FLORIDA ATLANTIC UNIVERSITY

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Project: Automated Volume change computation using Multi-spectral UAS Imagery

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Executive Summary

Being ever-changing and most important feature of coastal landscape, Shoreline reflects the natural processes of erosion as well as deposition, and hence volume computation after extracting the shoreline is of paramount importance. Coastline is the line that separates the water and shore while shoreline is the line that separates the shore and land. They are essential attributes of the earth surface that are considered as complex, dynamic, and unstable geomorphic components in the coastal environment. The dynamic nature is due to factors such as wave actions, sedimentation by longshore currents, natural disasters like tsunamis, dangerous waves and coastal erosion, variations in water level in the ocean and man-made events. However, volume computation for a region is mostly manual and time-consuming. This process can be improved by developing a custom Geoprocessing tool through automated Python script that would help in computing the volume for any given region. The ability of the developed tool is to make use of Red Edge Band to generate Normalized Index and thereby use the shoreline and coastline features, to compute volume in a short span of time without much human intervention. The study area considered for this research is 120-acre Jupiter Inlet Lighthouse Outstanding Natural Area (JILONA) that has more than 3500 feet of dynamic shoreline and the required UAS data has been collected using Micasense Multispectral Sensor Package. After performing Drone data processing using ‘Pix4D’, ‘ArcGIS Pro’ and ‘ArcPy’ has been used to automate the volume computation.

Introduction and Problem Statement

Coastline and Shoreline are two important features of the coastal landscape, that helps in computing volume for a specified region. The Visualization of ever-changing coastline and shoreline, along the Jupiter Inlet Lighthouse Outstanding Natural Area (JILONA) region is an important factor in case of determining the shoreline change detection and the volume of soil erosion. As of now, this computation process is being done manually which is labor intensive and takes a lot of time. This process can be improved by developing a custom Geoprocessing tool developed through automated Python scripts that would help in computing volume change by making use of coastline and shoreline.

The area considered for this research is the Jupiter Inlet Lighthouse Outstanding Natural Area (JILONA) region and the required Unmanned Aircraft System (UAS) data has been collected using drone with Micasense Multispectral Sensor Package in April 2021 and August 2021.

Background

In spite of being a volatile environment, the coastal area provides considerably high economic, social, and recreational opportunities, thereby being an important landscape to study and maintain.

Due to the acceleration of changes in the coastal landscape, there is a huge need in terms of effective and timely acquisition of both coastline and shoreline information in order to compute the volume change for any given region. Remote sensing satellite images have been extensively used to monitor position of shore zones and coastline, which delivers repeated and consistent statistics of coastal variations. This coastal variation plays a vital role in affecting the volume change along the shore. Manual computation of soil volume is time consuming, and accuracy depends on interpreter knowledge.

Today, to compute volume from satellite imagery, many methods exist, but in order to render the soil volume with more accuracy, satellite images with higher resolution is required. This in turn is not a cost-effective solution. Hence, an extraction tool has been developed from the collected UAS data using python scripts, which uses the shoreline, coastline and the orthomosaic generated from Pix4D, to compute the volume change of a region without much human intervention.

Purpose and Scope

Coastal regions are quite fragile landscapes as they are most vulnerable to climatic changes and natural disasters. Because of their dynamic nature, there is a need to understand the rate of change of soil deposits and drifted away for a wide range of coastal studies, such as development of coastal management planning, hazard zoning and erosion-accretion patterns.

Erosion control is one of the important aspects of coastal zone management and the degree of management required depends on density of population, extent of development of the region and the intensity of erosion.

The purpose of this project is to develop a Geoprocessing tool that would automate this process of volume change computation which would serve the purpose of coastal zone management is the need of the hour.

Objective

The primary objectives of this project are as follows:

1. To automate the process of volume change computation in the Jupiter Inlet Lighthouse ONA region by developing a geoprocessing tool using Python.

Software used

- **Citrix Server - GPU Desktop**
  - Citrix Server is a virtual application delivery tool that enables users to access the required applications from anywhere, without considering the fact of hardware that they use
  - GPU desktop is a remote desktop that can be connected through the citrix server, which helps in accessing all the windows application present in the system

- **ArcGIS Desktop - ArcGIS Pro**
  - ArcGIS Pro, a Desktop software helps in working with all kinds of geospatial information
  - It allows to create, view, edit and query the spatial data in both two dimension and three dimensions
  - It provides an infrastructure for GIS data management and manipulation of necessary tasks

- **Pix4D**
  - Professional photogrammetry drone mapping software
  - Drone Data processing to generate accurate and georeferenced Orth mosaics, three dimensional meshes, elevation models and point clouds

- **Geoprocessing**
  - Framework/ Process to run a series of specialized software tools, to create a new dataset after analysis and manipulation
  - It helps in performing a set of operation on vector and raster datasets to create a processed output dataset

- **ArcPy**
  - Python script to automate any available tools in the ArcGIS desktop software (ArcMap, ArcGISPro etc.,)
  - A Python site package that can be built on any ArcGIS scripting module, providing productive way to perform GIS analysis

- **ArcGIS Model Builder**
  - It is used in creating models and model tools, by integrating a sequence of tools for execution
  - A Series of geoprocessing tools can be modelled one after other, so that it can be useful in the future runs

Data Source

Data for this "**Automated Volume change computation using Multi-spectral UAS Imagery**" project has been collected from very high-resolution drone imagery. The **Unmanned Aircraft System** (UAS) data used in this project was collected using drone with Micasense Multispectral Sensor Package in April 2021 and August 2021.

Figure 1: Micasense Multispectral Sensor Package (Source: Micasense)

The following table represents the specification of the sensor used in the aircraft for collecting data in the JILONA region for two separate regions namely JILONA North and JILONA South.

Table 1: RedEdge-MX Camera Specifications (Source: Micasense)

Weight	**231.9 g (8.18 oz.) - (Includes DLS 2 and cables)**
Dimensions	8.7 cm x 5.9 cm x 4.54 cm (3.4 in x 2.3 in x 1.8 in)
Spectral Bands	Blue, green, red, red edge, near-infrared (NIR) (global shutter, narrowband)
Wavelength (nm)	Blue (475 nm center, 32 nm bandwidth), green (560 nm center, 27 nm bandwidth), red (668 nm center, 16 nm bandwidth), red edge (717 nm center, 12 nm bandwidth), near-IR (842 nm center, 57 nm bandwidth)
RGB Color Output	Global shutter, aligned with all bands
Ground Sample Distance (GSD)	8 cm per pixel (per band) at 120 m (~400 ft) AGL
Capture Rate	One capture per second (all bands), 12-bit RAW
Interfaces	Serial, 10/100/1000 ethernet, removable Wi-Fi, external trigger, GPS, SDHC
Field of View	47.2° HFOV
Triggering Options	Timer mode, overlap mode, external trigger mode (PWM, GPIO, serial, and Ethernet options), manual capture mode

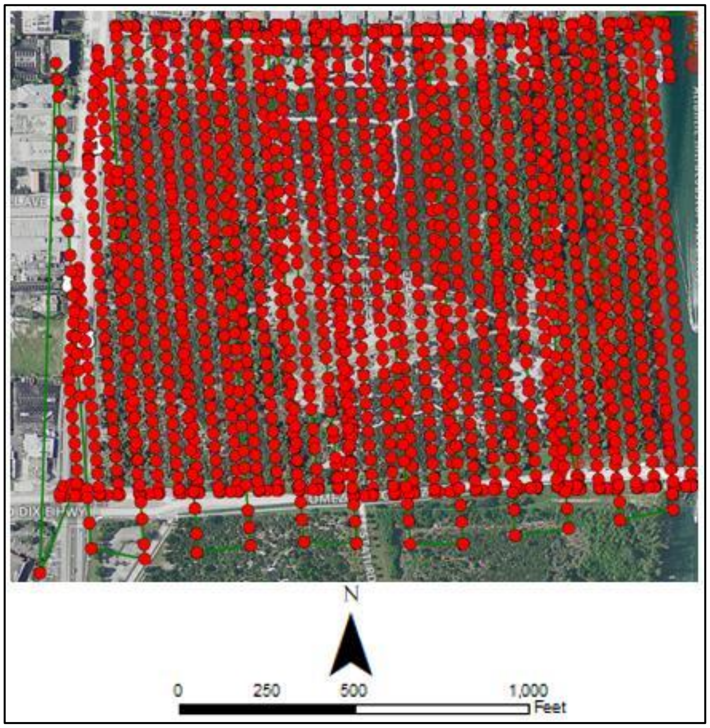


Figure 2: JILONA North

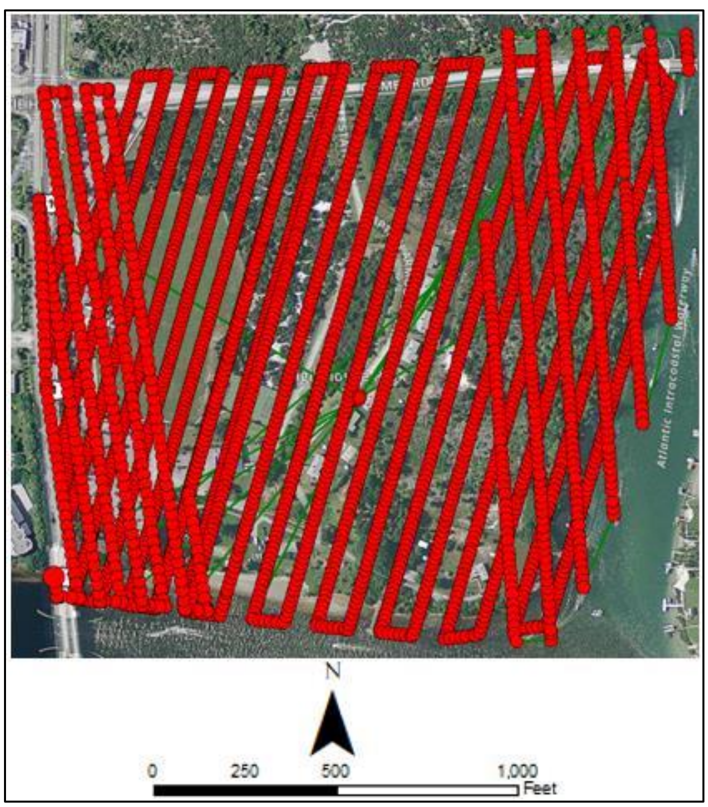


Figure 3: JILONA South

Workflow

The initial step of this study is to generate collect data using the Micasense RedEdge Camera. The collected raw point cloud data of April 2021 and August 2021 has to be further processed using Pix4D Mapper. The output from the Pix4D software will be the orthomosaic, DTM etc., Further this orthomosaic imagery is used in extracting the shoreline and coastline (waterline) features.

Coastline is the line that separates water body, and the shore region and Shoreline is the line separates the shore region and the land area. The areas considered to be unnecessary for the volume computation needs to be captured as a polygon features. By taking all these as input, a geoprocessing tool has to be developed that computes the volume change.

Initially the tool creates a polygon from the extracted shoreline and coastline, and then it erases the unnecessary features with the help of the created polygon data. Secondly, based on the output polygon, both the April and August DTM's are clipped. Using this clipped raster, raster difference is taken through "**Raster Calculator**". Thirdly, for this output difference raster, volume change can be computed using the "**Surface Volume**" tool available in the ArcGIS Pro. The volume is being converted to cubic yards, which can be further used for different kind of analysis.

Finally, the outcome of volume change is being stored as a Comma Separated Value (csv) format along with the deletion of unnecessary intermediate results.

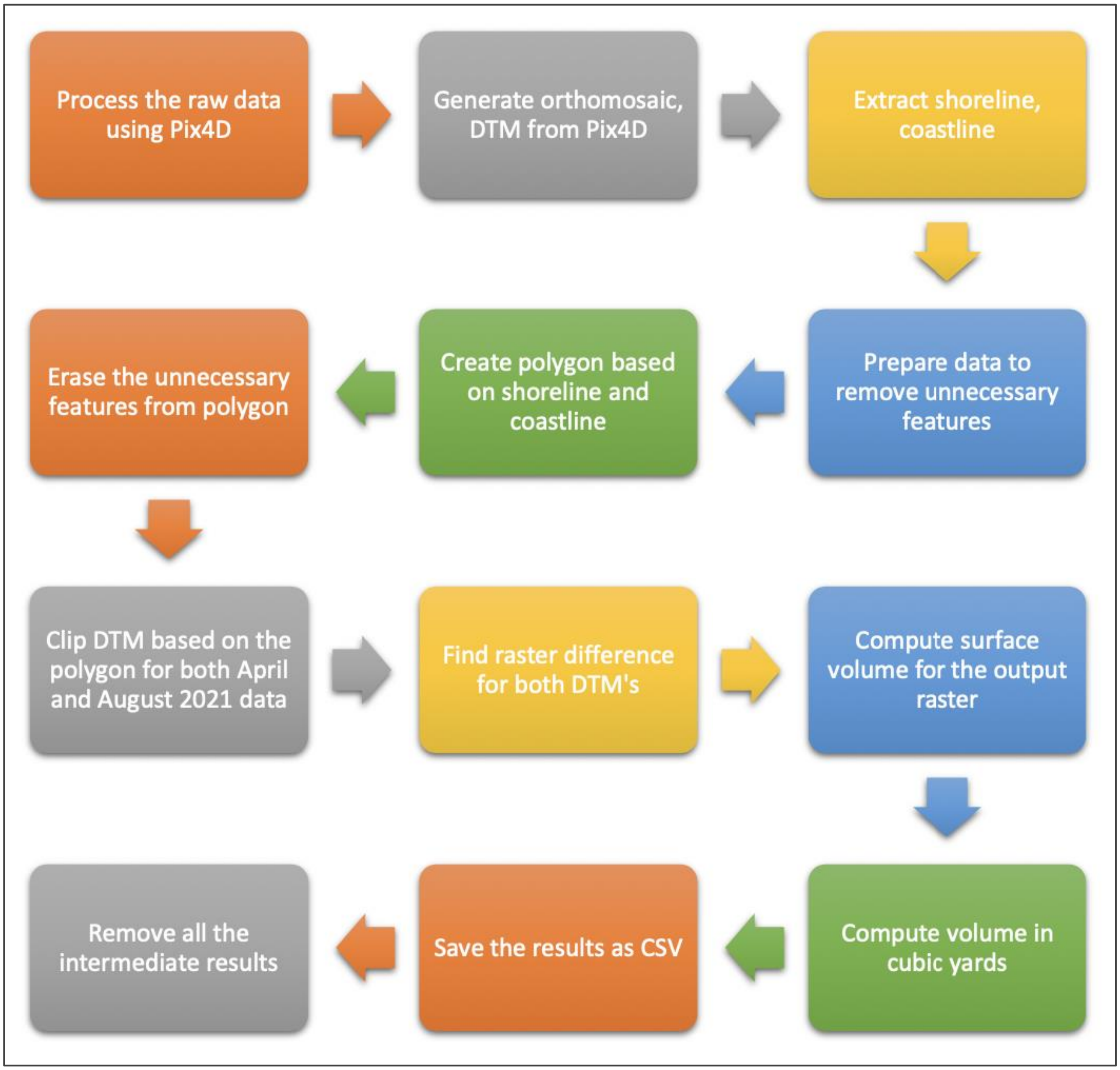


Figure 4: Overall workflow of the project

Project Area

The geographic region of interest for this project work is defined as **Jupiter Inlet Lighthouse Outstanding Natural Area** (JILONA). It is located in the northern Pam Beach County on the Atlantic coast of South Florida. JILONA is one of the parts of Bureau of Land Management’s 27-million-acre National Conservation Lands and being the only complete unit in east of Mississippi River. It is adjoined by the Loxahatchee River and the Indian River Lagoon and a half mile from the Atlantic Ocean. It is situated 14 miles north of West Palm Beach and it is present at approximately of 2 hours duration from the north of Miami via Interstate 95. The total land cover area of JILONA region is about 120 acres of open space.

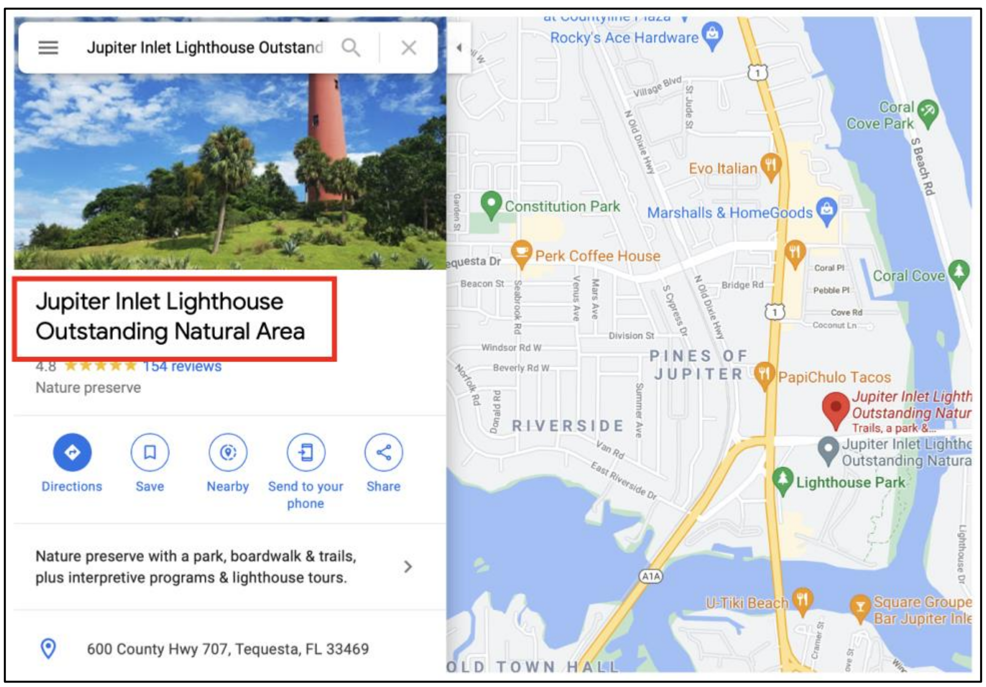
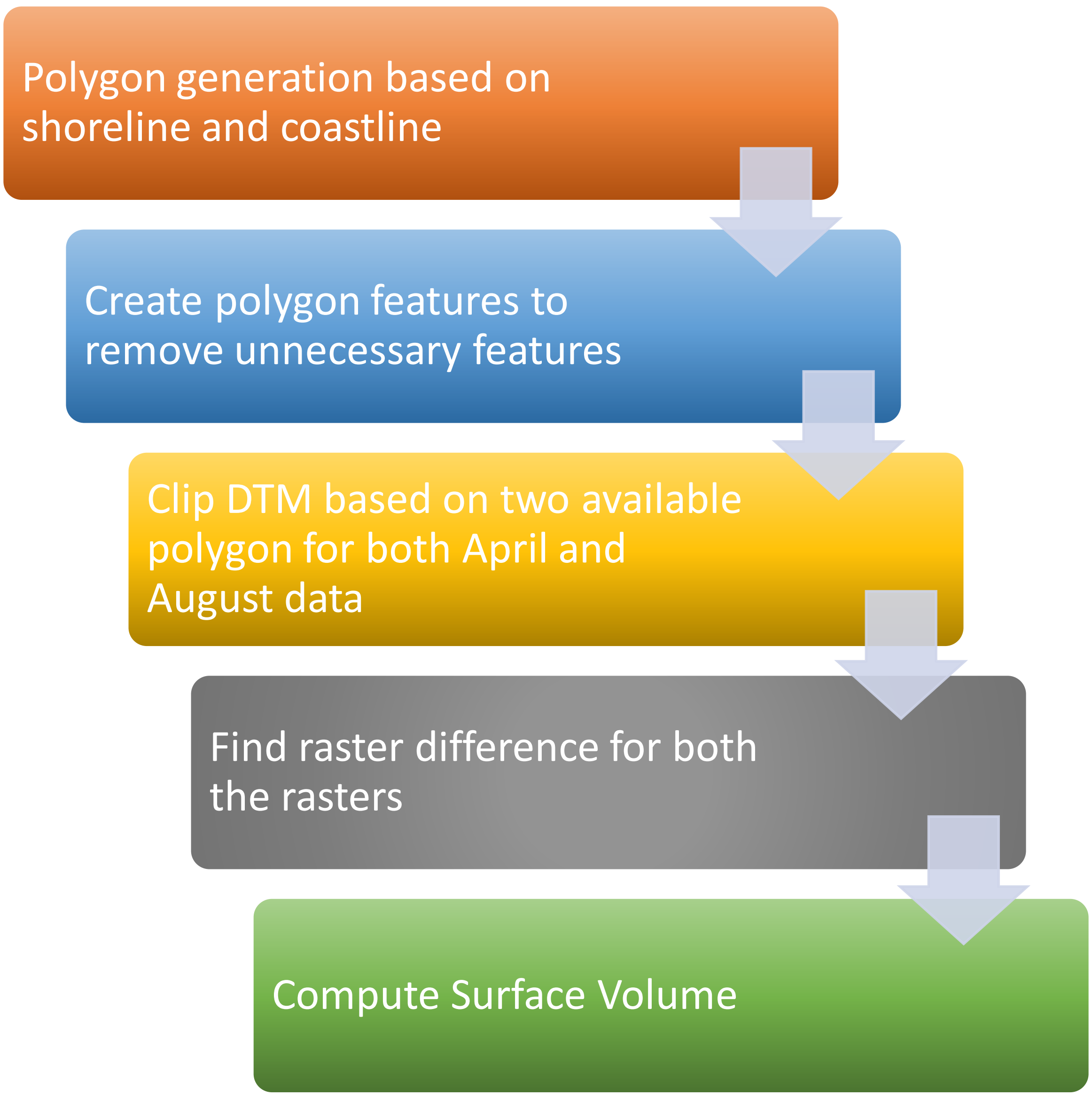


Figure 5: JILONA region in Google Map

Figure 6: JILONA AOI

Methodology

The necessary UAS data was acquired from the Micasense Red Edge Multi spectral camera and preprocessed it to render orthomosaic and DTM, through which the volume change for April 2021 and August 2021, after construction has been analyzed.



Procedure

The UAS multispectral imagery is used to extract DTM, shoreline and coastline, through which the volume change of Jupiter Inlet Lighthouse ONA from April2021 to August 2021 is being computed.

Data Preprocessing

As the initial step, the collected data must be cleaned up for further processing. The raw data from the Mica sense Red edge camera was processed using Pix4D software, which resulted in high resolution imagery.

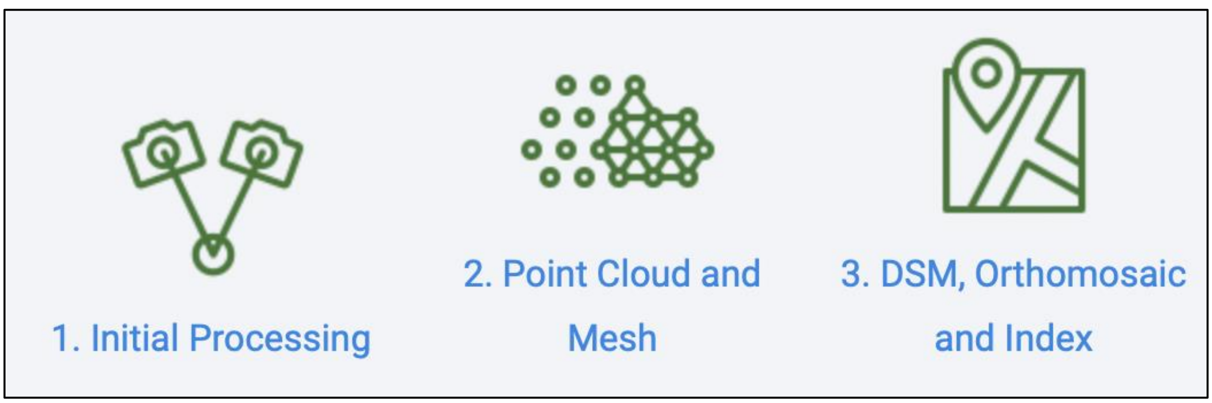


Figure 7: Steps to generate orthomosaic image

The steps shown in figure 7 need to carried forward in order to convert the raw data to orthomosaic data. Initial processing is to mark all the ground control points on the data, so that all the other points get automatically matched up, which would finally result in DSM, DTM and orthomosaic after several hours of processing.

Volume Change Computation tool

A custom geoprocessing tool was developed using ArcPy, through which volume change for two different DTM's is being computed by giving the high-resolution multispectral imagery consisting of 5 bands namely Blue, Green, Red, RedEdge and Near InfraRed.

Required Tools

All the required tools are being imported at the beginning, so that extraction process can make use of these and result in a better outcome. As an initial step, "**Spatial Analyst**" Extension has to be enabled in order to perform all kinds of spatial operations and access the spatial analyst tools available in the ArcGIS Pro.

1. ArcPy
2. Spatial Analyst
3. Image Analyst
4. 3D Extension Analyst

Process

To compute the volume change along the shore of Jupiter Inlet Lighthouse ONA, there exist five major steps to develop a customized geoprocessing tool. They are as follows:

<u>Available data:</u> Orthomosaic, DTM, Shoreline, Coastline, Unnecessary features polygon

In order to compute volume for the whole study area, a sample area has been selected along the south region. All the available data mentioned above has been used in this tool, so that the volume change can be computed for April 2021 and August 2021.

Figure 8: Orthomosaic of April 2021

Figure 9: Orthomosaic of August 2021

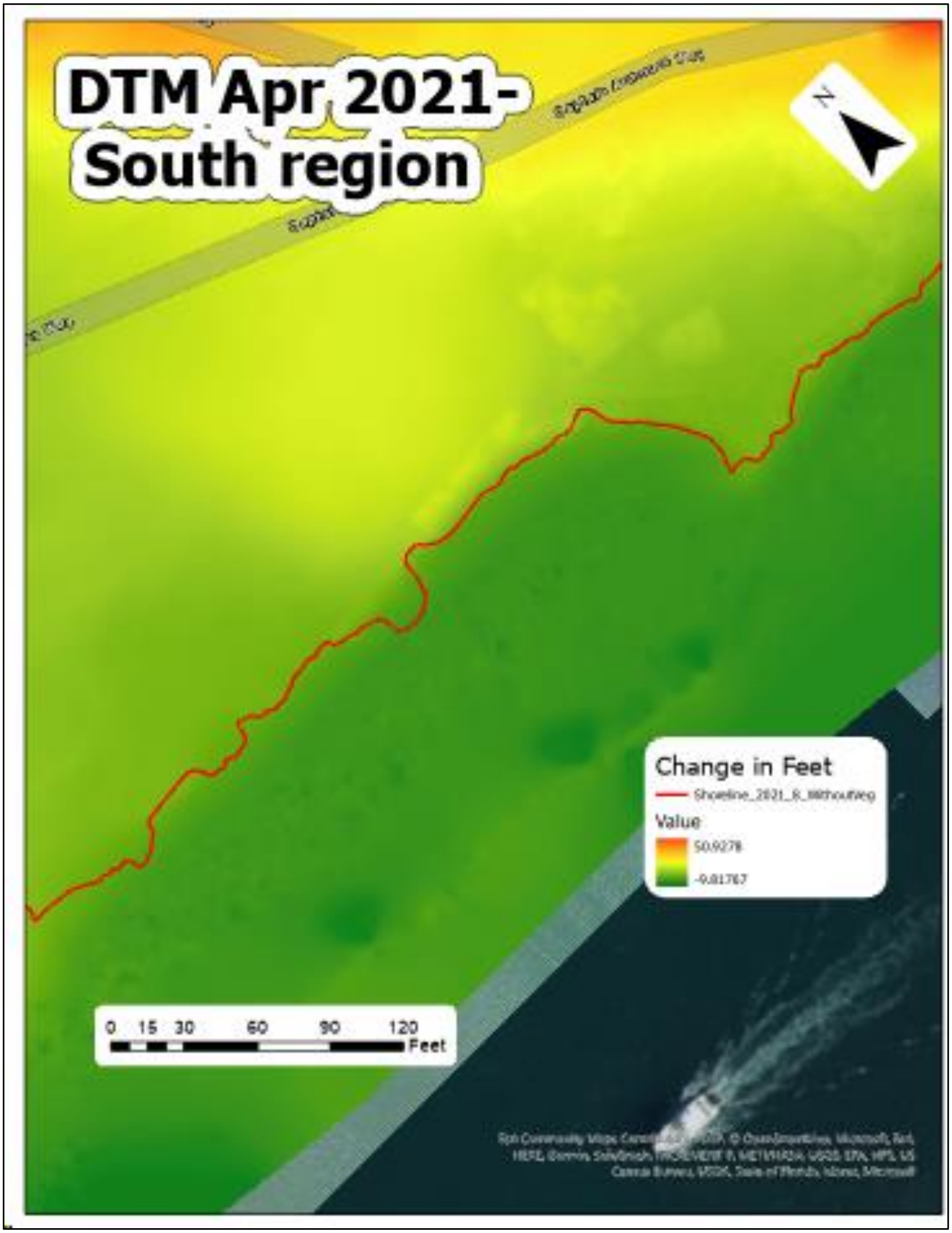


Figure 10: DTM of April 2021

Figure 11: DTM of August 2021

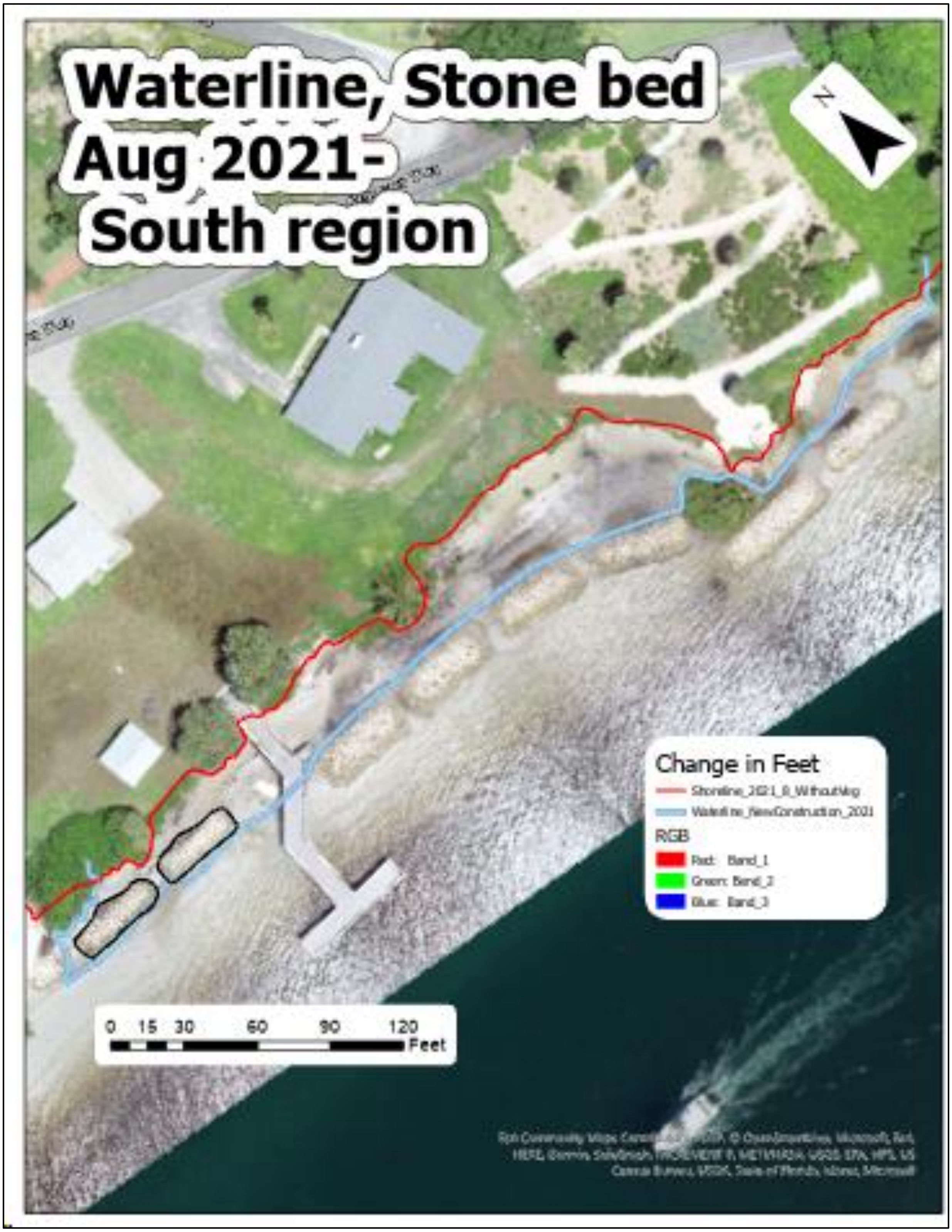


Figure 12: Waterline and Features to remove

Step 1: Generate polygon using shoreline and coastline

Input: Shoreline and Coastline line features

Tool Used: Feature To Polygon

Output: Polygon based on shoreline and coastline

Step 2: Erase the unnecessary features from the created polygon

Input: Polygon based on shoreline and coastline, Unnecessary polygon feature

Tool Used: Erase Features

Output: Polygon for computing volume change

Step 3: Clip DTM based on polygon for both April 2021 and August 2021 orthomosaic

Input: Polygon for computing volume change

Tool Used: Clip Raster

Output: DTM for April 2021 and August 2021

Step 4: Find Raster difference for both the DTM's

Input: DTM of April 2021 and August 2021

Tool Used: Raster Calculator

Output: Difference raster

Step 5: Surface volume computation

Input: Difference raster

Tool Used: Surface Volume

Output: Volume change result of April 2021 and August 2021 in cubic yards

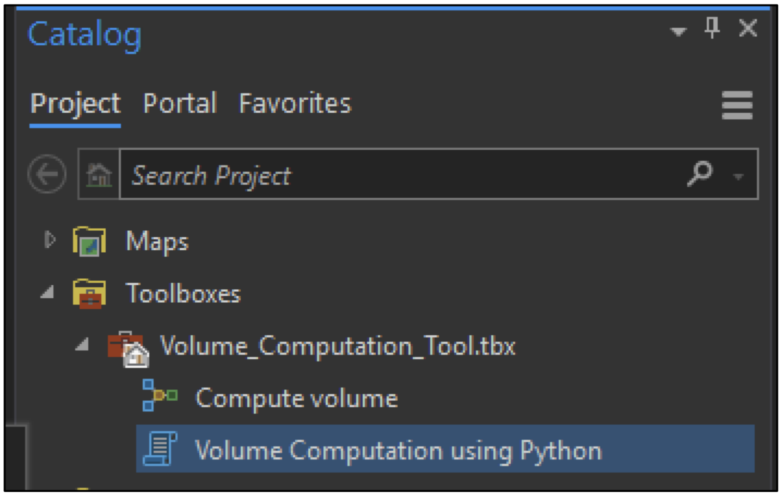


Figure 13: Volume computation Script

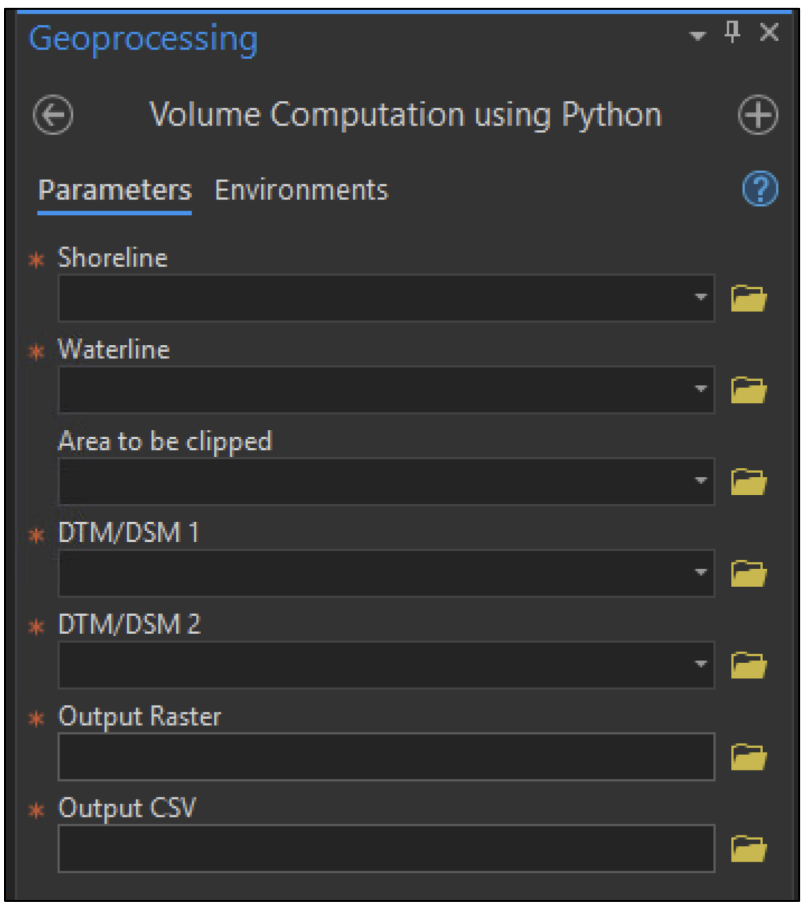


Figure 14: Volume change computing tool

Generated Results

The major outcome of this research is the DTM Difference map and the volume change computation for April 2021 and August 2021.

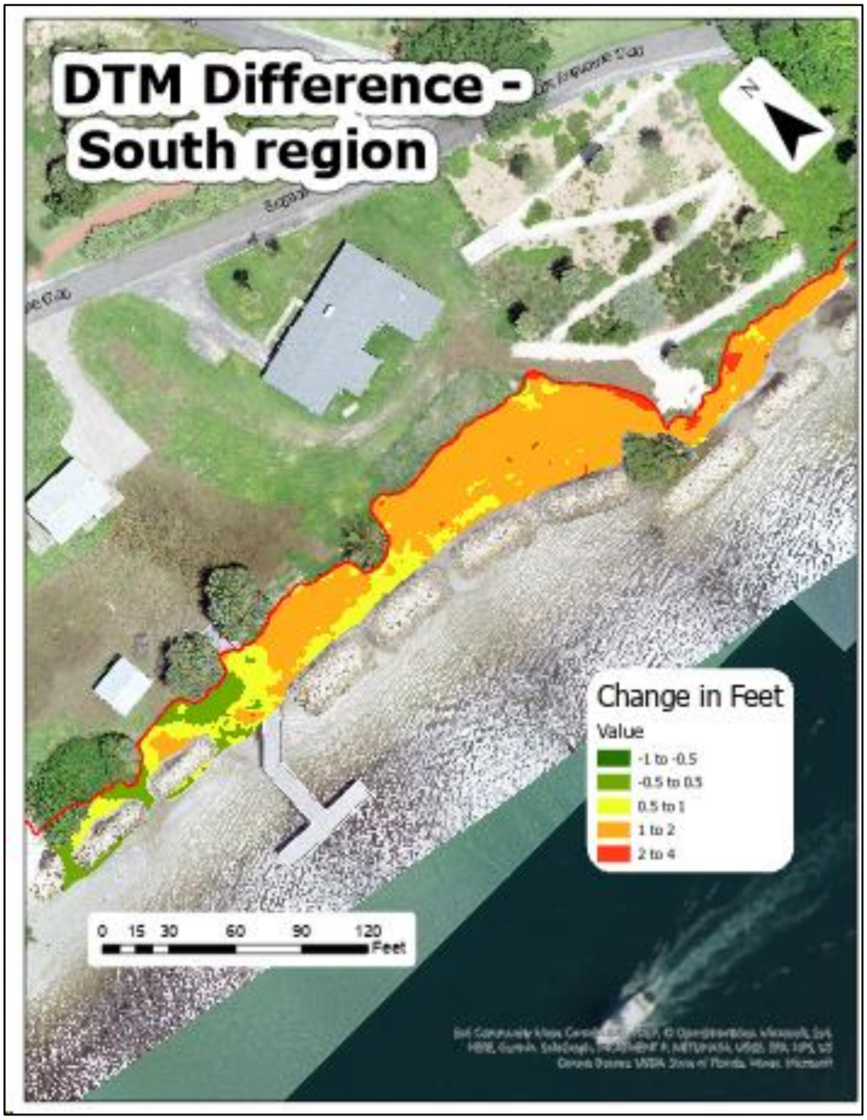


Figure 15: DTM difference map

Plane_Height	Reference	Z_Factor	Area_2D	Area_3D	Volume	Volume_CuYard
0	ABOVE	1	10018.46964	10175.0379	12144.05398	449.7793272
0	BELOW	1	113.7658687	115.3285094	17.14516125	0.635005337
			9904.703771	10059.70939	12126.90882	449.1443219

Figure 16: Volume change output in cubic yard

Conclusion

The process of automating the volume change along the shore of the Jupiter Inlet Lighthouse ONA region was automated by developing a geoprocessing tool using Python, which will help in easing work on manually analyzing. The developed volume change computation tool through this study, will be of time and cost efficient.

Results and Discussion

Through this project, a geoprocessing tool has been created, that automates the volume change along the Jupiter Inlet Lighthouse ONA shore region. The major outcome of this research is the DTM Difference map and the volume change computation for April 2021 and August 2021. The volume of erosion in the coastal region generated through this research work chosen region is available both in feet and cubic yards.

Statistics

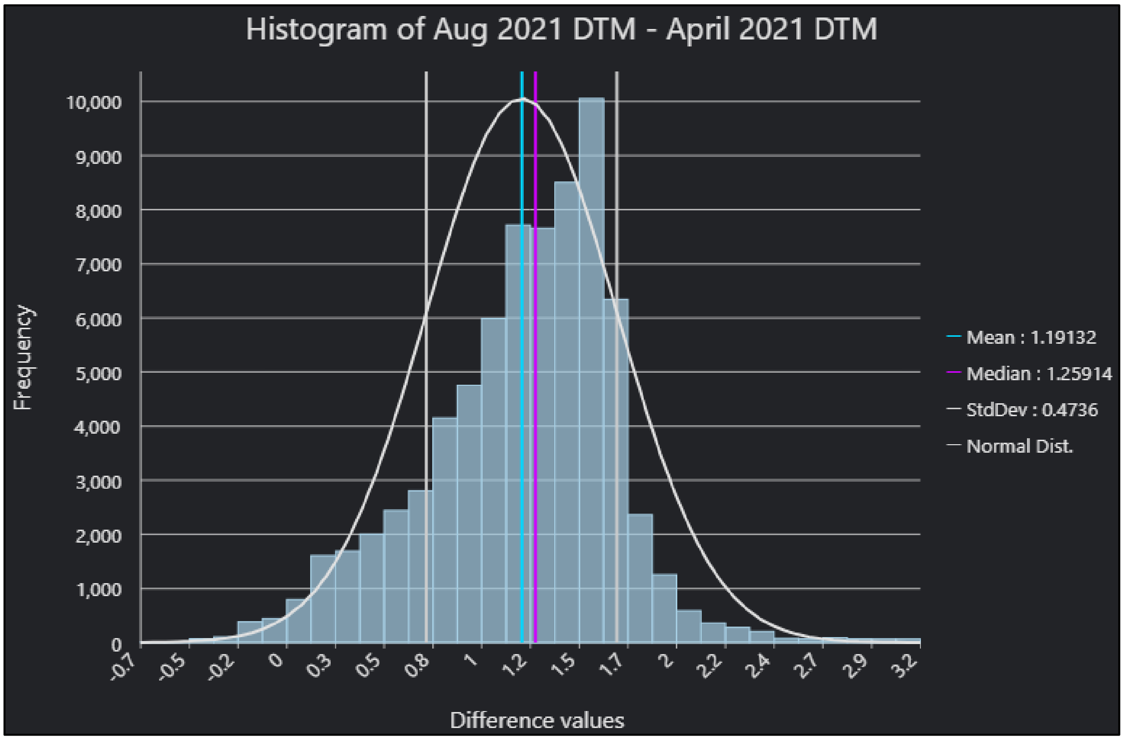


Figure 17: Histogram chart for difference raster pf DTM's

Future Scope

This project can be carried out for the whole shore region of the considered study area. The research work can be further extended to various other regions and explore the outcome.

Project Details

Power Point Presentation - Project Procedure Explanation

https://youtu.be/tDhBhe71iYQ

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https://youtu.be/DVJ2P-mxIeA

Shoreline & Coastline Extraction from UAS Imagery and determination of sea turtle concentration- Accessed Oct 23, 2021.

https://github.com/MonicaRaj/SpecialTopicsInCivilEng

Appendix A

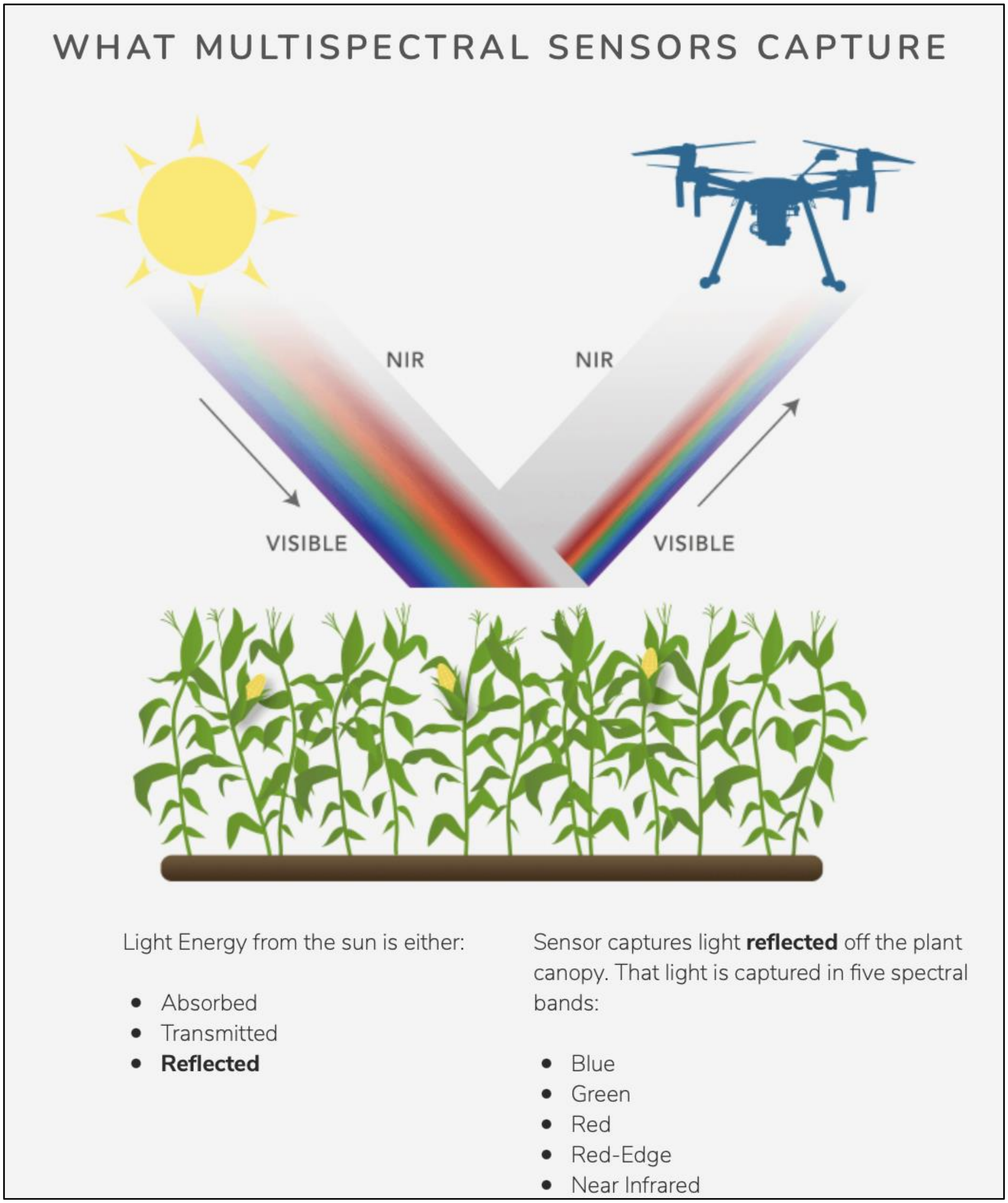

Figure 18: Micasense Red Edge sensor

Appendix B

Table 2: Band Wavelength information

Band Number	Band Color	WAVELENGTH	
		Center (nm)	Bandwidth (nm)
1	Blue	475	32
2	Green	560	27
3	Red	668	16
4	Red Edge	717	12
5	Near - IR	842	57

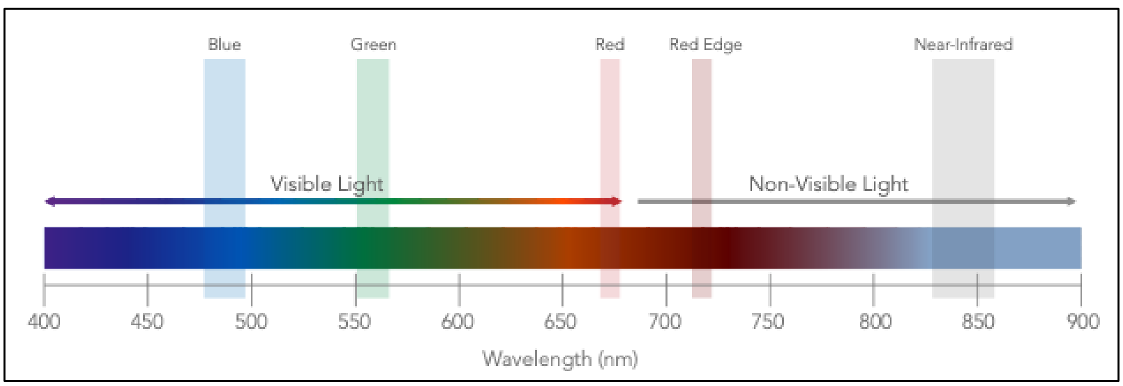

Figure 19: Visible to Non-visible Light Spectrum Range Represented (400 nm - 900 nm)

Appendix C

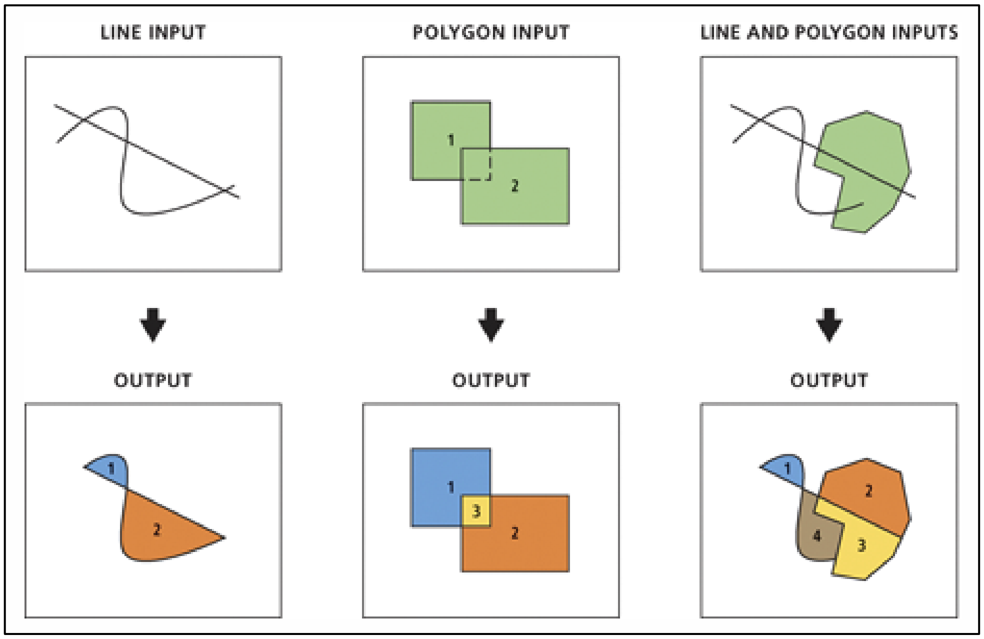

Figure 20: Feature to Polygon

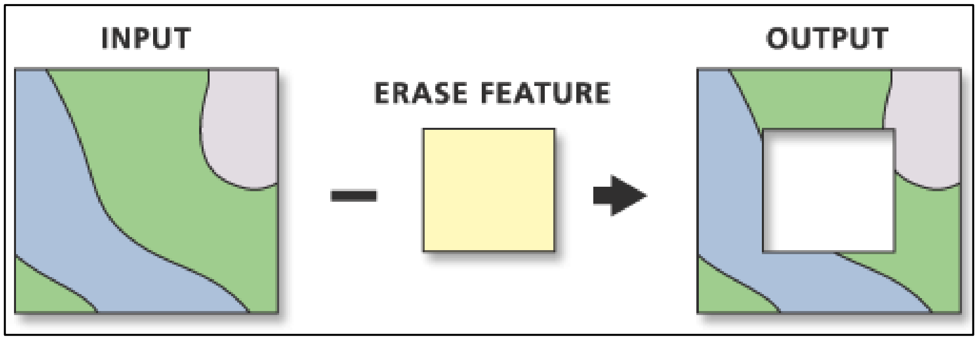

Figure 21: Erase feature

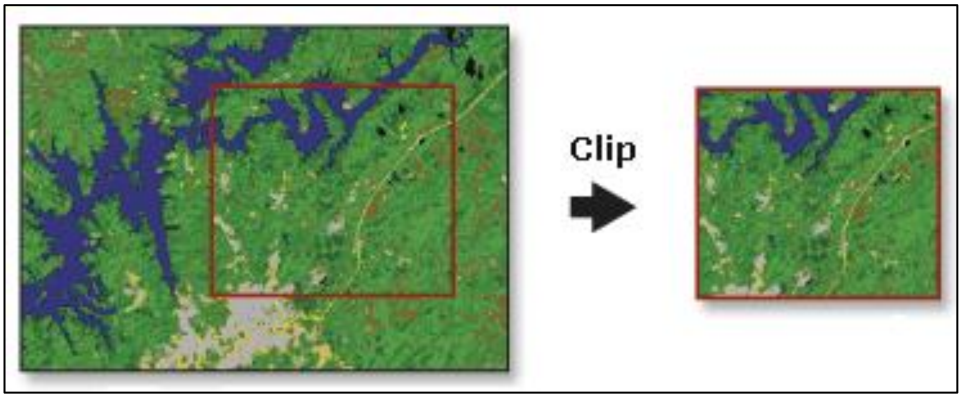

Figure 22: Clip raster

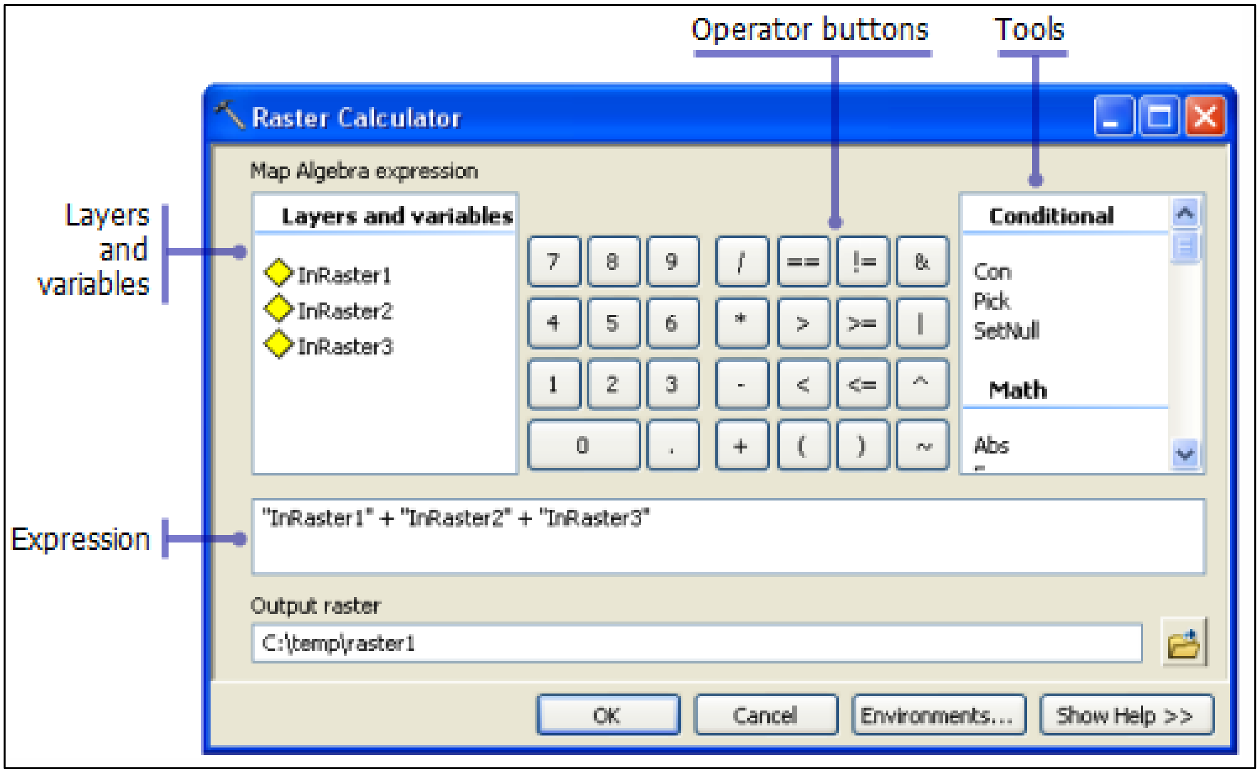

Figure 23: Raster Calculator

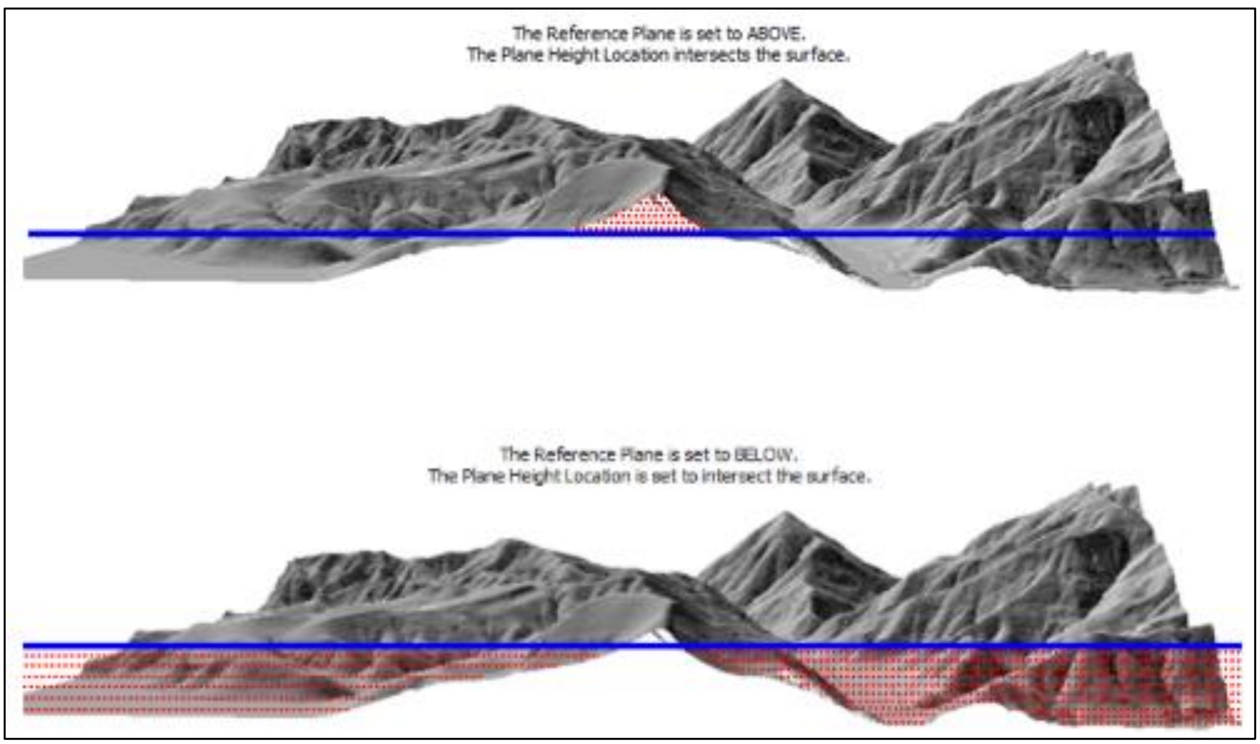

Figure 24: Surface volume

Glossary

JILONA	-	Jupiter Inlet Lighthouse Outstanding Natural Area region
UAS	-	Unmanned Aircraft System
GPU	-	Graphics Processing Unit
ESRI	-	Environmental System Research Institute
DSM	-	Digital Surface Model
DTM	-	Digital Terrain Model
DEM	-	Digital Elevation Model
GP Tool	-	Geoprocessing tool of ArcGIS software, ESRI