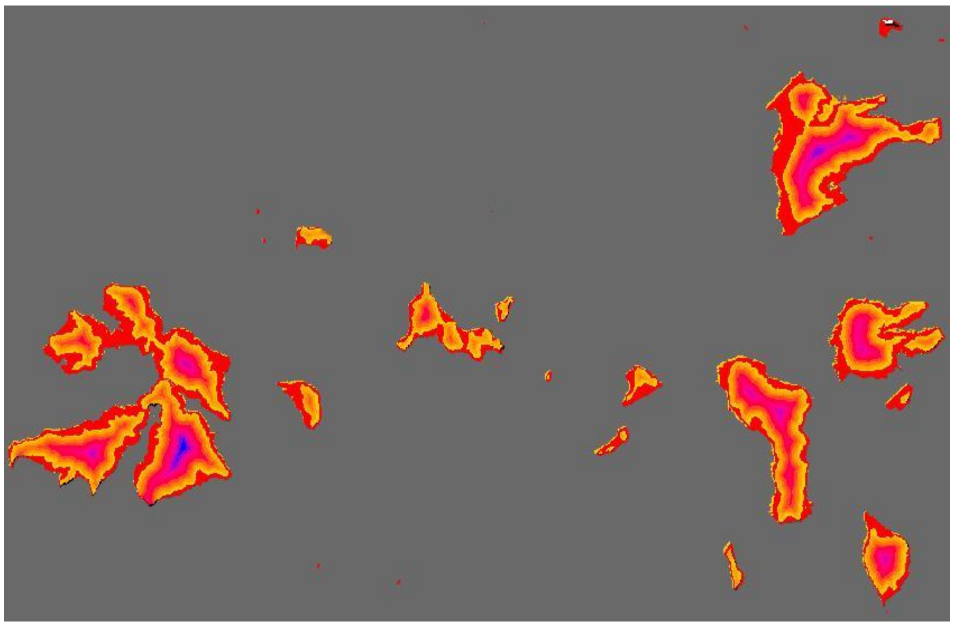


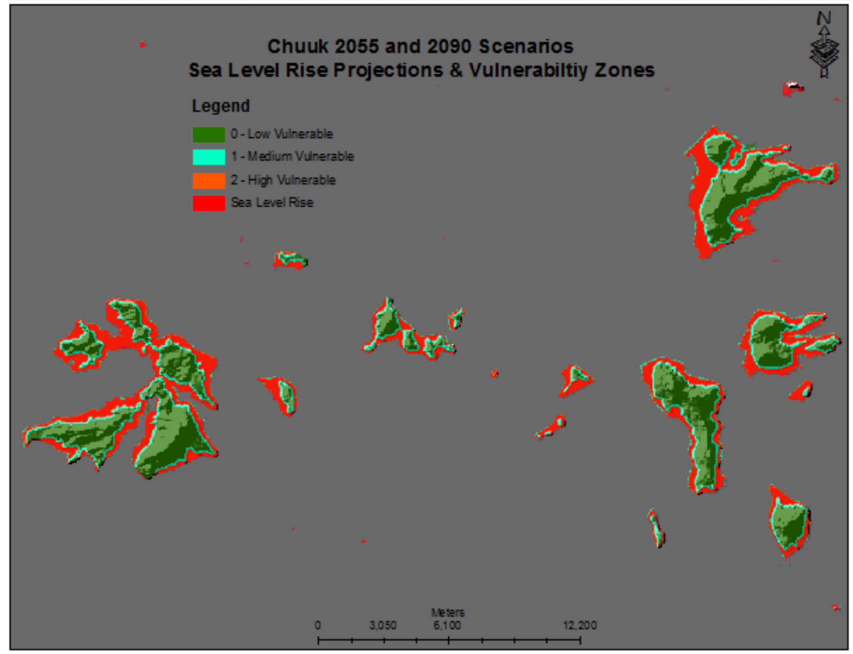
Since the effects of sea level rise projections occur only in **2055** and **2090** scenarios and the effects in both scenarios are same, the vegetation overlay analysis was done for only the **2055** scenario. The analyses and the results for the **2055** scenario are presented in the following pages.

Chuuk 2055 Scenario Analyses

The two images below portray the straight line distance zone calculation and the reclassification of the **2055** scenario. The reclassification of the zones indicates the vulnerability zones for the scenario. As shown in the attributes for the 2055 vulnerability map:

1. The Sea Level Rise areas cover at approximately 7311.52 acres of land along the coastline of Chuuk
2. The High Vulnerable Zone covers at approximately 7900.80 acres of land mostly along the coastline of Chuuk
3. The Medium Vulnerable Zone covers at approximately 3575.93 acres of land
4. The Low Vulnerable Zone covers at approximately 10,293.62acres of land





Attributes of Export_Output

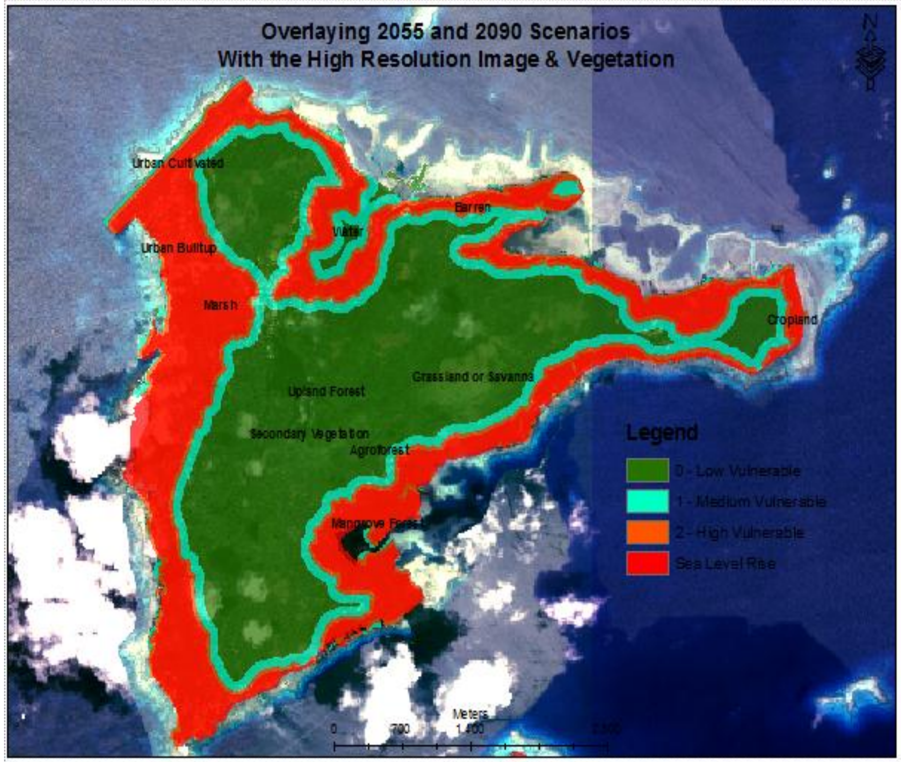
Value	Count	Zone	Acres
2	295893	Sea Level Rise	7311.51603

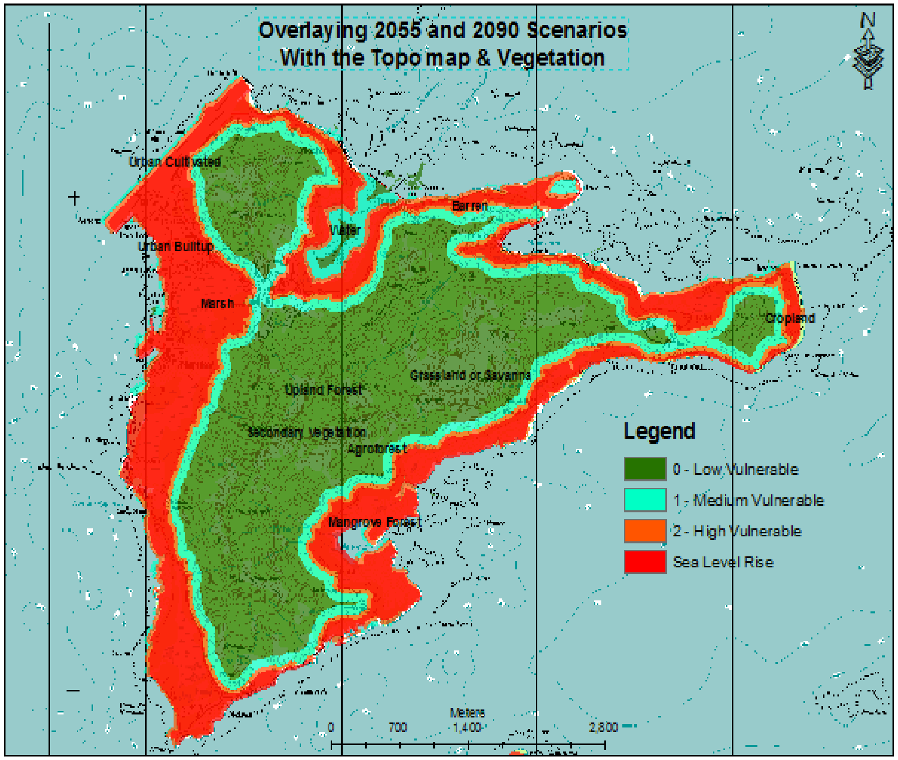
Attributes of Export_Output_2

Value	Count	Zone	Acres
0	416577	Low Vulnerable	10293.61767
1	144716	Medium Vulnerable	3575.93236
2	319741	High Vulnerable	7900.80011

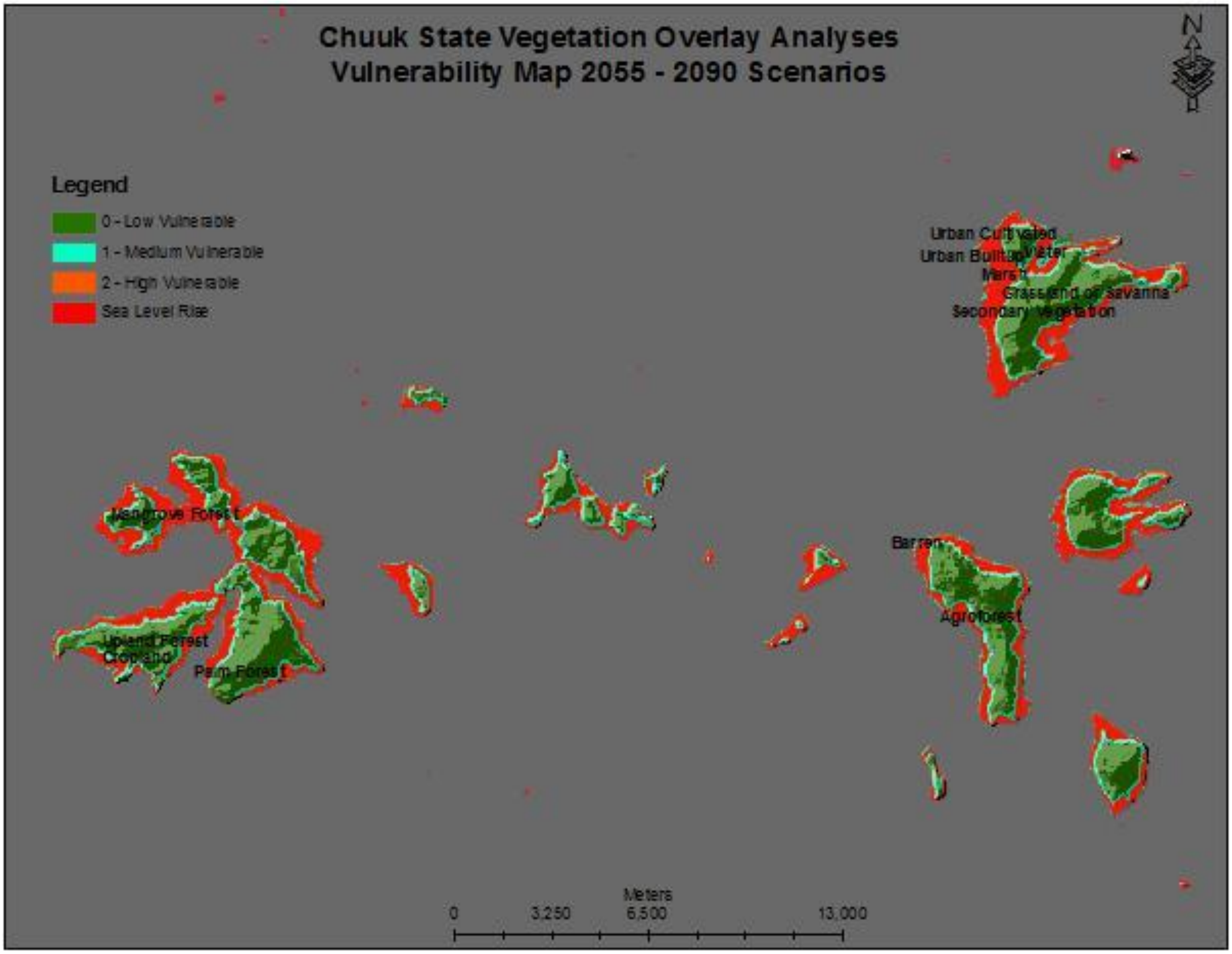
Record: 0 Show: All Selected Records (0 out of

The images below are the results of overlaying the vulnerability map of **2055** scenario with the vegetation classes map and land cover images (high resolution and the topographic) to portray the vegetation and land cover classes that will be affected in **2055 - 2090**. The overlay indicated that most of the urban built-ups and urban cultivated along the coastline of Chuuk are in high risk zones due to sea level rise in **2055**. The airport and the main town of Chuuk in Wono will be greatly impacted by this projection.





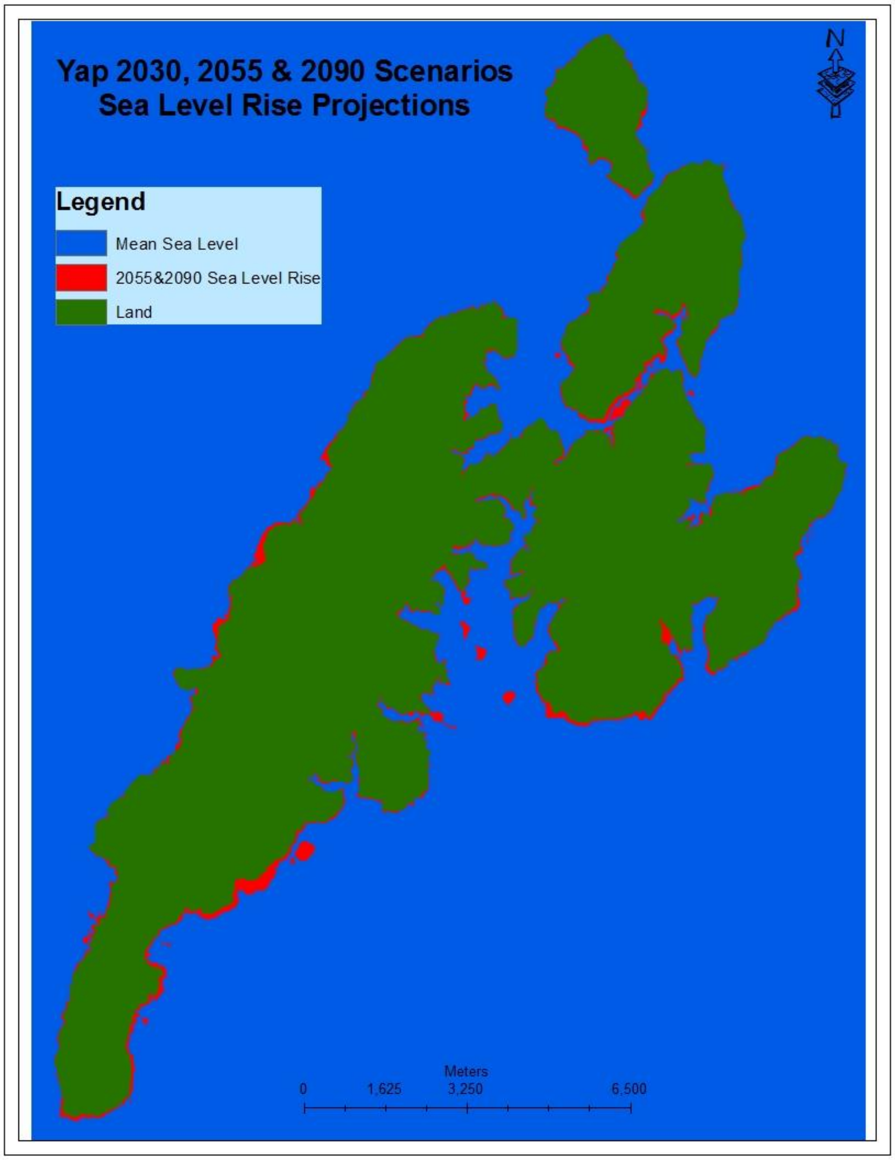
Chuuk 2055 Sea Level Rise and Vulnerability Map:



YAP STATE SCENARIOS

The image below portrays the 3 scenarios of the sea level rise projections in year 2030, 2055 and 2090 for Yap State. The image shows that the effects of sea level rise for Yap only occur in the **2055** and **2090** scenarios and the effects are same. There is no effect of sea level rise in 2030 scenario.

Yap 3 Scenarios

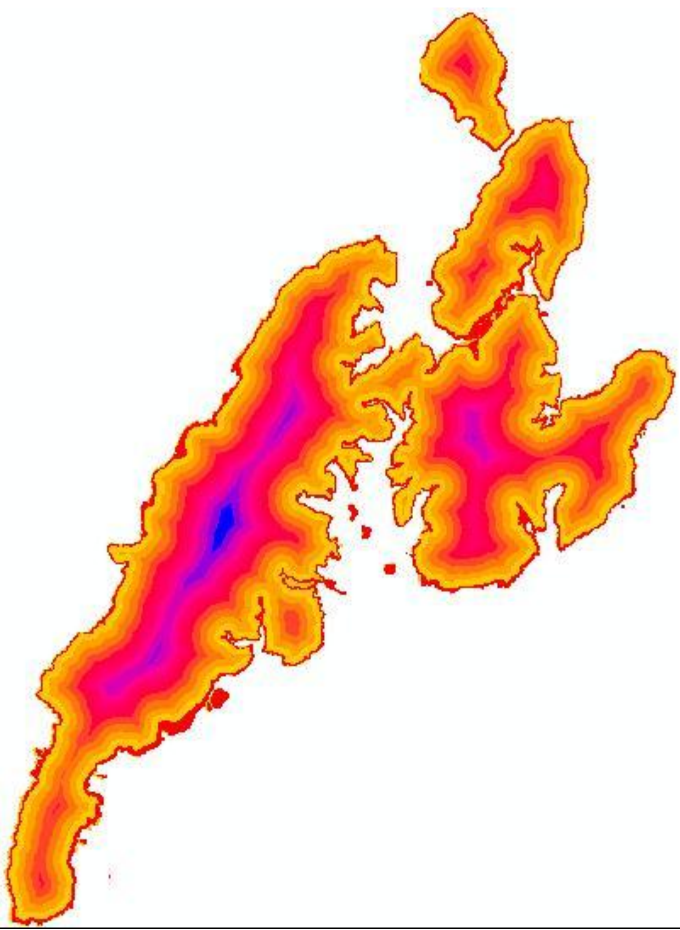


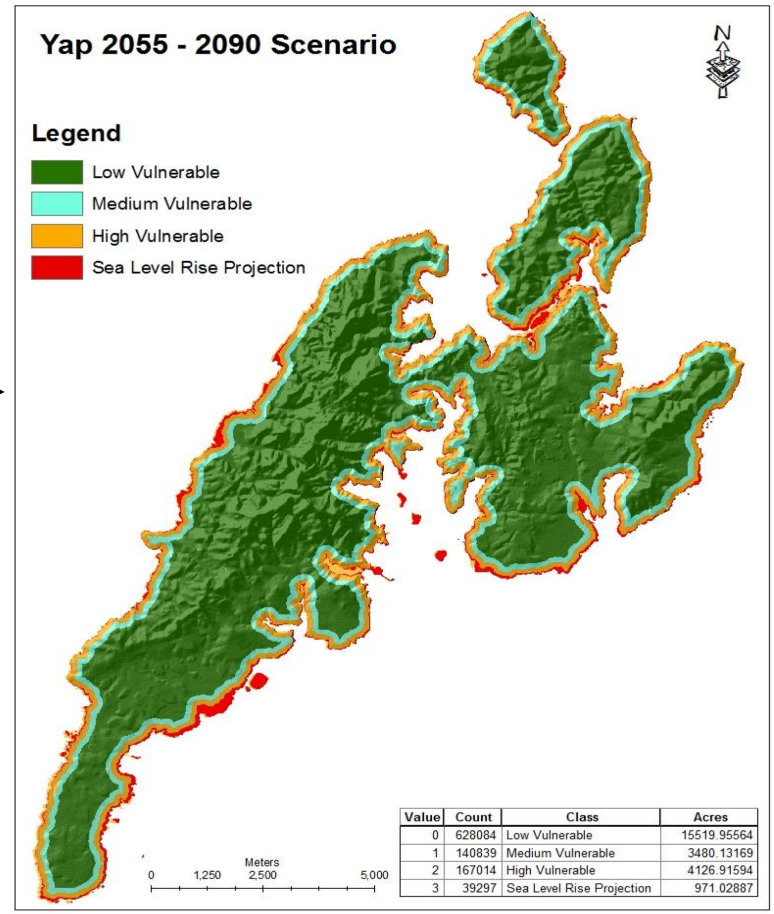
Since the effects of sea level rise projections occur only in **2055** and **2090** scenarios and the effects in both scenarios are same, the vegetation overlay analysis was done for only the **2055** scenario. The analyses and the results are presented in the following pages.

Yap 2055 Scenario Analyses

The two images below portray the straight line distance zone calculation and the reclassification of the **2055** scenario. The reclassification of the zones indicates the vulnerability zones for the scenario. As shown in the attributes for the **2055** vulnerability map:

1. The Sea Level Rise areas cover at approximately 971.03 acres of land along the coastline of Yap
2. The High Vulnerable Zone covers at approximately 4,126.92 acres of land mostly along the coastline of Yap
3. The Medium Vulnerable Zone covers at approximately 3,480.13 acres of land
4. The Low Vulnerable Zone covers at approximately 15,519.96 acres of land

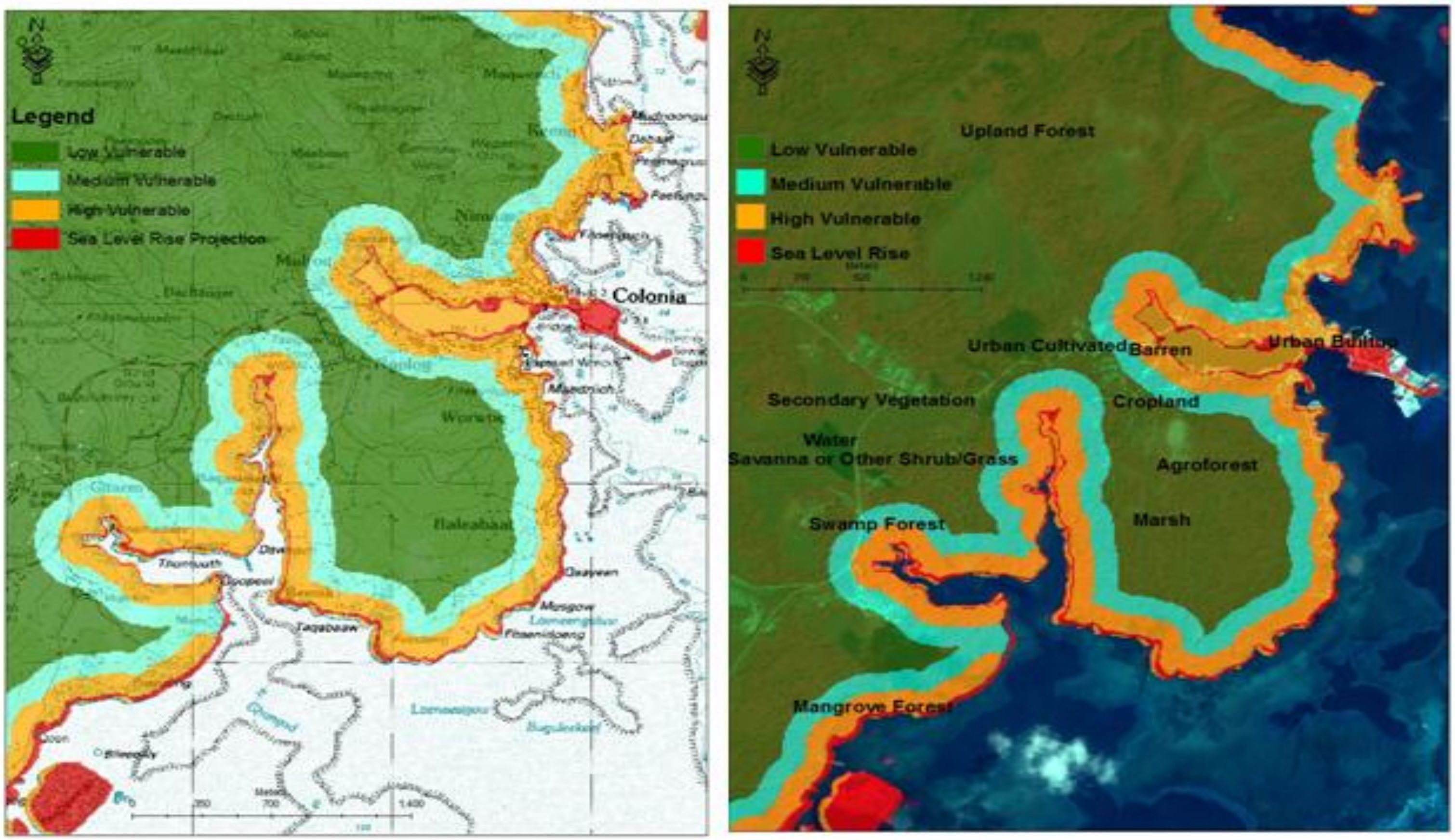




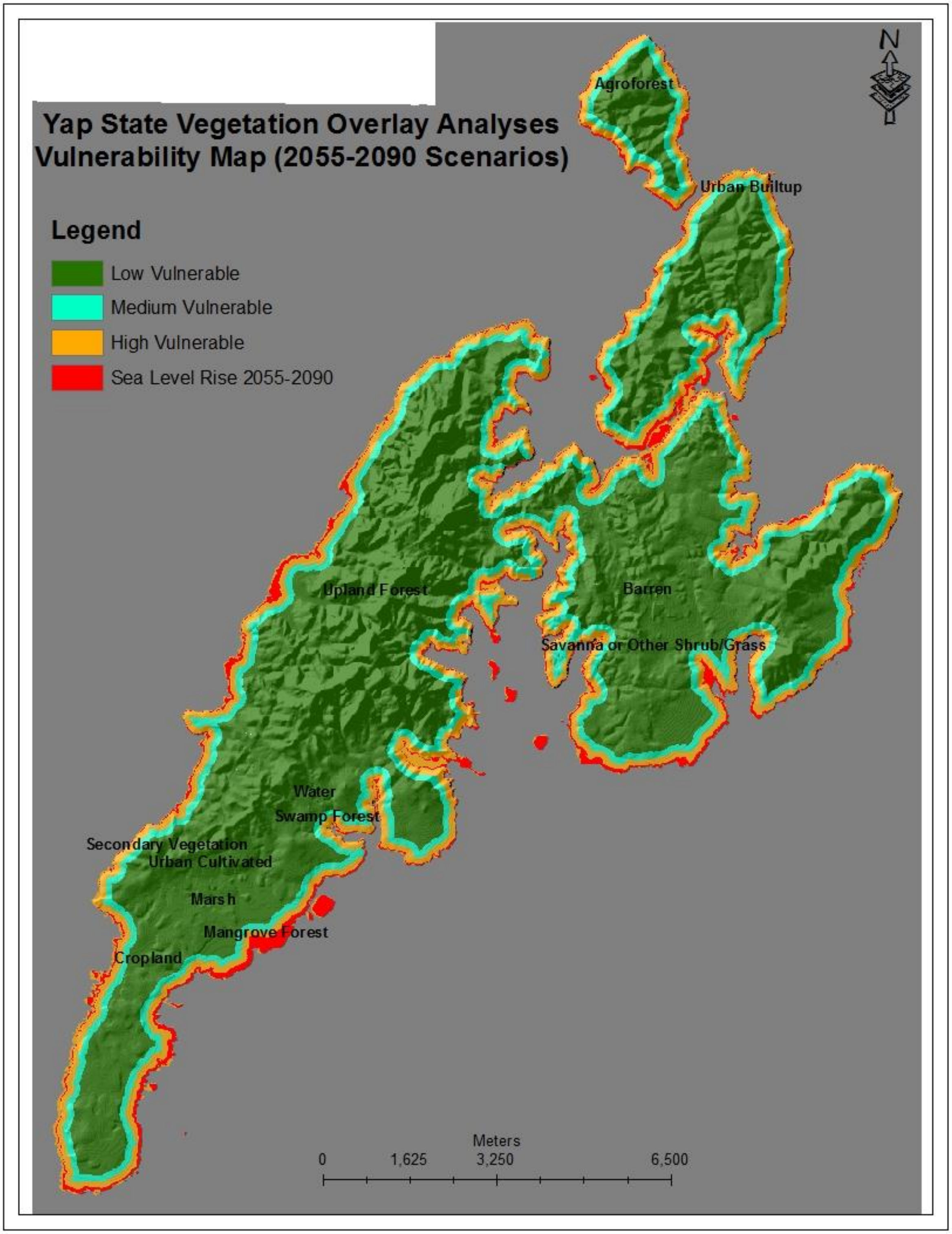
Value	Count	Class	Acres
0	628084	Low Vulnerable	15519.95564
1	140839	Medium Vulnerable	3480.13169
2	167014	High Vulnerable	4126.91594
3	39297	Sea Level Rise Projection	971.02887

The images below are the results of overlaying the vulnerability map of **2055** scenario with the vegetation classes map and land cover images (high resolution and the topographic) to portray the vegetation and land cover classes that will be affected in **2055 - 2090**. The overlay indicated that most of the urban built-ups and urban cultivated along the coastline of Yap are in high risk zones due to sea level rise in **2055**. The Colonia town in Yap will be greatly impacted by this projection.

Overlay Scenario with Land Cover and Vegetation



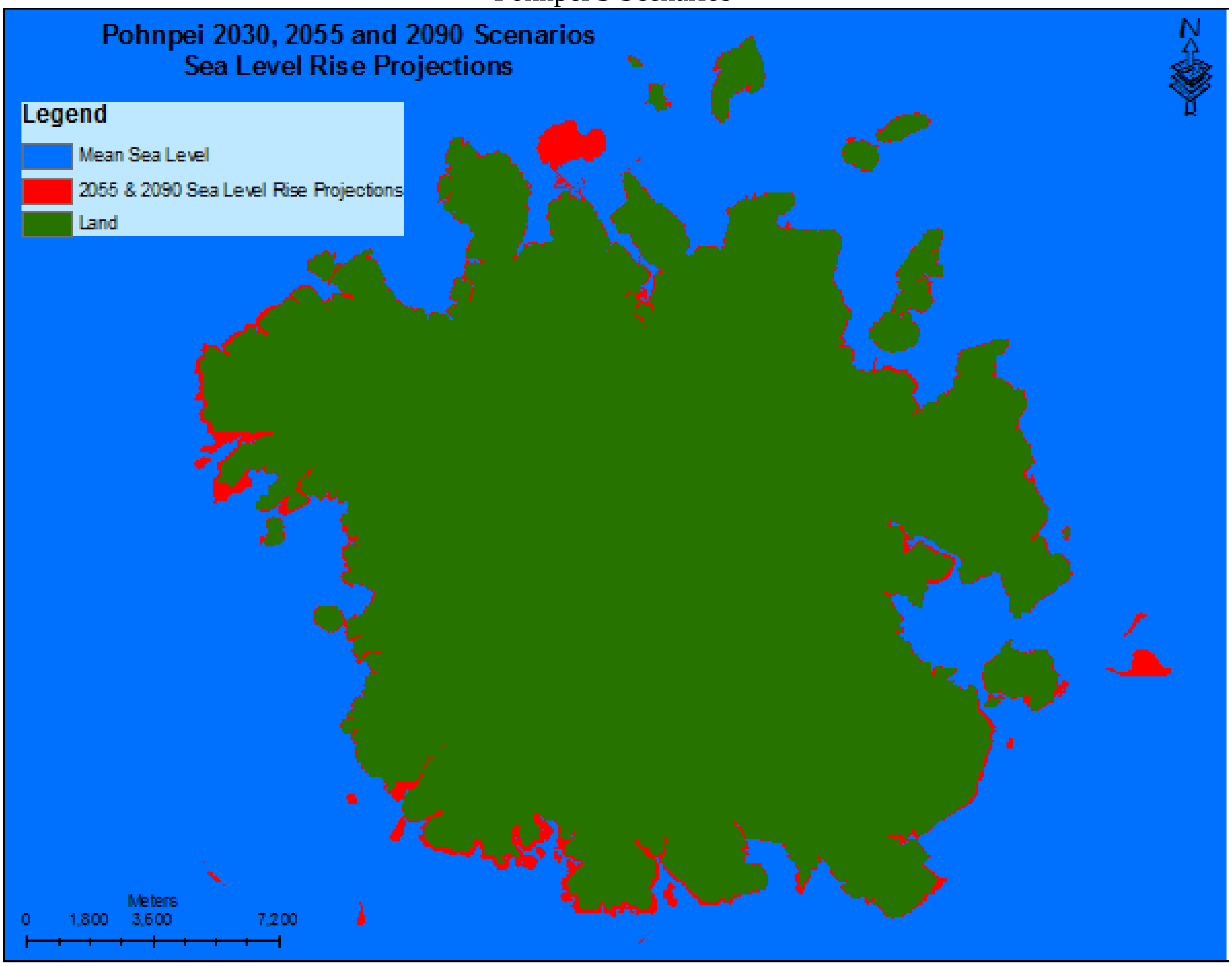
Yap 2055 Sea Level Rise and Vulnerability Map:



POHNPEI STATE SCENARIOS

The image below portrays the 3 scenarios of the sea level rise projections in year 2030, 2055 and 2090 for Pohnpei State. The image shows that the effects of sea level rise for Pohnpei only occur in the **2055** and **2090** scenarios and the effects are same. There is no effect of sea level rise in 2030 scenario.

Pohnpei 3 Scenarios

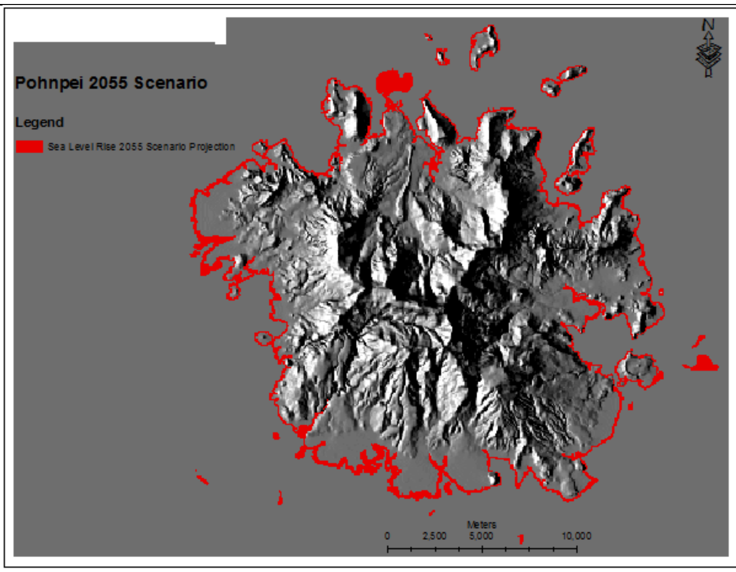


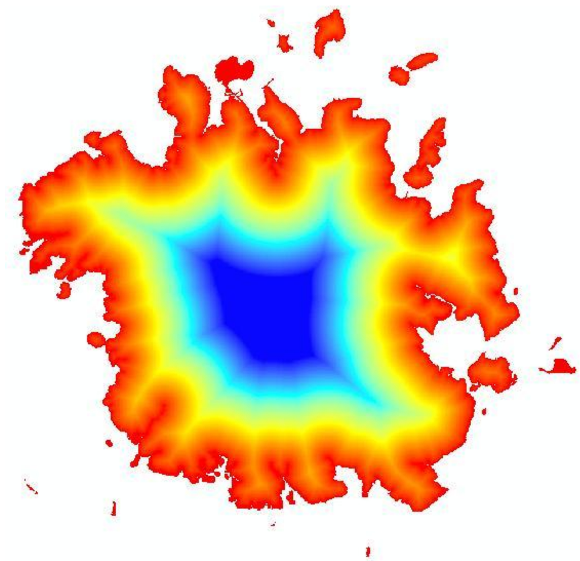
Since the effects of sea level rise projections occur only in **2055** and **2090** scenarios and the effects in both scenarios are same, the vegetation overlay analysis was done for only the **2055** scenario. The analyses and the results are presented in the following pages.

Pohnpei 2055 Scenarios Analyses

The three images below are the **2055** scenario sea level rise projection image, the straight line distance zone calculation from the sea level rise projection, and the reclassification of the **2055** scenario. The reclassification of the zones indicates the sea level rise zones and the vulnerability zones for the scenario. As shown in the attributes for the **2055** sea level scenario, and the vulnerability map:

1. The Sea Level Rise areas cover at approximately 3114.37 acres of land along the coastline of Pohnpei
2. The High Vulnerable Zone covers at approximately 8867.92 acres of land mostly along the coastline of Pohnpei
3. The Low Vulnerable Zone covers at approximately 5108.20 acres of land
4. The Not Vulnerable Zone covers at approximately 73,425.10 acres of land





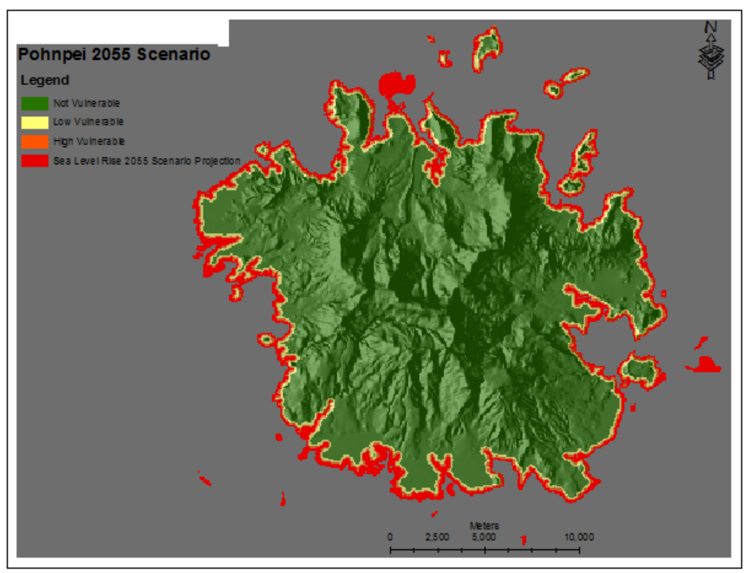
Attributes of Export_Output_2

Count	Zone	Acres
2971473	Not Vulnerable	73425.09783
206726	Low Vulnerable	5108.19946
358880	High Vulnerable	8867.9248

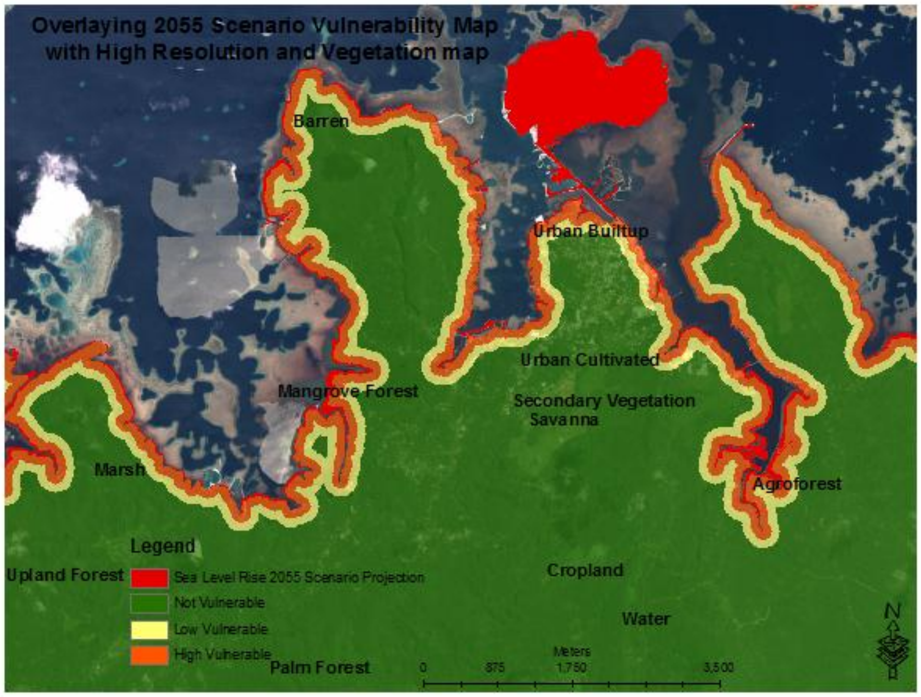
Attributes of Export_Output

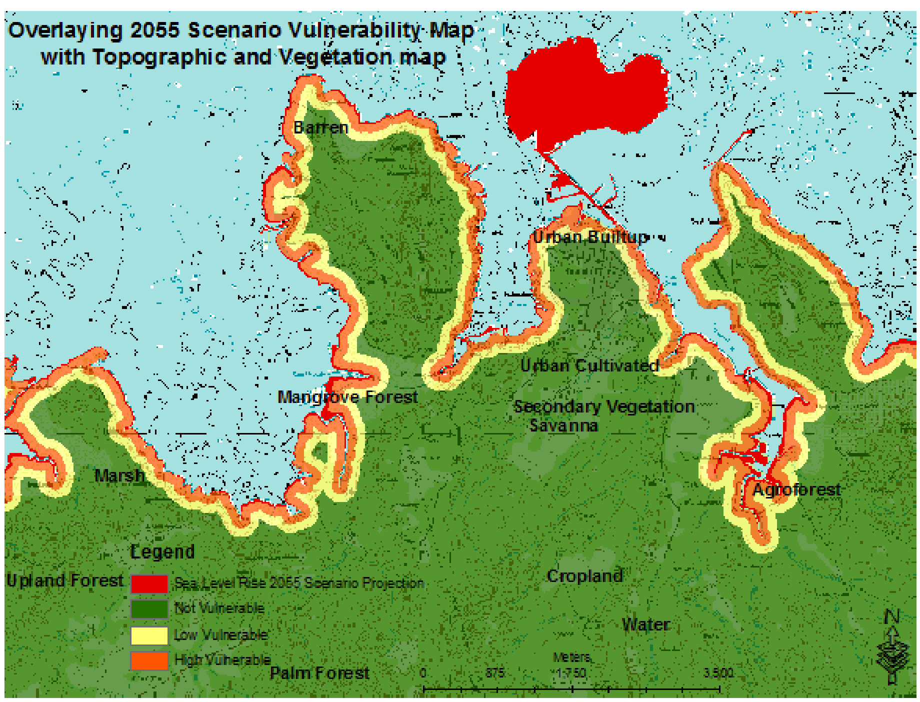
Count	Zone	Acres
126037	2055 Scenario Sea Level Rise	3114.37427

Record: 1 Show: All Selected Records (0 out of

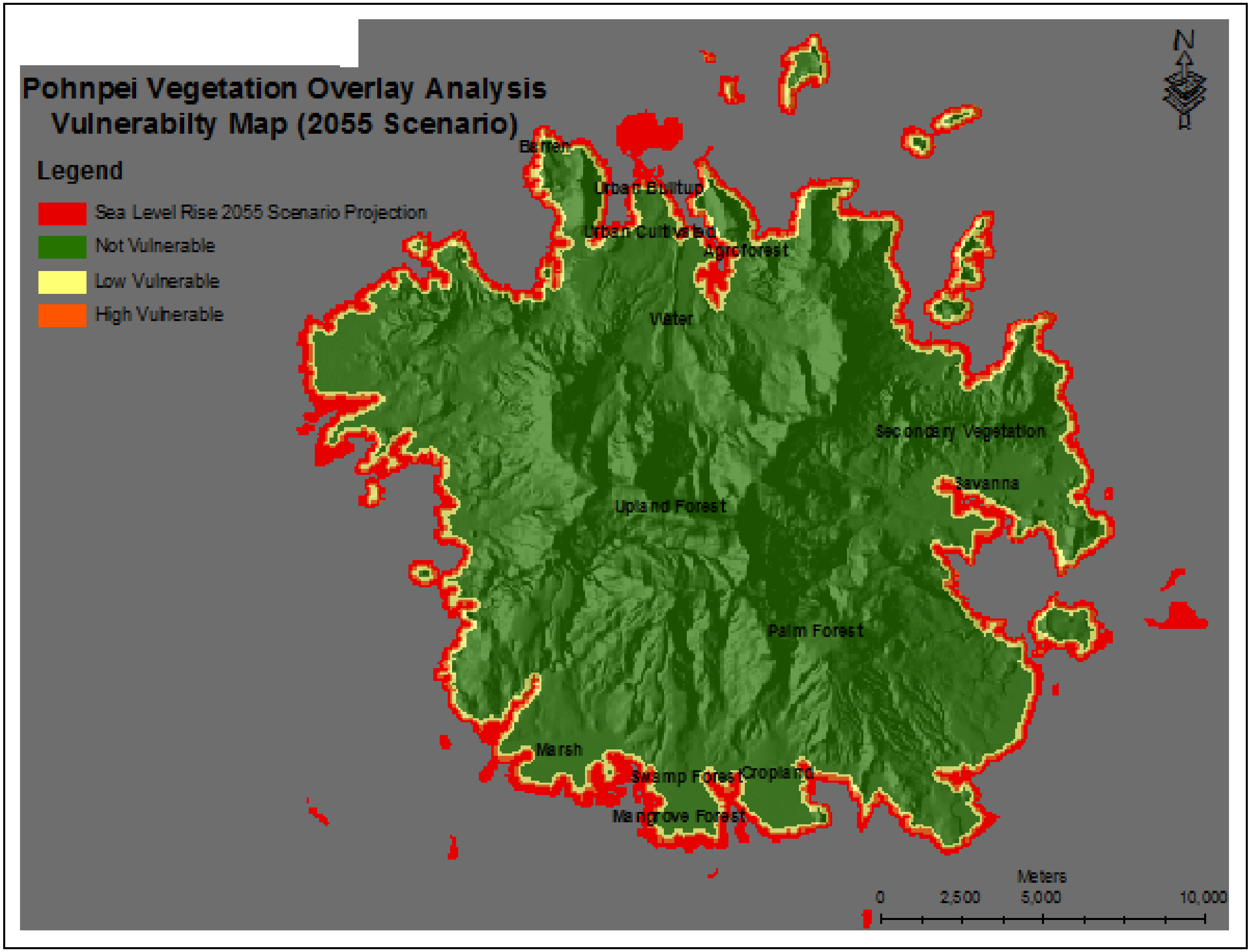


The images below are the results of overlaying the 2055 sea level rise scenario, and the vulnerability map of **2055** scenario with the vegetation map and land cover images (high resolution and the topographic) to portray the vegetation and land cover classes that will be affected in **2055 - 2090**. The overlay indicated that most of the urban built-ups and urban cultivated along the coastline of Pohnpei are in high risk zones due to sea level rise in **2055**.





Pohnpei 2055 Sea Level Rise and Vulnerability Map:



Vegetation Impact Analyses Summary and Conclusion:

STATE:	Kosrae	Chuuk	Yap	Pohnpei
2030 Scenario Impacts:	Approximately ***134.74 acres*** of land will be affected or under water due to sea level rise projection from this scenario.	No sea level rise impact projected from this scenario.	No sea level rise impact projected from this scenario.	No sea level rise impact projected from this scenaro.
2055 Scenario Impacts:	Approximately ***240.13 acres*** of land will be affected or underwater due to sea level rise projection from this scenario.	Approximately ***7311.52 acres*** of land will be affected or underwater due to sea level rise projection from this scenario.	Approximately ***971.03 acres*** of land will be affected or underwater due to sea level rise projection from this scenario.	Approximately ***3114.37*** acres of land along the coastline of Pohnpei will be affected or underwater due to sea level rise projection from this scenario.
2090 Scenario Impacts:	Approximately ***347.50 acres*** of land will be affected or underwater due to sea level rise projection from this scenario.	According to the model projection, the impacts of 2090 scenario are same as the 2055 scenario.	According to the model projection, the impacts of 2090 scenario are same as the 2055 scenario.	According to the model projection, the impacts of 2090 scenario are same as the 2055 scenario.
Summary & Conclusion:	By year 2055, a total of ***374.87 acres*** of land in Kosrae will be affected or underwater. By year 2090, a total of ***722.37 acres*** of land in Kosrae will be affected or underwater. Most of the vegetation cover include mangrove, several agroforest and urban cultivated and builtups along the coastline of Kosrae.	From 2055 to 2090, a total of ***7311.52 acres*** of land along the coastline of Chuuk will be affected. Most of the vegetation cover include mangrove, several agroforest and urban cultivated and builtups along the coastline of Chuuk. Chuuk's airport and the main town will be affected mostly.	From 2055 to 2090, a total of ***971.03 acres*** of land along the coastline of Yap will be affected. Most of the vegetation cover include mangrove, several agroforest and urban cultivated and builtups along the coastline of Yap.	From 2055 to 2090, a total of ***3114.37 acres*** of land along the coastline of Pohnpie will be affected. Most of the vegetation cover include mangrove, several agroforest and urban cultivated and builtups along the coastline of Pohnpei. Pohnpei's airport and the coastway will be affected mostly.

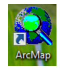
Recommendations:

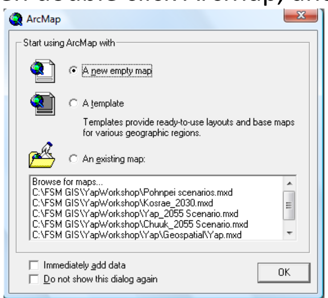
1. Obtain updated Digital Elevation Model (DEM) for FSM (50 yrs lapse) of the main islands and the outer islands
    - The DEM used for this modeling and analyses work is an old DEM and several current land areas were not included, such as the airport runways for the states.
2. Strengthened GIS and Remote Sensing capacity units for each state in FSM
    - Useful tools/resources for disaster and food security decision making for the FSM
3. Availability & accessibility of GIS data for users
4. Standardized and legalize FSM baseline data (i.e. rectify images/maps– accurate base maps)
5. Centralized GIS information

Attachment:

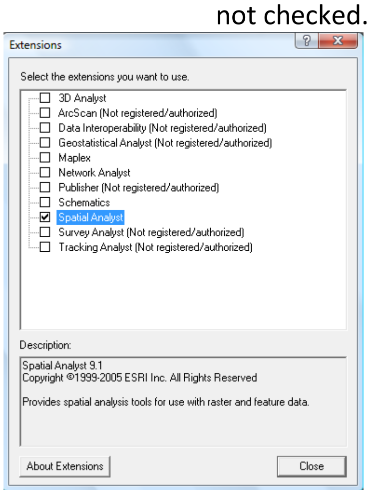
The *specific procedures* for using the Spatial Analyst toolbar to do geospatial analysis:

Using Kosrae's 2030 sea level rise model result/image

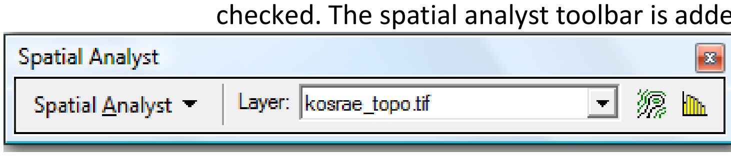
1. **Open/Launch ArcGIS** by double clicking this icon  on your desktop, or go to Start > All Programs > ArcGIS > then double click ArcMap, and then accept 'A new empty map'.



2. ***Add*** the Spatial Analyst toolbar
   - Enable the spatial analyst extension
     i. In ArcMap, go to Tools menu, Extensions, and check the Spatial Analyst check box, if it is not checked. Then close the Extensions window.

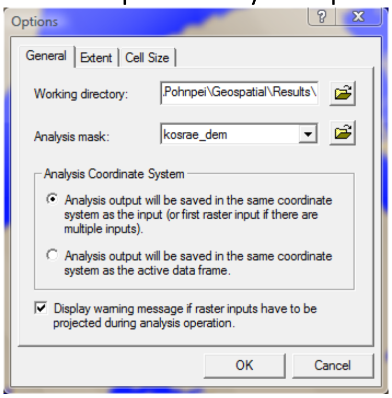


   - Add the spatial analyst toolbar
     i. In ArcMap, go to View menu, Toolbars, then check the Spatial Analyst, if it is not checked. The spatial analyst toolbar is added.



3. ***Add*** the layers to ArcMap. Use the Add in tool  to add in layers
   - Add the following layers into ArcMap, and rearrange them in the following order
     i. 2030.img
     ii. kospic_veg
     iii. kosrae_topo.tif
     iv. *kosrae_dem*

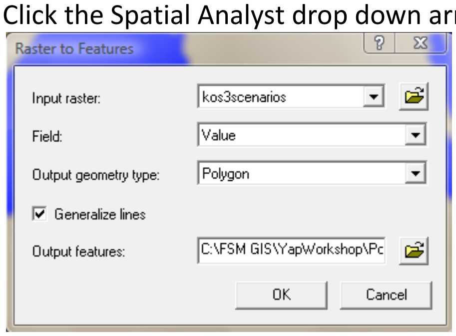
4. ***Set*** the analysis environment: Before performing analyses, it is crucial that you set the analysis environment within which you are working. The analysis environment includes the workspace into which results will be placed, and the extent, mask, cell size, and coordinate system of your results. Since we'll be using the Spatial Analyst Toolbar, we'll set the analysis environment via the Options dialog box on the Spatial Analyst toolbar.
    - Click the Spatial Analyst dropdown arrow and select Options

    - The working directory will be the 'Results' folder I created in the Kosrae's folder. Browse to that 'Results' folder to set as the working directory
    - Set the analysis mask, the extent and cell size as 'same as kos_dem'.
    - Click OK

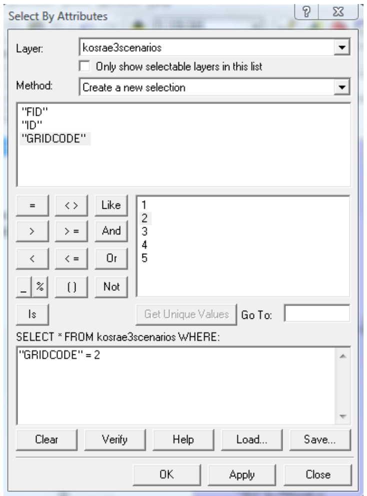
Since we'll be generating vulnerable or at-risk zones from the submerge polygons from the 2030, 2055 and 2090 images (results from the Erdas models), we need to extract the submerge polygons from the images. First, we'll convert the image from raster to features, select only the submerge polygons, create the submerge polygons as new features layer, and then convert the layer back to raster to perform the analysis.

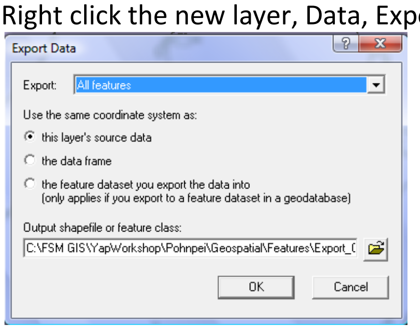
5. ***Convert*** the 2030.img image from Raster to Features
    - Click the Spatial Analyst drop down arrow and select Convert, then Raster to Features

    - In the Raster to Features window, select 2030.img as input, value as the field, polygon as the output geometry type, then click OK.
    - The 2030.img features layer is added to the TOC
    - Open its attributes and notice that the GRIDCODE field contains 1, 2 and 3. 1 represents the mean sea level polygons, 2 represents the submerge polygons and 3 represents the land polygons.

Next we'll select only the submerged polygons (GRIDCODE = 2) using the 'Select by Attributes' and then export the selected polygons to create a new features layer

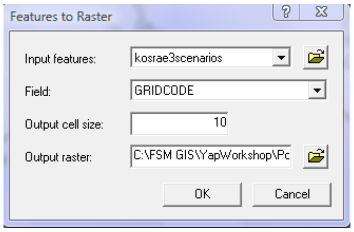
6. ***Create*** the submerge polygons (GRIDCODE 2) as a new layer
    - Go to Selection menu, then ‘Select by Attributes’. The layer should be the 2030 features layer, and the method should be ‘create a new selection’.
    

    - Double click the ‘GRIDCODE’, and then = 2. In the ‘SELECT FROM 2030_features WHERE’, notice that the query should be “GRIDCODE” = 2
    - Click OK
    - All submerged polygons in the 2030 image features layer are selected/highlighted
    - In the TOC, right-click the 2030 features layer, go to ‘Selection’, then ‘Create Layer from Selected Features’.
    - A new layer is added to the TOC called the 2030_features selection
    - Right click the new layer, Data, Export data. Rename the layer as kos2030_submerged. Then OK
    

    - OK to add to the map
    - Then Remove the selection layer from the TOC

Notice there are some submerge polygons outside of Kosrae and also two inland submerge polygons. Those needed to be removed or deleted. To do so, use the select tool to select those polygons and then switch the selection. Again export the highlighted/selected polygons, save as kos2030_submerge, and then add it to the TOC. And remove the other submerge layer.

7. ***Convert*** the kos2030_submerge features layer to raster
    - Select the Spatial Analyst > Convert > Features to Raster

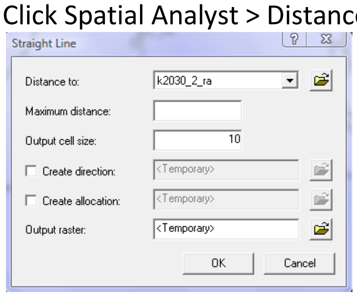


- In the Features to Raster window, select input as kos2030_submerge, Field as GRIDCODE, and give an Output name as *kos2030_2_ra* in the Results folder. Then click OK
- The raster layer is then added to the map

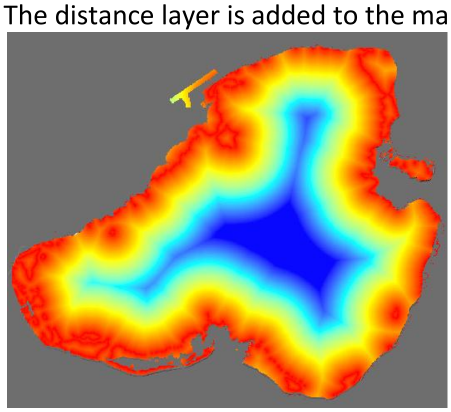
Before we get into analyzing the raster layer that we just created, we need to set the analysis mask and extent using the *kospic_veg*, so the analysis will be done only on the land. Go to Options in the Spatial Analyst toolbar and change the analysis mask and extent to *kospic_veg*.

The analysis will include (a) calculating the distance zones from the submerge pixels/polygons using the straight line distance tool of the spatial analyst toolbar and then (2) reclassifying the distance zones into '2' – High Vulnerable, '1' – Low Vulnerable, and '0' – Not Vulnerable.
The distance zones will depend on the need of each State. As for this example exercise, the distance zones were reclassified into 20 Equal Interval distance zones, and then also reclassified down to 3 zones, which include zone values of 2, 1, and 0.

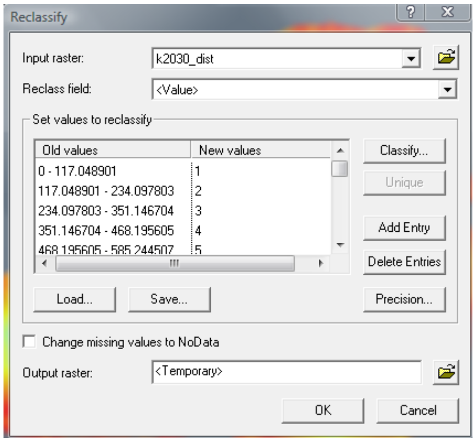
8. ***Calculating*** the Straight Line Distances
    - Click Spatial Analyst > Distance > Straight Line

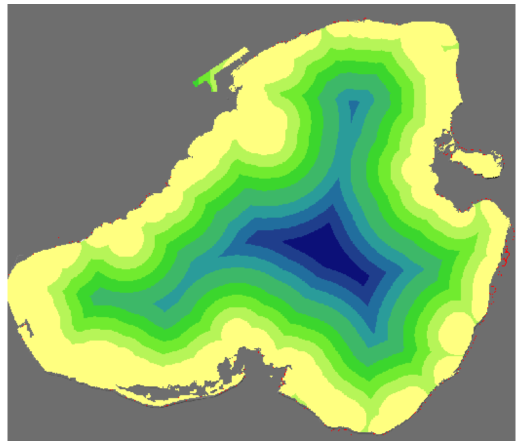


    - In the Straight Line window, select *kos2030_2_ra* as input and give an output name as '*distance*'. Click OK
    - The distance layer is added to the map

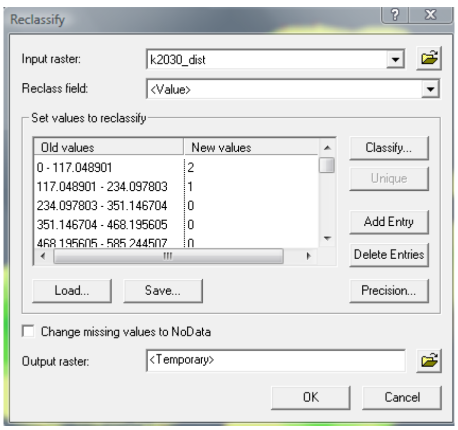


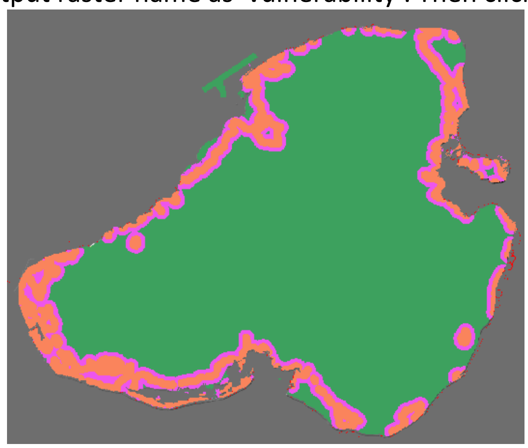
9. ***Reclassifying*** the distance layer into *'2' for 'High Vulnerable'*, *'1' for 'Medium Vulnerable*, and *'0' for 'Low Vulnerable'*.
    - Click Spatial Analyst > Reclassify





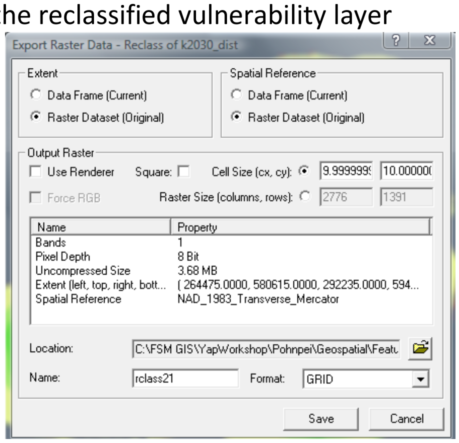
- In the Reclassify window, select *distance* layer as input raster, Value as reclass field, and then change the new values, and give an output raster name as ‘vulnerability’. Then click OK.



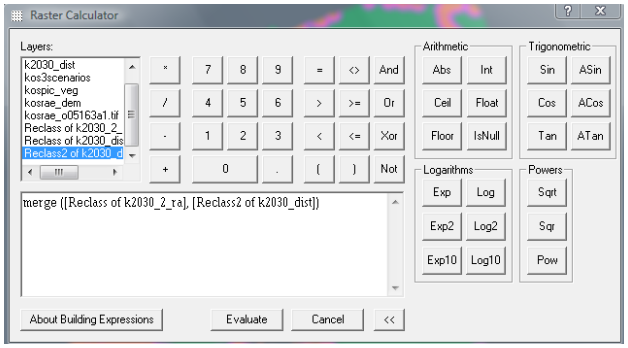


- The vulnerability layer is added to the map containing only three classes/zones (0, 1 & 2)

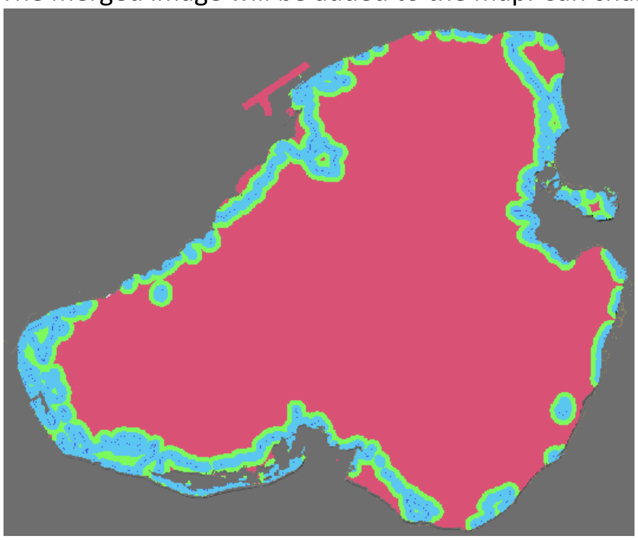
10. ***Export*** the reclassified vulnerability layer



11. **Merge** the sea level rise projection layer and the 3 zones reclassified layer into a *vulnerability or risk map,*
    - Open the Raster Calculator from the Spatial Analyst Toolbar and type in ‘merge (reclass k2030_ra, reclass k2030_dist)



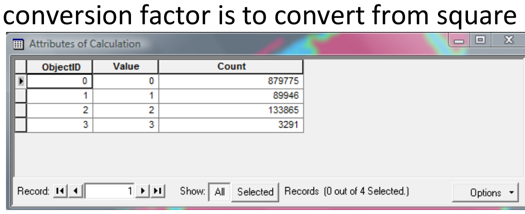
- Click OK
- The merged image will be added to the map. Can change the color for each class to your liking.



Rename the values of the merged image in the TOC as follow:

- 0 – Low Vulnerable
- 1 – Medium Vulnerable
- 2 – High Vulnerable
- 3 – 2030 Sea Level Rise Projection

12. ***Calculate*** total areas/acreages for the High Vulnerable Zone, Medium Vulnerable Zone, Low Vulnerable Zone, and the Sea Level Rise Projection.
    - Open the merged layer attribute table and notice the Count field for each Value field. The count field contains the number of pixels for each value field. We will calculate total acres for each class/value field by multiplying the pixel size and the count field by the conversion factor. The conversion factor is to convert from square meters to acres.

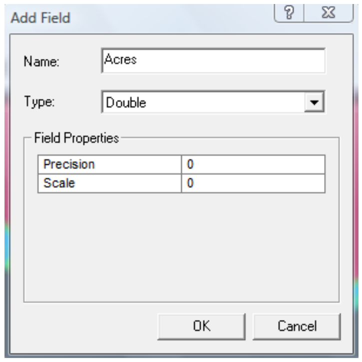


Attributes of Calculation

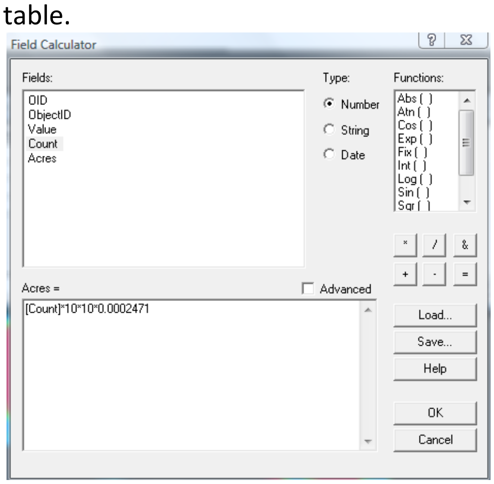
ObjectID	Value	Count
0	0	879775
1	1	89946
2	2	133865
3	3	3291

Record: 1 Show: All Selected Records (0 out of 4 Selected.) Options

- Export the merged vulnerable layer attribute table
- Open the exported attribute table, go to Options on the exported attribute table and click Add Field



- Name ‘Acres’, and type ‘Double’. Then click OK
- To calculate the acres for each vulnerability class/zone, right click the ‘Acres’ heading and click ‘Calculate Values’. In the Field Calculator window, type in ‘Count’*10*10*0.0002471, then click OK. This will automatically calculate the acreages for each vulnerability zone in the attribute table.



And finally, **Overlay** the vulnerability map from the previous step of each scenario with the vegetation map, and the land cover maps, such as topographic map and high resolution image(s), to *depict* vegetation class(s) and land covers that will be affected by the sea level rise projection for each scenario.The final vulnerability map can also be used/overlay with other data sets such as census and infrastructure