

A GIS Workflow for the Mangrove Action Project to Remotely Monitor and Assess Mangrove Restoration Sites



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GIS for Sustainability Management Capstone Project
August 18th, 2017



Recommended Course of Action:

This GIS project was designed to provide a multi-method approach of workflows to suit the user's needs in evaluating mangrove forest restoration sites around the world. The provided workflows for analysis allow the user to compare in both space and time the change in forest cover by building a Normalized Difference Vegetation Index (NDVI). Multiple year analysis at a selected study site, or focal scale, can be compared and calculated by a difference calculation, to represent the gains or losses of the vegetation health or cover. In addition, the workflows provided take into account budgetary restrictions, imagery suggestions for analysis, and imagery consultants, in order to further the mission of the Mangrove Action Project (MAP). Please note -- this is a small step in the overall process of mangrove forest restoration site analysis, but a critical one. This analysis allows the user to examine the NDVI data and assess large areas of vegetation for determination of further needed study for a given area.

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Introduction:

Mangrove forests grow in the tropics and subtropics in loose wet soil. Mangrove forests are greatly dependent and influenced by the hydrology of fresh and saltwater. Mangroves are known as halophytes (salt tolerant), and grow in brackish to saline marine estuaries and marine shorelines. Mangrove forests globally are the most productive ecosystems and provide economical, social, and ecological benefits ([Aheto et al, 2011](#)). They protect coastal shorelines from storm surges and tidal waves, act as water quality filters for pollutants, provide habitat for aquatic species, build and support marine food-chains, and provide protection for many aquatic species. In terms of climate change, mangrove forests are gaining more recognition for their part in carbon sequestration, and greenhouse gas reduction. Working to restore natural processes is recognized as an efficient method for carbon sinks ([Trumper et al, 2009](#)).

According to a journal publication authored by Research Physical Scientist at U.S. Geological Survey (USGS) Jordan Long and others: The total mangrove area in the Philippines has decreased by almost half, from an estimated 500,000 ha in 1918. An estimated 50 percent of mangrove deforestation can be directly attributed to brackish-water pond development for aquaculture seafood farms ([Long, et al., 2011](#)).

The Mangrove Action Project (MAP) works to restore degraded mangrove forests globally; the goal of the project is to suggest workflow, tools and partners that will assist MAP achieve this. An important requirement from MAP for this project was to identify tools that are low-cost, or free of charge, and focus on Free and Open Source Software (FOSS), where applicable. At present MAP relies heavily on field surveys to assess the health of mangrove forests and to determine the location of shrimp farms. Utilizing Landsat imagery to calculate and develop NDVI data, MAP can assess site conditions remotely, and determine critical locations where field surveys need to be completed to thoroughly assess conditions on the ground. Landsat imagery is updated on a daily basis, is available free of charge, and can be used in conjunction with ArcGIS (which offers a free tier to nonprofit organizations), QGIS, or other GIS platforms.

MAP was founded in 1992 as a global network to save the mangroves. Since 2005, the Mangrove Action Project (MAP) has been working with coastal communities in the Asia region to implement a Community-based Ecological Mangrove Restoration (CBEMR); helping them to facilitate natural regeneration of their mangroves.

Community Based Ecological Mangrove Restoration (CBEMR) is a mangrove restoration methodology that is grounded in the basic principle that restoring mangroves requires that the natural ecological processes that once supported the healthy mangrove need to be restored first and foremost. CBEMR thus places a strong emphasis on correcting hydrological problems and dealing with natural or man-made stressors in order to

facilitate natural mangrove regeneration. It reaches far beyond mere hand-planting of seedlings, as is typical of mangrove restoration projects, and increases the effectiveness of restoration of degraded mangrove forests by embracing and understanding the mangrove ecosystem as a whole ([Enright, 2015](#)).

MAP has 15 CBEMR demonstration sites in 4 provinces in Thailand with the first site completed in 2009. MAP has given CBEMR trainings in Cambodia, El Salvador, Honduras, India, Indonesia, Malaysia, Myanmar, Sri Lanka and Thailand. MAP intends to revisit some of these CBEMR sites as well as other restoration sites to assess the success of their implementation; the organization is looking for GIS solutions to accomplish the analysis. MAP provided site locations which detail the Philippine's National Greening Project and requested a workflow that allows them to analyze the existing data with high resolution satellite photography and researched restoration site data.

Primarily, our team will create temporal scale analyses of forest development using satellite imagery in the Philippines, where limited field data is available. MAP will also be given suggestions of available practices that can help them to reach their ultimate goal.

Study Area

For this GIS project, the Province of Masbate, Philippines, was chosen. While examining preliminary ancillary data, it was discovered that Masbate has many shrimp farms on its coastline, dense forests, as well as built-up areas. The centrally located islands of the province have a population of 892,393 people, according to the 2015 census ([Philippine Statistics Authority](#)).

The general topography of the province is generally rugged, ranging from hills to mountains. The economy of Masbate is predominantly agriculture. Recent statistics shows that agriculture and fishery sectors continued to be the primary sources of income and employment of the people. The agricultural land comprises 93% of the total land area of the province ([Philippines Guide, 2016](#)).

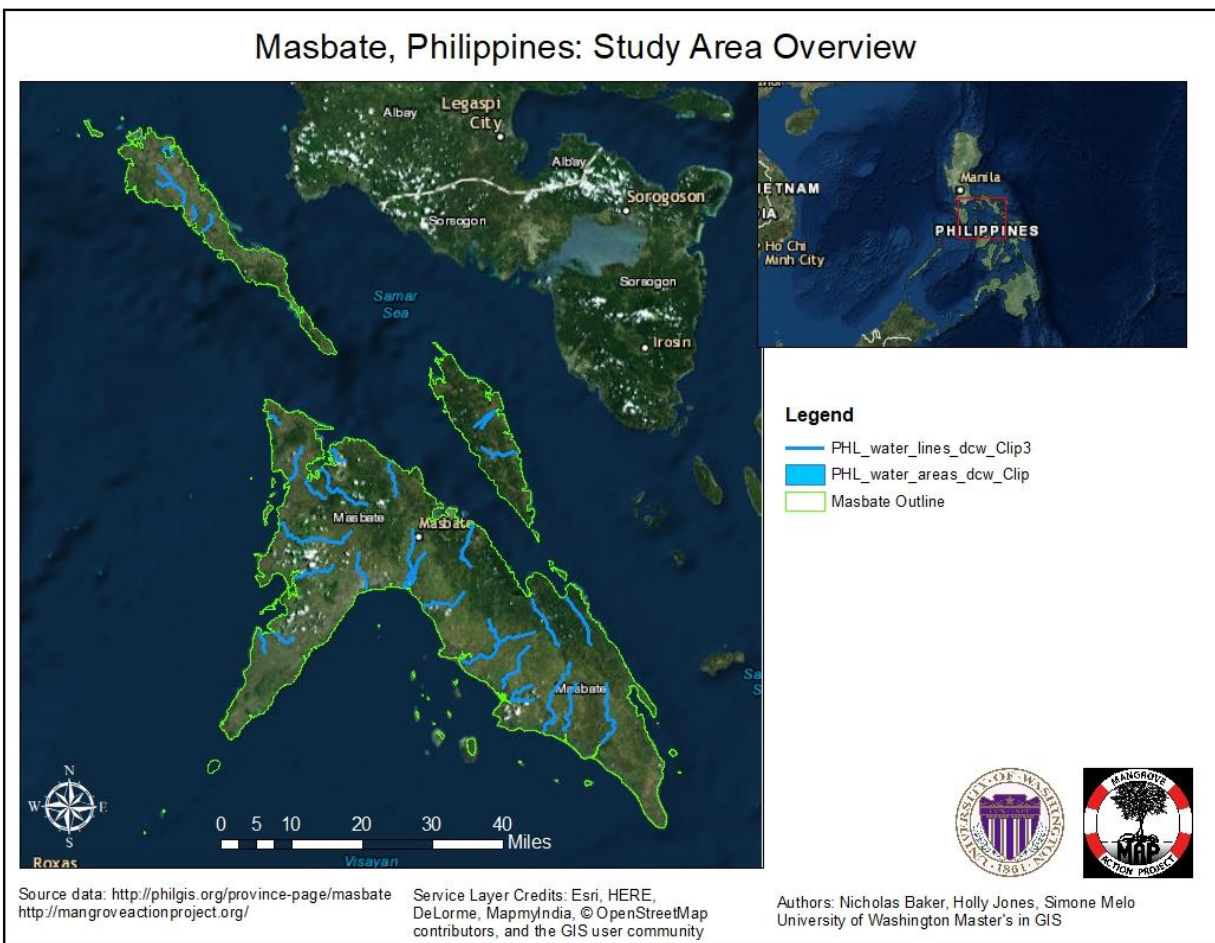


Figure 1

Social, Economical, and Environmental Systems Table:

Spatial & Temporal Scale	Environment	Economic	Social
<p>Above Focal Scale</p> <p>(+1)</p> <p>Mangroves Worldwide</p>	<p>Mangroves provide habitat for fish and other aquatics, protect the inland ecosystems, and prevent erosion of shorelines.</p> <p>Mangroves preserve water quality, reducing pollution by filtering suspended material and by assimilating dissolved nutrients.</p>	<p>Shrimp ponds are being built in mangrove habitat across the world as food demand increases.</p> <p>Mangrove forests protect property.</p> <p>Shrimp ponds provide income.</p>	<p>Mangroves are the first defense from climate change, tropical storms, tsunamis and other weather phenomena.</p> <p>Mangroves provide food, building supplies and other necessities for coastal communities.</p>
<p>Focal Scale</p> <p>(0)</p> <p>The Philippines</p>	<p>Buffering capacity against storms and flooding. Mangroves can hold back the sea waves and reduce wave forces with their extensive and dense above-ground roots by an estimated 70–90% on average. (Gavino-Gumba, 2010)</p>	<p>Subsistence fishing is essential for coastal communities living near mangrove forests. Of the one million Filipinos involved in fishing, 800,000 are involved in small-scale operations.</p>	<p>Coastal areas are becoming more populated as population grows.</p> <p>Large port developments have displaced many fishing communities</p>
<p>Embedded Scale</p> <p>(-1)</p> <p>The Island of Masbate</p>	<p>Shrimp ponds threaten water quality. Shrimp farms threaten healthy mangrove in Masbate simply by removing these forests.</p>	<p>Masbate is one of the poorest provinces in the Philippines with a poverty rate of 51%. Foreign corporations have created export-oriented trade patterns that have caused small-scale fishing operations to become more marginalized. (Blitz, 1987)</p>	<p>Mangrove restoration will increase access to clean drinking water and reduce vulnerability to storm events (46.37% of Masbate households didn't have access in 2005 and 52.86% of households live in makeshift housing) (Gavino-Gumba, 2010).</p>

Figure 2

Design & Methods:



The provided workflows for analysis allow the user to compare in both space and time the change in forest cover by building a Normalized Difference Vegetation Index (NDVI). Multiple year analysis at a selected study site(s), or focal scale(s), can be compared and calculated by a difference calculation, to represent the gains or losses of the vegetation health or cover.

A Normalized Difference Vegetation Index (NDVI) is a metric where vegetation is measured by taking the difference of the Near Infrared subtracting the Visible Red Light Spectrum from the Near Infrared adding to the Red Light Spectrum ([Carlson, et.al., 1997](#)).

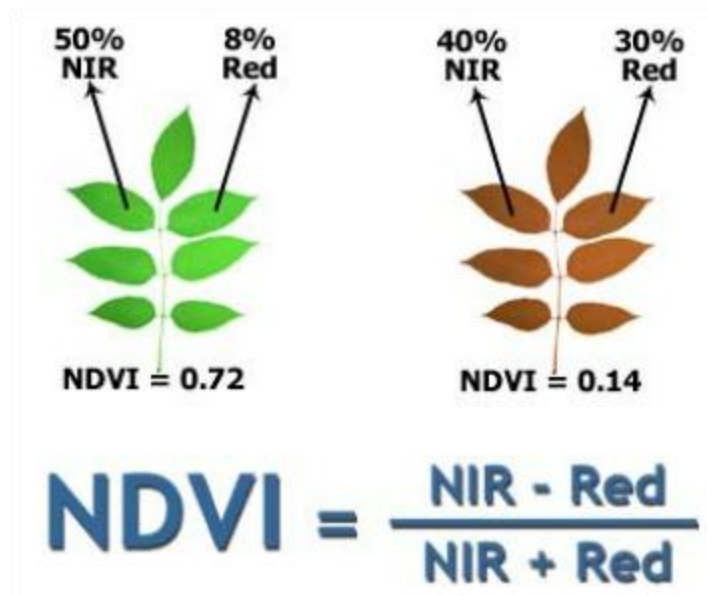


Figure 3

All plants absorb visible light to be used in Photosynthesis within the chlorophyll of the cell. A healthier plant will emit more green visible light, whereas an unhealthy plant will emit more blue and red visible light ([Gandhi, et.al. 2015](#)). By using this simple ratio we can develop a range of values to assess and monitor vegetation change for a given area.

Please note -- the calculations for the NDVI in this project were developed by using 30 meter Landsat, and MODIS satellite imagery. Having access to higher resolution satellite imagery would produce a more accurate NDVI. However, the user is still able to identify changes in vegetation at 30 meters ([Carlson, et.al., 1997](#)). MAP requested that we use free data sources; higher resolution imagery is available, but at cost outside of MAP's resources.

Workflow and Methodology to Assess Restoration Sites:

1. Define the Study Area for mangrove forest examination.

This project focuses on the Masbate Province of the Philippines; the province was chosen due to human impacts on the mangroves, the presence of urban areas and an abundance of shrimp farms.

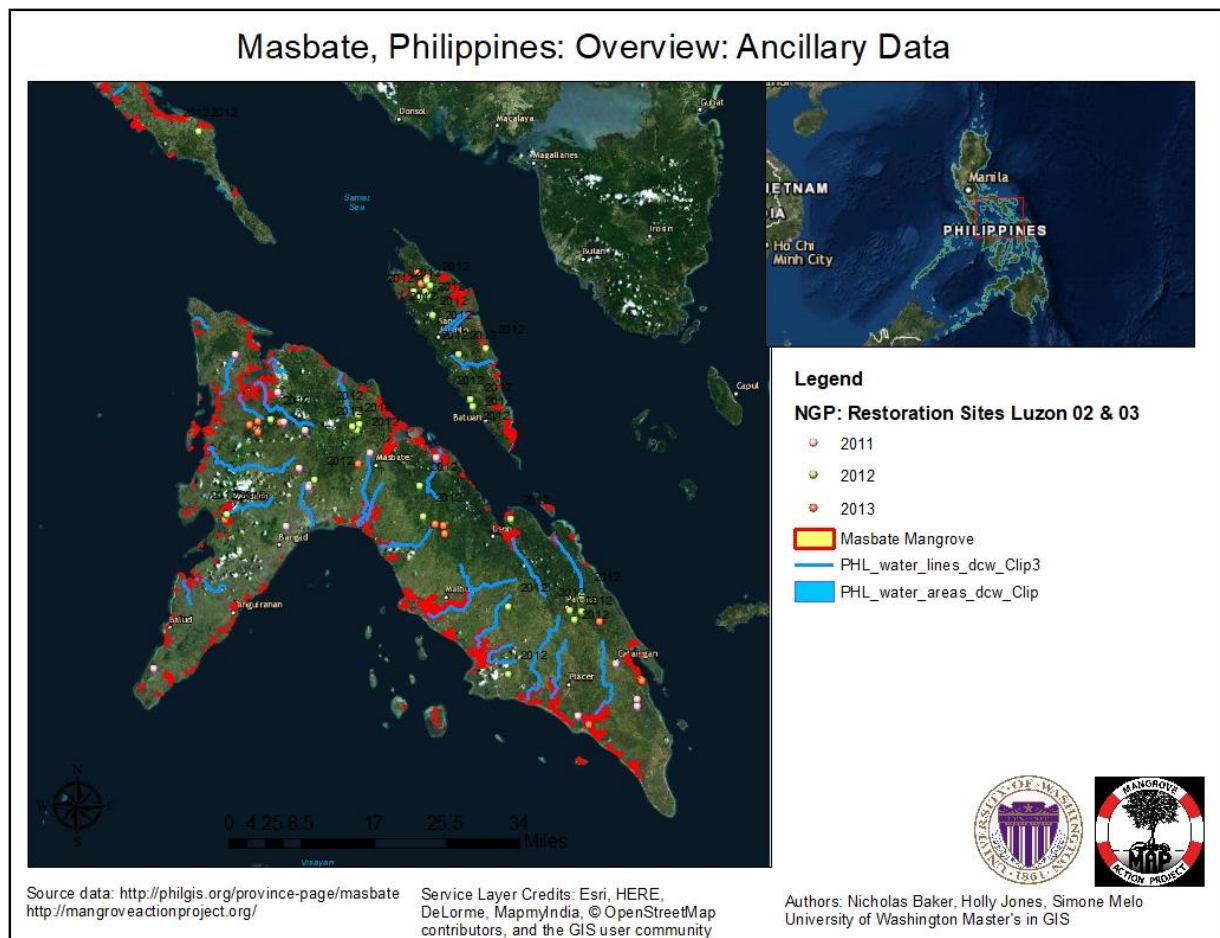


Figure 4

2. Once a study area has been chosen, find GIS data layers to support the analysis for mangrove forest Restoration Sites.

Existing Landcover, DEM's, Slope, Soils, Hydrology, Tidal Data, Tree Cover, Historical Landuse Data, Aquaculture, Survey Points – Restoration, health, roads, etc.

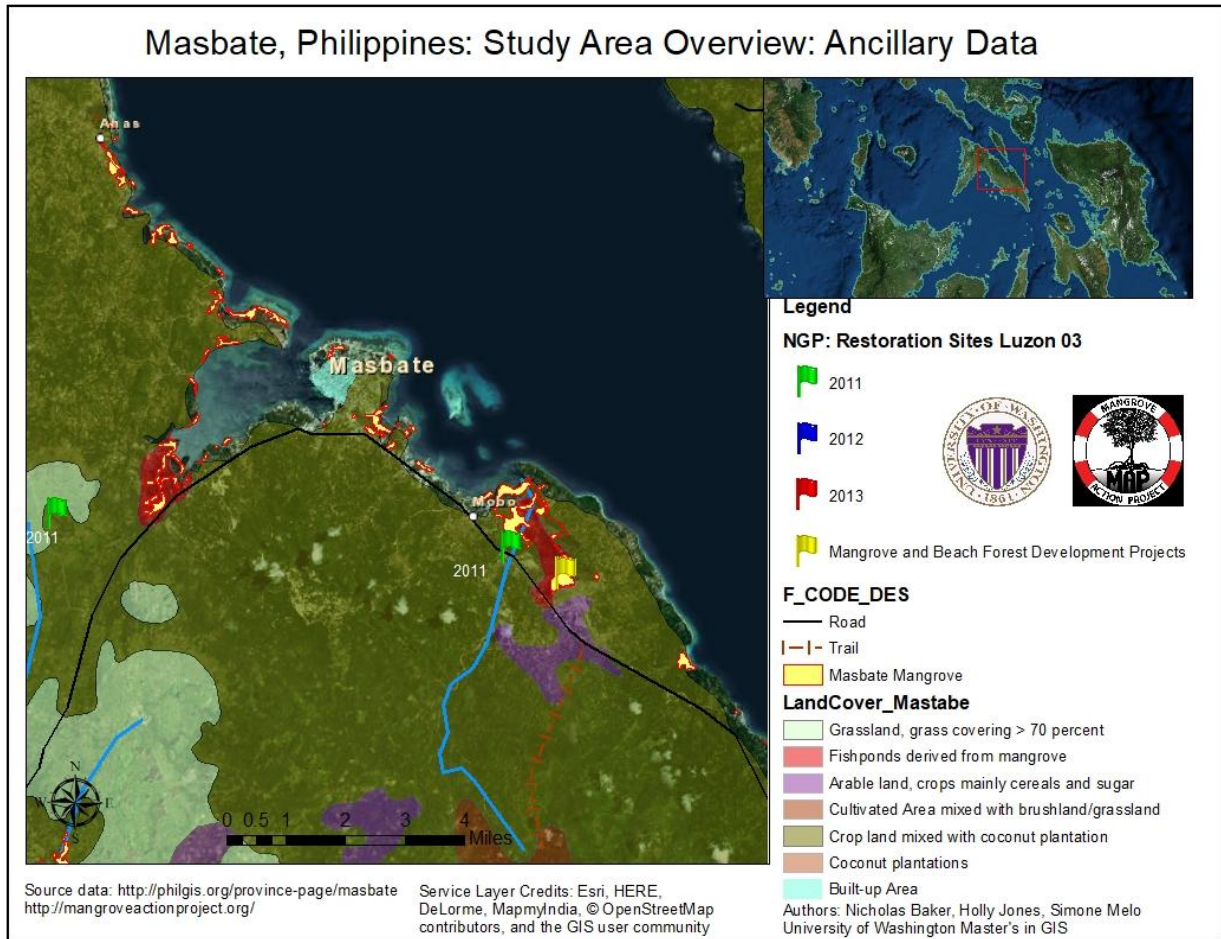
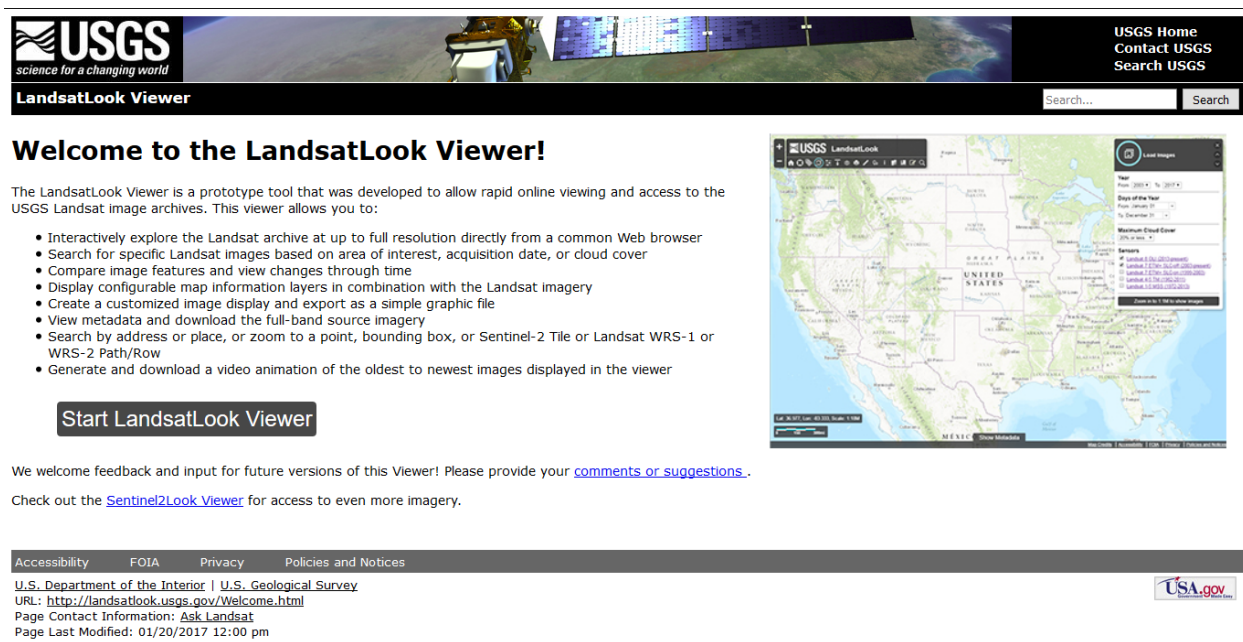


Figure 5

3. Find [Landsat](#) or [MODIS](#) satellite Imagery for the Study Area.

Below we outline the process for searching for and acquiring satellite imagery:



USGS
science for a changing world

LandsatLook Viewer

USGS Home
Contact USGS
Search USGS

Search... Search

Welcome to the LandsatLook Viewer!

The LandsatLook Viewer is a prototype tool that was developed to allow rapid online viewing and access to the USGS Landsat image archives. This viewer allows you to:

- Interactively explore the Landsat archive at up to full resolution directly from a common Web browser
- Search for specific Landsat images based on area of interest, acquisition date, or cloud cover
- Compare image features and view changes through time
- Display configurable map information layers in combination with the Landsat imagery
- Create a customized image display and export as a simple graphic file
- View metadata and download the full-band source imagery
- Search by address or place, or zoom to a point, bounding box, or Sentinel-2 Tile or Landsat WRS-1 or WRS-2 Path/Row
- Generate and download a video animation of the oldest to newest images displayed in the viewer

[Start LandsatLook Viewer](#)

We welcome feedback and input for future versions of this Viewer! Please provide your [comments or suggestions](#).

Check out the [Sentinel2Look Viewer](#) for access to even more imagery.

Accessibility FOIA Privacy Policies and Notices

U.S. Department of the Interior | U.S. Geological Survey
URL: <http://landsatlook.usgs.gov/Welcome.html>
Page Contact Information: [Ask Landsat](#)
Page Last Modified: 01/20/2017 12:00 pm

USA.gov

Figure 6

4. Populate a Geodatabase – ArcMap, ArcCatalog, QGIS, etc.

Using your GIS software of choice open up its catalog feature to add the data layers acquired for ancillary and satellite imagery, and tools for analysis.

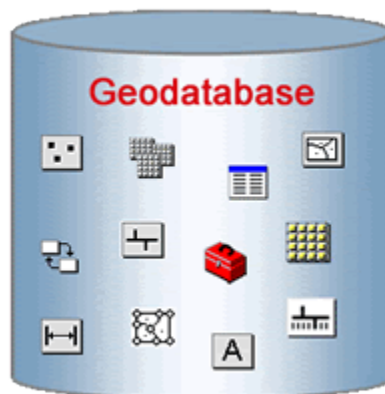


Figure 7

5. Overlay the Pertinent Data for Initial Analysis of Study Area to conceptualize the GIS project.

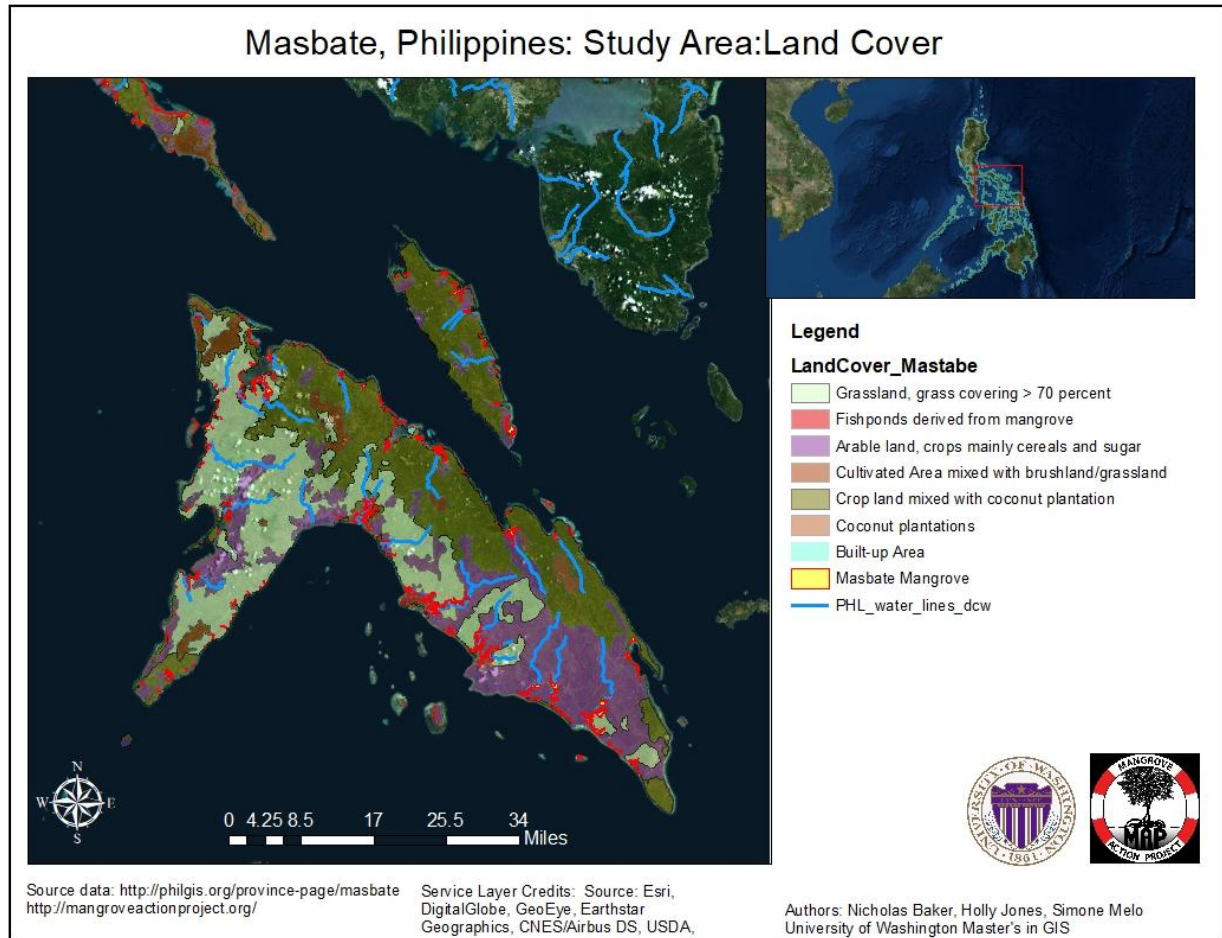


Figure 8

6. Define the mangrove forest within the study area

Using existing data layers (shapefiles, etc.), or use the Classifier Method below.

7. Run Statistics on the Classification Tool to examine Output Efficiency

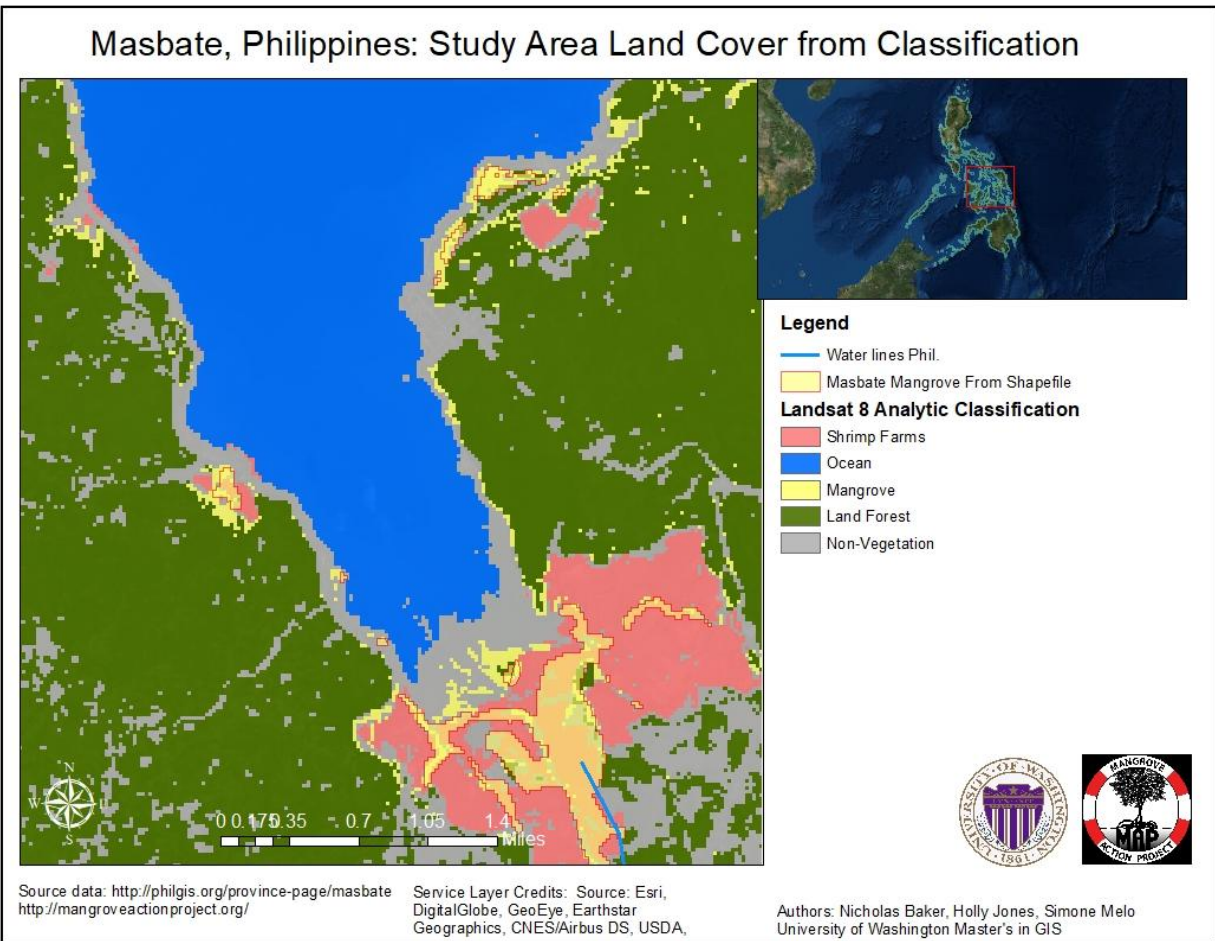


Figure 9

8. Prep the Landsat Data:

- Image Enhancement (outline below)
- Build Pyramids and Statistics
- Build Raster Attribute Table, if needed
- Raster Mosaic Tool, if needed
- Clip Rasters to Study Area – Extract by Mask, if needed

9. Run the NDVI Analysis for a given date for the defined study area:

- NDVI toolbox depending on the Workflow Chosen
- Run the NDVI calculation
- NDVI tool
- Raster Calculator
- Image Analysis Window
- Google Earth Engine

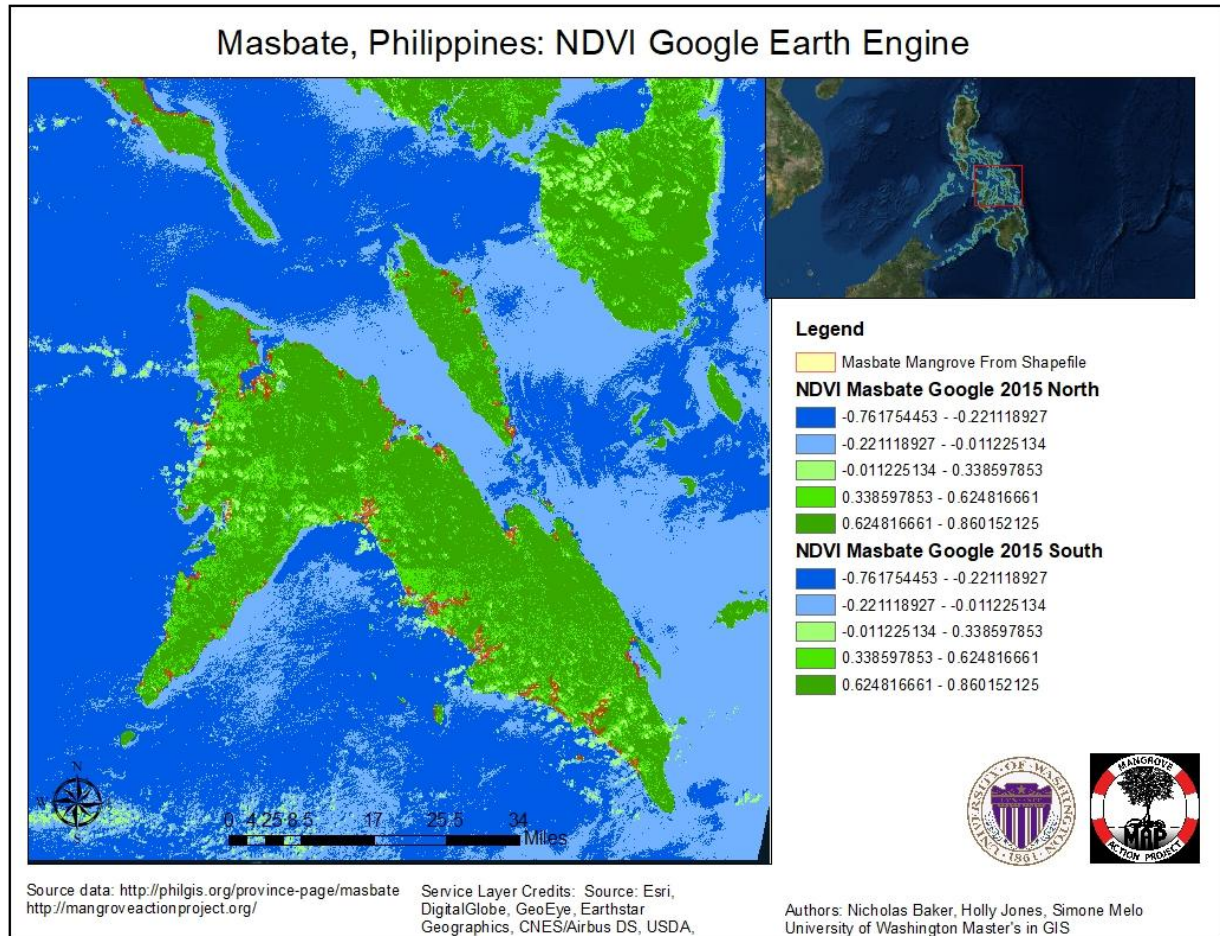


Figure 10

10. Run the NDVI Analysis for a different date for the defined study area

- NDVI toolbox depending on the Workflow Chosen
- Run the NDVI calculation
- NDVI tool
- Raster Calculator
- Image Analysis Window
- Google Earth Engine

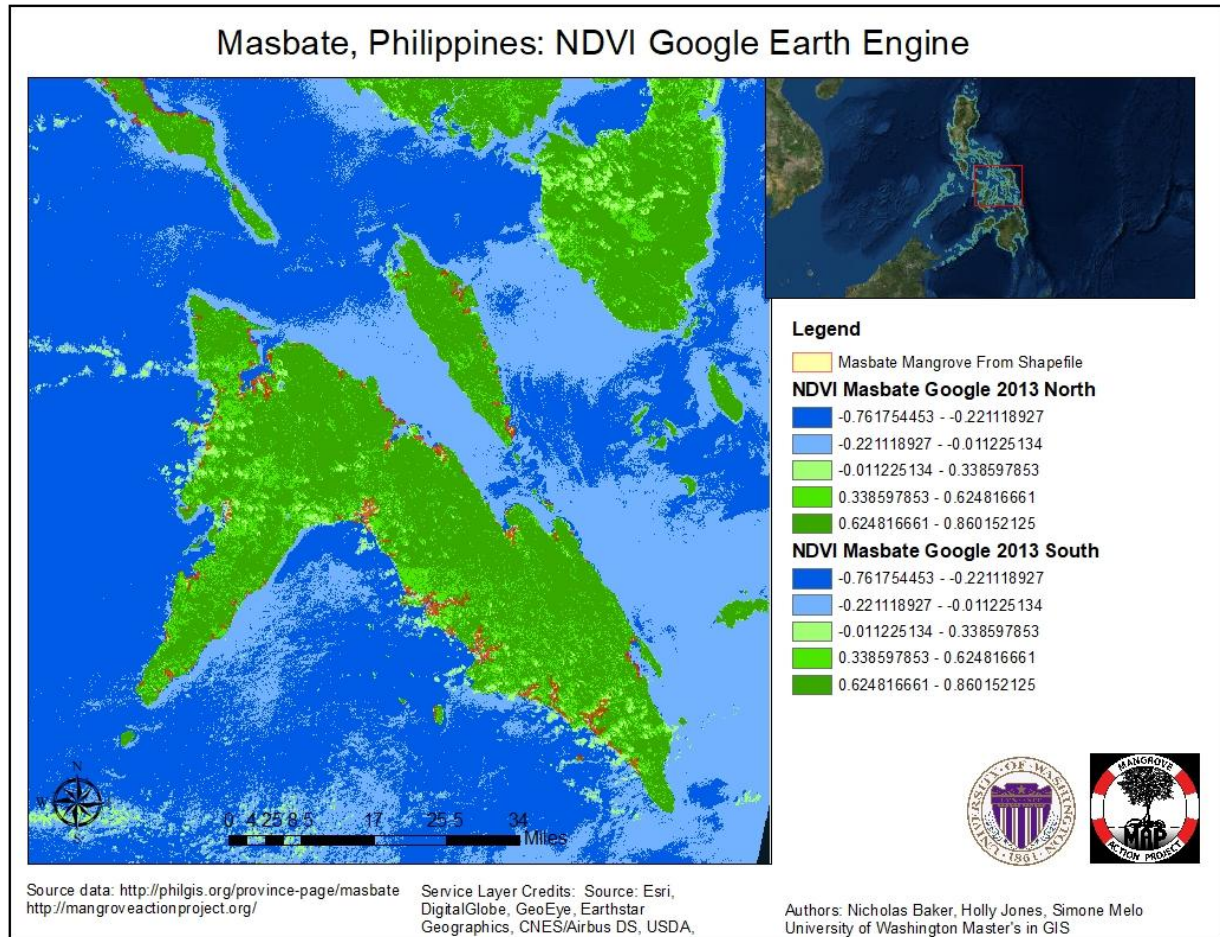


Figure 11

11. Compare the two NDVI rasters: Mosaic to new raster

- Raster Calculator subtract the two NDVI rasters (Newer date- Older date)
- Use the Difference Button in ArcGIS's Image Analysis Tool (see below)

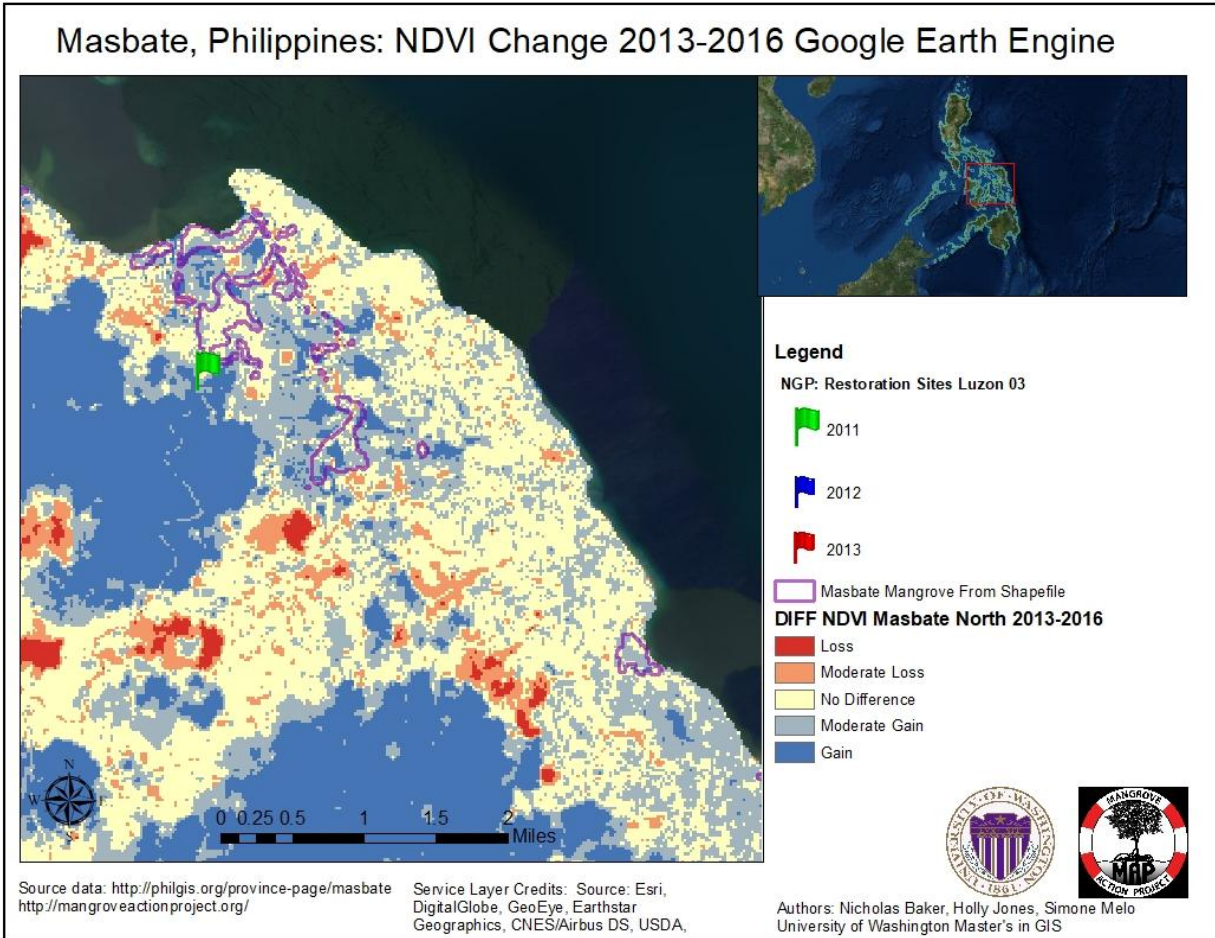


Figure 12

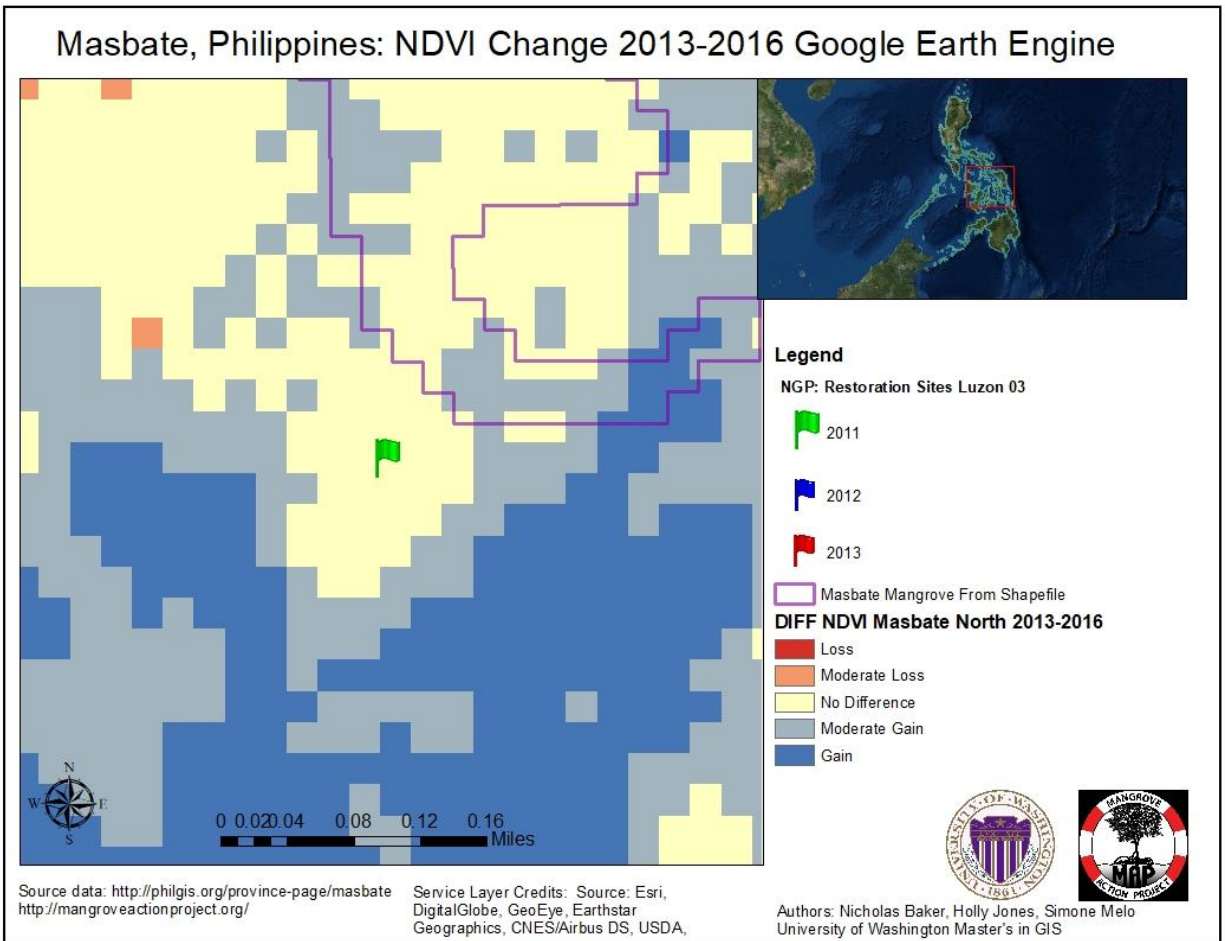


Figure 13

12. Compute the Loss of Forest Cover

- Export by Mask: Loss Raster from known polygon shapefile
- Examine the Properties of the New Raster made from the Export by Mask
- Examine the Count of cells within the Symbology tab
- Multiply the Count by the Raster Cell Size

Collection of Satellite Imagery

Landsat

For more than 40 years, the United States government has invested billions in the collection and archiving of continuous worldwide Landsat imagery for earth observation. Through ArcGIS Online, ESRI has made 30-meter spatial resolution Landsat imagery much more widely available. Imagery at this scale is excellent for mapping regional trends in climate change, agriculture, wildlife habitat, forestry, regional planning, coastal zones, and national security. Because data is collected in non-visible wavelengths such as the infrared and optical (natural color) portions of the electromagnetic spectrum, Landsat satellite images allow researchers to see also more

than the human eye can. Delivering imagery as services extends monitoring of the landscape to Internet users worldwide.

These Landsat 8 scenes from the US Geological Survey are accessible as image services that can be used in web maps, ArcGIS for Desktop, and other applications.

Users can also select any user-defined band combination. Functions can be applied with fixed enhancements or with Dynamic Range Adjustment Stretch, which requests the server to maximize the contrast so as to get the most out of the extended dynamic range of sensors

LandsatLook Images (full resolution files) available for Landsat 8 scenes, as they are for all previous Landsat scenes. In addition to the Natural Color, Thermal, and Geographic Reference bundle files available, Landsat 8 scenes also include a Quality .png file. This provides a visual representation the QA.tif file. Details about LandsatLook images can be found on <http://landsat.usgs.gov/landsatlook-images>. Consult USGS [Landsat 8](#) home page to learn more about Landsat 8 products.

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Bands	Wavelength (micrometers)	Resolution (meters)
	Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
	Band 2 - Blue	0.452 - 0.512	30
	Band 3 - Green	0.533 - 0.590	30
	Band 4 - Red	0.636 - 0.673	30
	Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
	Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
	Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
	Band 8 - Panchromatic	0.503 - 0.676	15
	Band 9 - Cirrus	1.363 - 1.384	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)	

Table source: <https://landsat.usgs.gov/what-are-band-designations-landsat-satellites>

Figure 14

1 - Downloading Landsat 8 Data Scenes (11 bands)

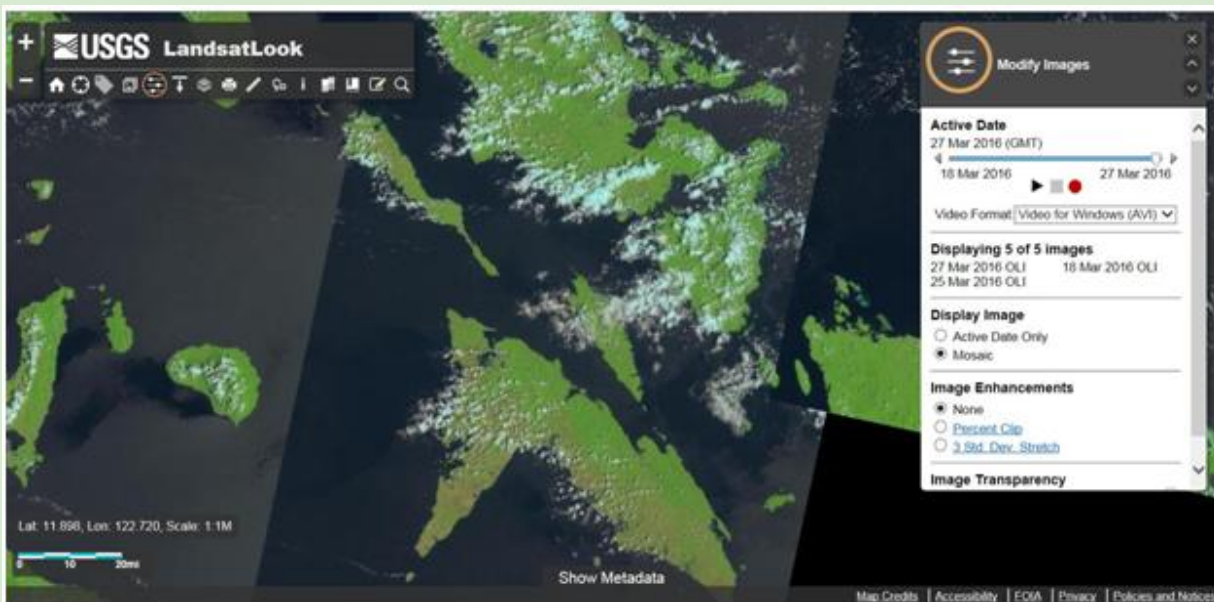
Go to the [USGS LandsatLook Viewer](#) online tool.

Using the "Load Images" menu panel, adjust the search parameters such as date and cloud cover and check the option "Landsat 8 OLI (2013-present)".

Zoom in to the area of interest.

A good practice is to zoom to a smaller area and chose time intervals of one year or less.

Click on "Show Images" to load all available scenes matching the selected parameters.




Click on tab "Show Metadata" on the bottom of the screen to open a table with information on each scene.

Showing: 4 scenes															
[Show All] [Show Displayed] [Show Footprint(s)] [Clear Footprint(s)] [Zoom To] Search: <input type="text"/>															
	Scene ID	Sensor	Acquisition Date	Path	Row	Cloud Cover	Sun Elevation	Sun Azimuth	Receiving Station	Scene Start Time	Month	Year	Day Of Year	Full Product	LandsatLook Product
<input type="checkbox"/>	LC81130512017217LGN00	OLI	05 Aug 2017	113	51	6	64.11199	77.9268	LGN	05 Aug 2017 01:59:00 GMT	8	2017	217	Download	Download
<input type="checkbox"/>	LC81130522017217LGN00	OLI	05 Aug 2017	113	52	17	63.56859	75.12117	LGN	05 Aug 2017 01:59:24 GMT	8	2017	217	Download	Download
<input type="checkbox"/>	LC81140512017176LGN00	OLI	25 Jun 2017	114	51	8	63.52113	63.28105	LGN	25 Jun 2017 02:04:57 GMT	6	2017	176	Download	Download
<input type="checkbox"/>	LC81140522017176LGN00	OLI	25 Jun 2017	114	52	13	62.65666	60.91409	LGN	25 Jun 2017 02:05:21 GMT	6	2017	176	Download	Download

Select a scene and click on "Show Footprint(s)" to see its extent.

Click on the link "Download" under "Full Product". If you do not have a USGS registered username and password, you'll be directed to the EROS Registration page where you can create a free account in order to download data.



Click on the  icon to download each scene. Download "Level-1 GeoTiff Data Product". Click "Save" (these will take a while)

You should now have a .tar.gz file in the designated folder (these are compressed .tar files and will need to be extracted two times in total before using it).

The scene ID:

Example: LC08_L1TP_114052_20160318_20170328_01_T1.tar

The first two values of the Landsat 8 scene ID designates the data provided in each scene:

LC08_L1TP_003055_20170207_20170216_01_T1 = Combined (both OLI and TIRS data)

LO08_L1TP_021047_20150304_20170227_01_T1 = OLI data only

LT08_L1GT_137206_20170202_20170215_01_T2 = TIRS data only

LC08_L1TP - combine data

114052 - Imagery ID

20160318 - Date from

20170328 - Date to

01_T1 - Level 1

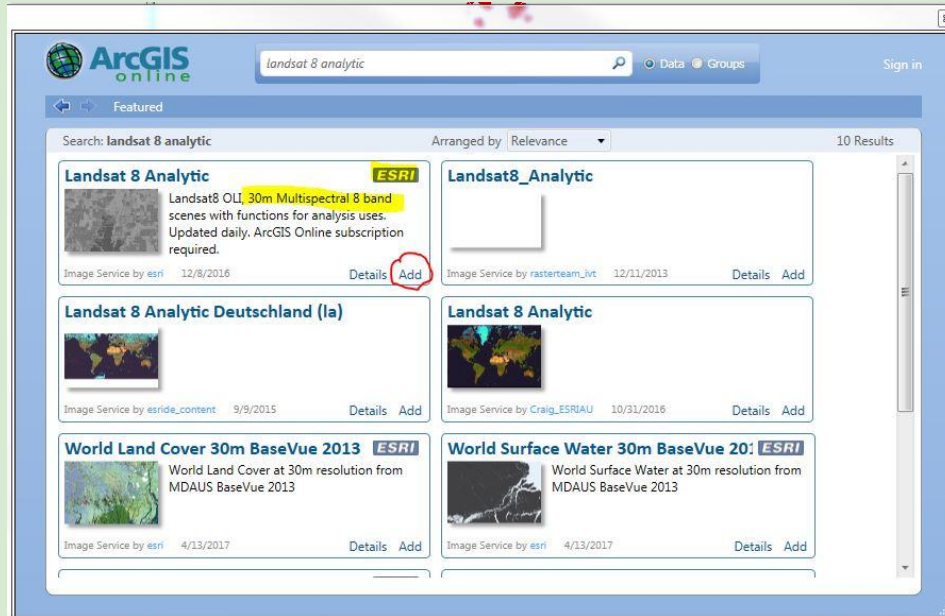
.tar - this is the compressed file extension. Extract the files using [7-Zip](#) by right clicking on the file and choosing the option "7-Zip >> Extract Files".

You should have 18 items in the designated folder. Note that 11 files are numbered by bands (B1, B2...B11). Please refer to design and method to learn how to use imagery to calculate NDVI, classify and calculate NDVI and vegetation change.

2 - Downloading Landsat 8 ArcGIS WMS (8 bands)

Another way to use Landsat 8 data to calculate NDVI is to calculate directly from ArcGIS' WMS Landsat 8 Analytic. It is possible to download small areas. The WMS is updated daily.

To load the imagery, open ArcMap and click on "Add Data>>Add Data From ArcGIS Online". Search for "Landsat 8 Analytic". Click "Add" to add WMS to ArcMap.



To save the image, zoom in to the area of interest and right click on Landsat 8 Analytic layer on the TOC go to "Data>>Export Data". Chose current Data Frame, a location and name for the new TIFF file.

ArcGIS Online

Landsat Data in ArcGIS Online ([link](#))

The latest and greatest Landsat 8 scenes are available from ESRI as a new set of image services in ArcGIS Online. A subscription to ArcGIS Online for Organizations is required to access the services, but there is no charge for usage.

These image services made the collection of Landsat Global Land Survey (GLS) scenes spanning the epochs of 1980, 1990, 2000, 2005, and 2010 accessible as more than 20 dynamic, multispectral and multitemporal image services. These dynamic services enable a wide range of client applications temporal access to any of the band combinations and products without downloading or locally processing any data. All these Landsat scenes are hosted on ESRI's cloud infrastructure.

The Landsat 8 imagery, available in ArcGIS Online, provides several image services from the same source. Most popular is the Landsat 8 Views services, which allow users to view a range of different band combinations including Natural Color (bands 4, 3, 2) and Color Infrared (bands 5, 4, 3). The Agriculture band combination (bands 6, 5, 2) highlights differences in different crop types. The SWIR band combination (bands 7, 6, 5) provides better penetration for clouds. The bathymetric option (bands 4, 2, 1) provides better water penetration and is especially useful for coastal applications.

The [Landsat 8 Views](#) service also provides two indexes: the colorized Normalized Difference Vegetation Index (NDVI) and the colorized Normalized Difference Water Index. NDVI provides information on the health of

vegetation. The colorized Normalized Difference Water Index highlights areas that have high moisture content.

MODIS

MODIS by NASA is another excellent FOS data resource to assess vegetation coverage change. With products with up to 15 meter pixel size, the data is readily available through a variety of applications. MODIS is available daily as low resolution multi-band imagery. Daily low resolution (15-30 m) data by NASA. The spatial reference is D_WGS_1984 but can be reprojected. Sign up for a USGS account to download data.

1 - Connecting to MODIS Server in ArcMap

Adding Global Imagery Browse Services (GIBS) layers to ArcGIS Online as Several GIS and imagery viewing tools support access to NASA's GIBS via OGC Web Map Tile Service (WMTS) and Tiled Web Map Service (TWMS) protocols. Listed below is a set of these tools along with instructions and screen captures to help import imagery into them.

The time slider allows you to see imagery daily.

GIBS imagery layers can be directly imported into ESRI ArcGIS/ArcMap 10.2.1 or later. It uses an ESRI-run relay service which adds an ArcGIS Server interface layer in front of GIBS. You will need ESRI ArcGIS ArcMap 10.2.1 or later (earlier versions are untested, though possibly usable)

In ArcGIS is very easy to connect directly to the source of MODIS data.

1- Adding MODIS WMS to ArcMap and Using Time Slider

To add MODIS layers to ArcGIS, simply follow the steps available at [NASA Earth Data](#). The help page includes instructions on how to use the tool "Time slider" to see daily imagery. Remember to change the time to "1 day".

Open the "Catalog" window in ArcMap and under "GIS Servers"

- *Click on "Add ArcGIS Server" to open the wizard*
- *Select "Use GIS Services" and click next*
- *Enter the following URL for the field "Server URL":*
<http://modis.arcgis.com/arcgis/rest/services/MODIS/ImageServer>
- *Click "Finish"*

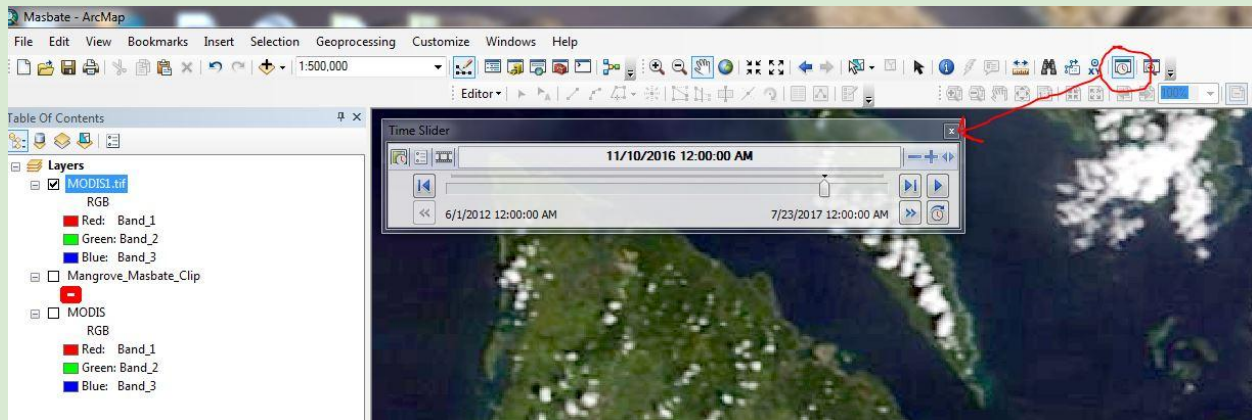
You should now see a new layer on the Table of Contents named "MODIS"

Using Time Slider

- To enable time controls, right-click on MODIS on TOC and click "Properties..."
- Click the "Time" tab and "Enable time on this layer"

Change the "Time Step Interval" to 1 Days

Click on "Time Slider" icon on your menu bar to open the time bar



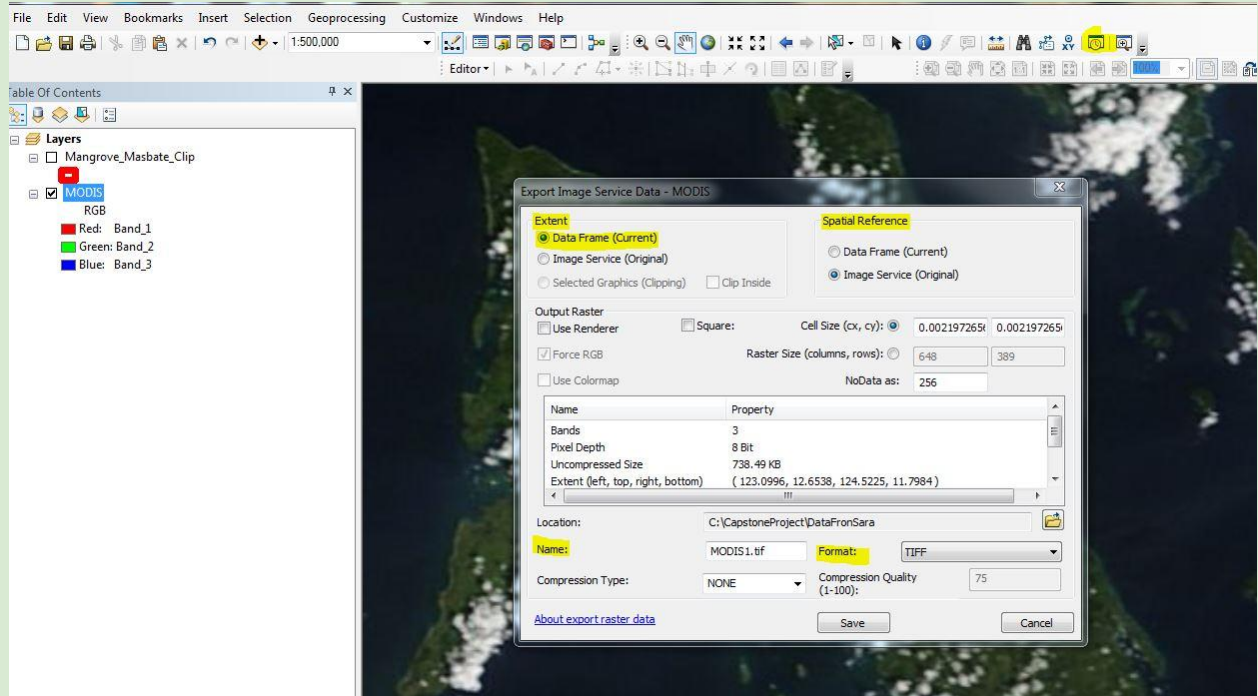
Saving the imagery:

Right click on the "MODIS" layer on the Table Of Contents and click on "Data" and "Export Data"

The "Export Service Data - MODIS" wizard opens with options to rename the file and chose a format

Choose "TIFF" or the file you prefer to work with

Click on "Save"



You now have a TIFF file with the selected extend in your directory.

Data management tip: include the date in the file name. Make sure the name makes sense to you and it will be easy to file and search for the image

ESRI Landsat Data "Do it Live" Interactive Web Tool

ArcGIS has made available an interactive website that allows users to retrieve historical information using Landsat Imagery. The page has a well designed user friendly interface and it produces statistical analysis for specific site on the fly.

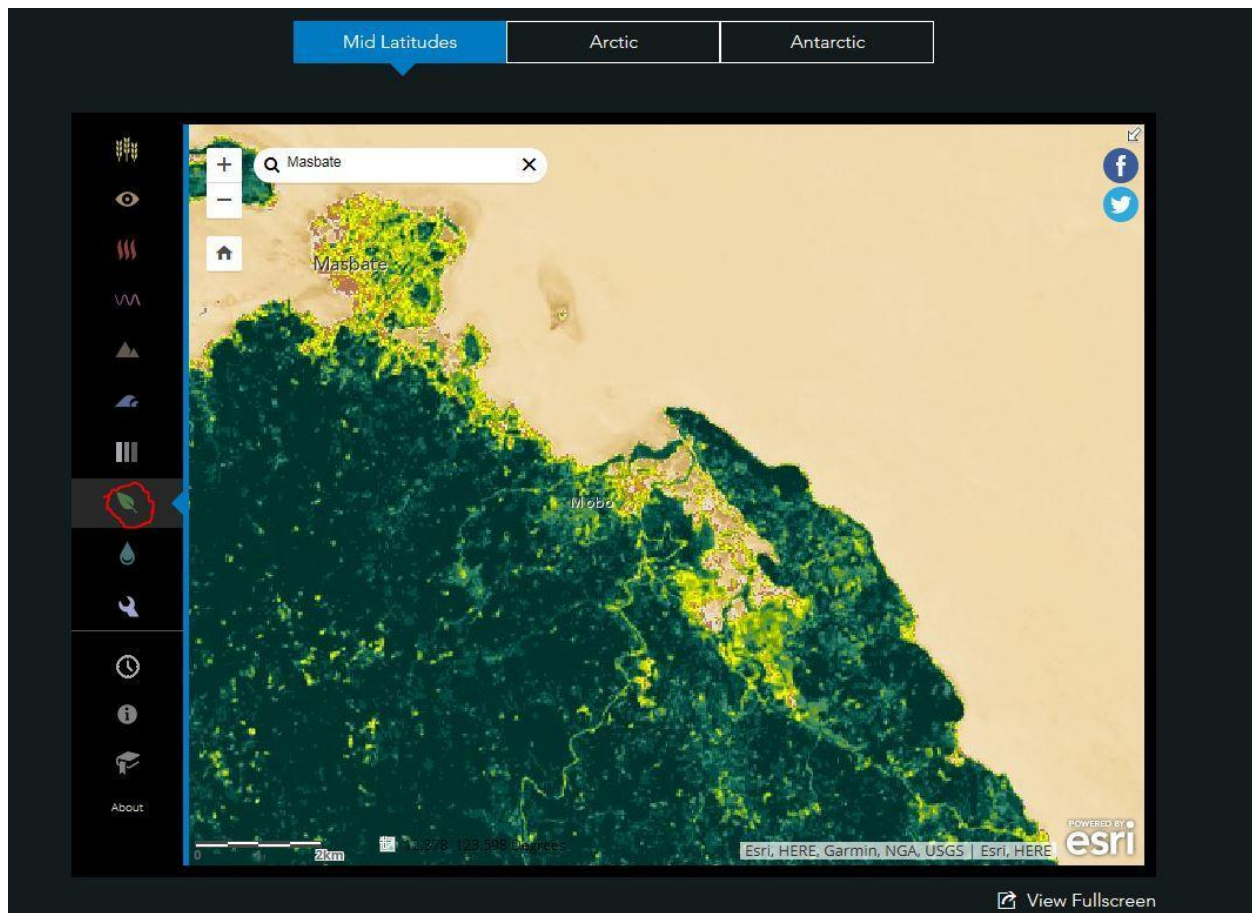
Workflow

Go to <http://www.esri.com/landing-pages/software/landsat/unlock-earths-secrets>

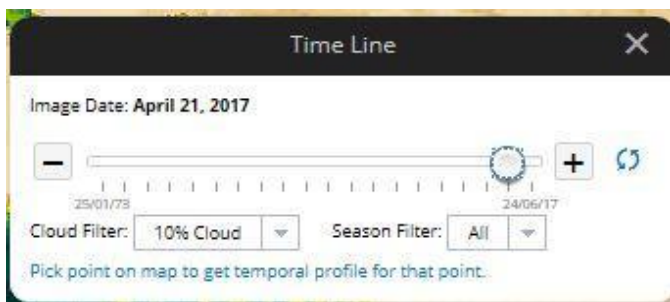
Click on "Try It Live"

On the search bar, type the name of the location of the site

On the map interface, click on "NDVI" icon

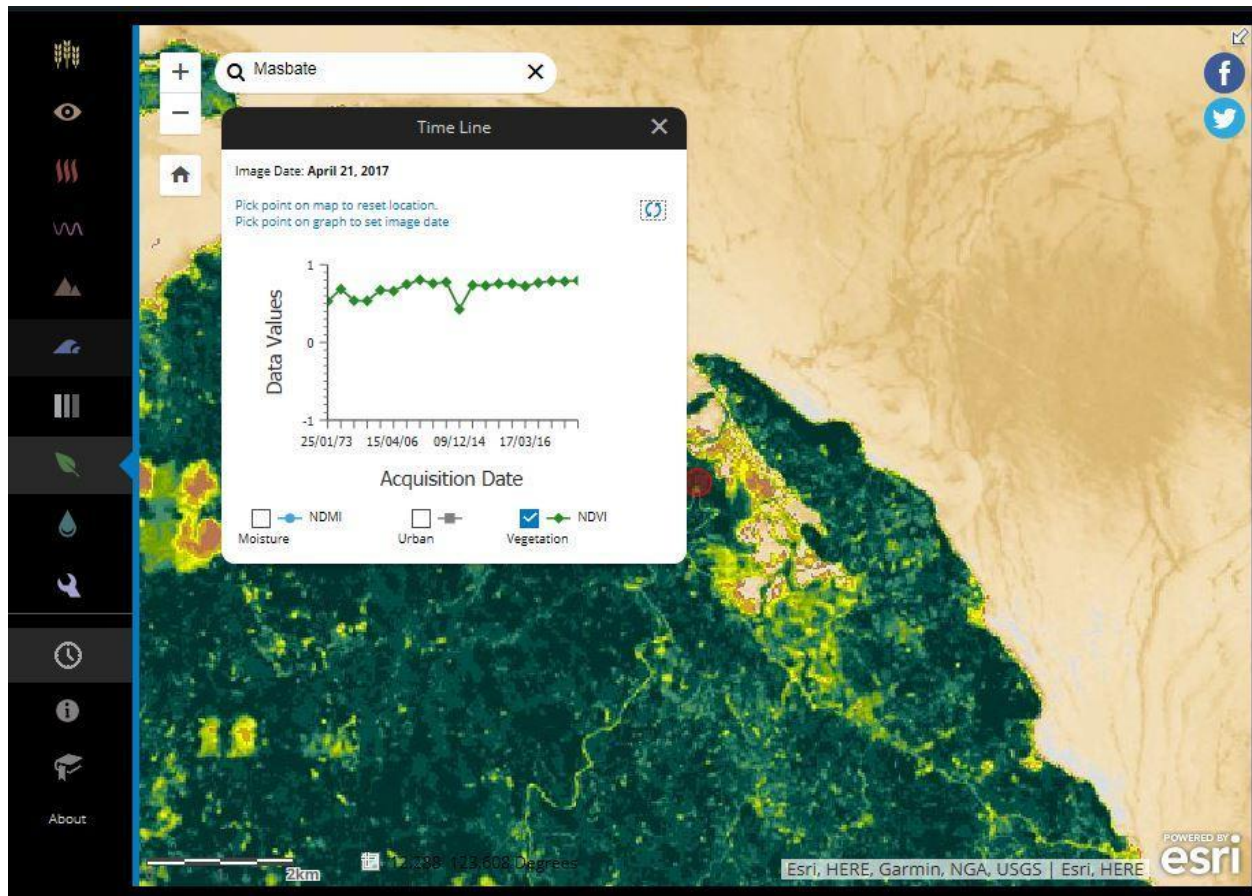


Click on the "Time" icon  to open the time slider



To pick a point on the map, simply click on the area of interest.

A timeline graph containing NDVI variation for the area of interest will be displayed.



Ground Truth Data and Crowdsourcing

Use QMap on Windows based tablet devices to save field data as shapefiles. The data can be used later as the Polygon Classification Training layer using ArcGIS Image Classification Toolbar (see ArcGIS>>Classifying Imagery Raster>>Interactive Classification Tool). For more on how to install QMap on your tablet, visit QMap's [help page](#).

Other FOS apps for cell phones are readily available to download at [OpenDataKit](#) or [Field Database Free](#). Chose an app with appropriate functionalities and capabilities for the data you intend to collect.

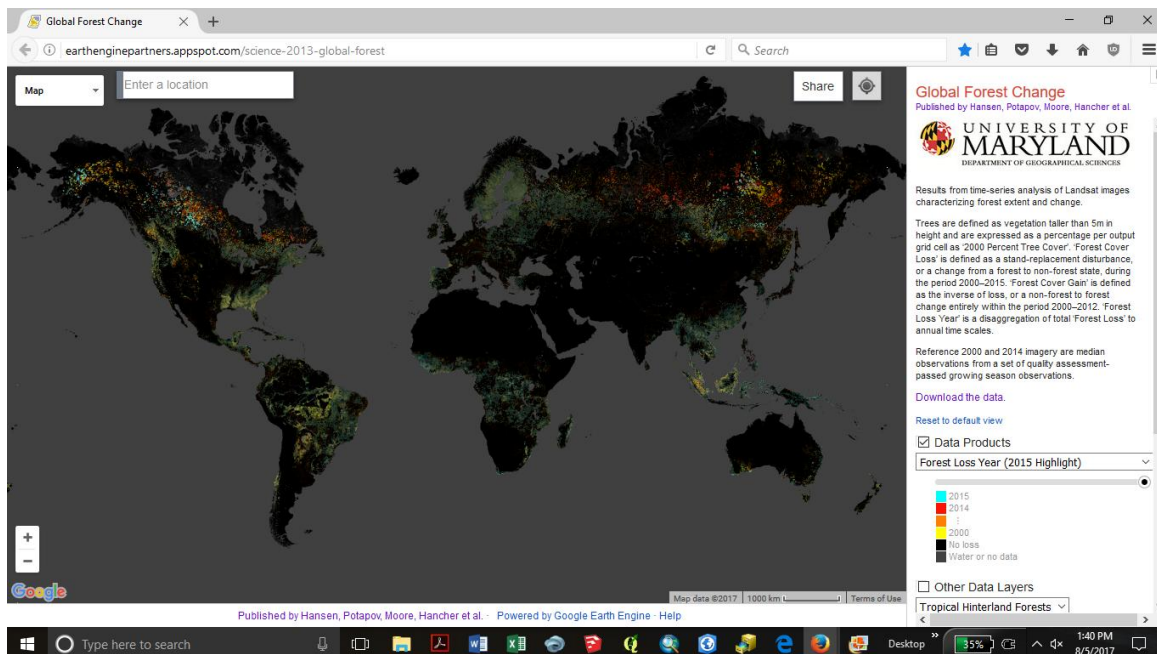
Workflows

Workflow Suggestion #1:

Google Earth Engine

Google Earth Engine brings together 40 years of satellite imagery for use in environmental data analysis. Google Earth Engine provides a “multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities...” ([Google, 2017](#)).

The Global Forest Cover Change project, led by the University of Maryland’s Matt Hansen, provides an excellent starting point to generating a workflow for analyzing satellite imagery for forest cover. While this study is on a global scale, the code can be adjusted to set geometry boundaries for analysis. The Global Forest Cover Change project worked to cover forest cover above 5 meters in height, and does not specifically define types of forests ([Miller, 2016](#)). A study of the Global Forest Cover in Australia, Miller 2016, found some errors with the method expressed both in forest gains and losses where there should not be. However, the Global Forest Change Model provides the user of the Google Earth Engine API an example, tutorial, and sample code to examine and begin designing their own project. Simply put, this project focused on forest gains and losses which can be examined quickly in the web API, or exported to be used within a GIS platform.



The Online API Tool:

Running on Google’s cloud services, the user can choose either Java or Python script languages within the Google Earth Engine API. The code can be adjusted in order to filter dates and imagery, as well as run specific ecological evaluation tools such as a NDVI, a Normalized Difference Vegetation Index. The web-based code editor allows for an easy and fast connection.

For in depth information migrate to the Google Earth Engine API help page at: <https://developers.google.com/earth-engine/getstarted>. Here you'll find helpful tutorials, Java and Python help, and much more. In addition, many helpful YouTube videos are available to help get you started.

```
Google Earth Engine Search places and datasets... Help bakermick1
```

```
Scripts Docs Assets
```

```
Filter scripts...
```

```
Private
```

```
MAP
```

```
This folder is empty.
```

```
Compare Landsat Imagery
```

```
MAP Script For Forest Cover
```

```
MAP Script For Forest Cover 2
```

```
NDVI Mapping
```

```
Supervised Classification
```

```
+ New folder
```

```
+ New file
```

```
Shared
```

```
No accessible shared repositories.
```

```
+ New repository
```

```
Examples
```

```
Image
```

```
From Name
```

```
Where Operator
```

```
Normalized Difference
```

```
Expression
```

```
HDR Landsat
```

```
Hillshade
```

```
Landcover Cleanup
```

```
Reduce Region
```

```
Bitwise And
```

```
Canny Edge Detector
```

```
Center Pivot Irrigation Detector
```

```
Clamp
```

```
Connected Pixel Count
```

```
Download Example
```

```
From Name Landsat8
```

```
HSV Pan Sharpening
```

```
Hough Transform
```

```
Landsat MSS
```

```
Ledaps Surface Reflectance
```

```
NDVI Mapping *
```

```
Get Link Save Run Reset
```

```
Imports (2 entries)
```

```
var geometry: Polygon, 4 vertices
```

```
var geometry2: Polygon, 4 vertices
```

```
var l8 = ee.ImageCollection('LANDSAT/LC8_L1T_TOA');
```

```
1
```

```
2
```

```
3 var spatialFiltered = l8.filterBounds(geometry);
```

```
4 print('spatialFiltered', spatialFiltered);
```

```
5
```

```
6 var temporalFiltered = spatialFiltered.filterDate('2015-01-01', '2015-12-31');
```

```
7 print('temporalFiltered', temporalFiltered);
```

```
8
```

```
9 // This will sort from least to most cloudy.
```

```
10 var sorted = temporalFiltered.sort('CLOUD_COVER');
```

```
11
```

```
12 // Get the first (least cloudy) image.
```

```
13 var scene = ee.Image(sorted.first());
```

```
14
```

```
15 Map.centerObject(scene, 9);
```

```
16 Map.addLayer(scene, {}, 'default RGB');
```

```
17
```

```
18 var visParams = {bands: ['B4', 'B3', 'B2'], max: 0.3};
```

```
19 Map.addLayer(scene, visParams, 'true-color composite');
```

```
20
```

```
21 var landsat2016 = l8.filterDate('2016-01-01', '2016-12-31');
```

```
22 Map.addLayer(landsat2016, visParams, 'l8 collection');
```

```
23
```

```
24 var landsat2016 = l8.filterDate('2016-01-01', '2016-12-31');
```

```
25 Map.addLayer(landsat2016, visParams, 'l8 collection');
```

```
26
```

```
27 // Get the median over time, in each band, in each pixel.
```

```
28 var median = l8.filterDate('2016-01-01', '2016-12-31').median();
```

```
29
```

```
30 // Make a handy variable of visualization parameters.
```

```
31 var visParams = {bands: ['B4', 'B3', 'B2'], max: 0.3};
```

```
32
```

```
33 // Display the median composite.
```

```
34 Map.addLayer(median, visParams, 'median');
```

```
35
```

```
36
```

```
37 // Load or import the Hansen et al. forest change dataset.
```

```
38 var hansenImage = ee.Image('UMD/hansen/global_forest_change_2015');
```

```
Inspector Console Tasks
```

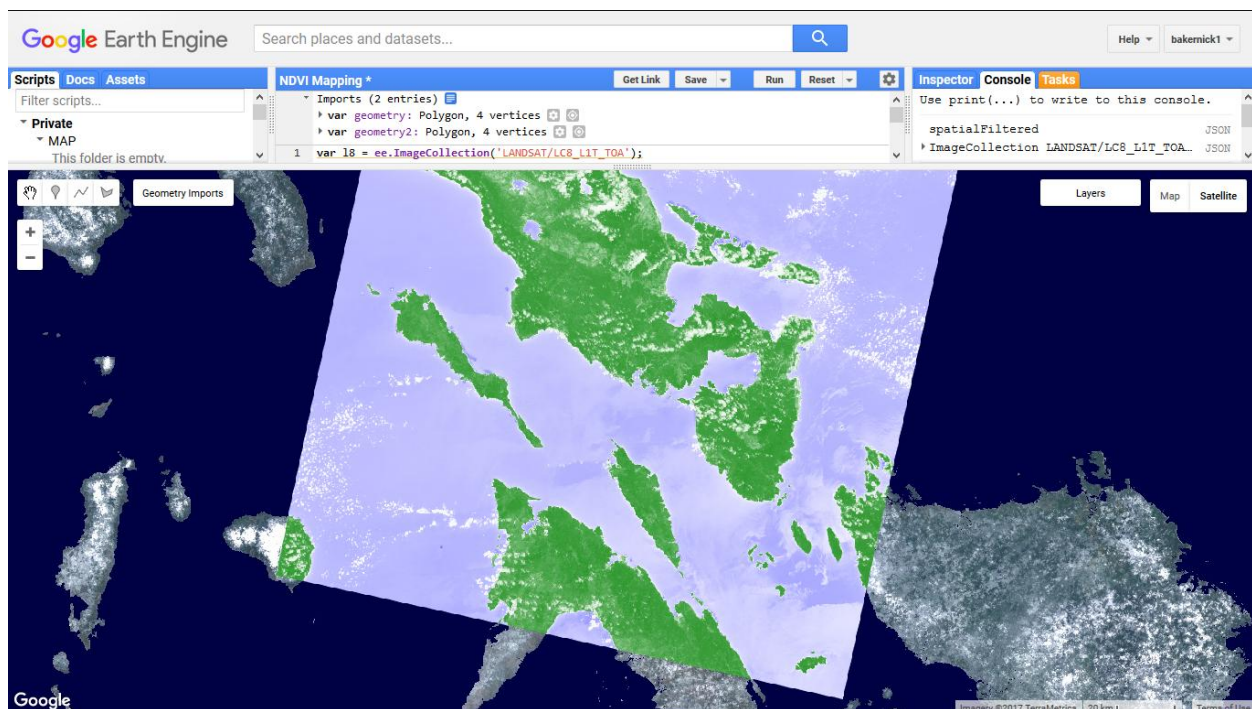
```
Use print(...) to write to this console.
```

```
spatialFiltered JSON
```

```
ImageCollection LANDSAT/LC8_L1T_TOA (...) JSON
```

```
temporalFiltered JSON
```

```
ImageCollection LANDSAT/LC8_L1T_TOA (...) JSON
```



Desktop ArcGIS

This workflow will walk you through the steps necessary to produce the NDVI images you see above in Figure X. This script, which we will provide for you to add to the code editor, pulls Landsat 8 data from the web for a given period of time that the user specifies. The NDVI .tif files can then be added to ArcGIS or QGIS for further analysis and / or for map generation. Please note that multiple year analysis allows for the measurement of change in forest cover.

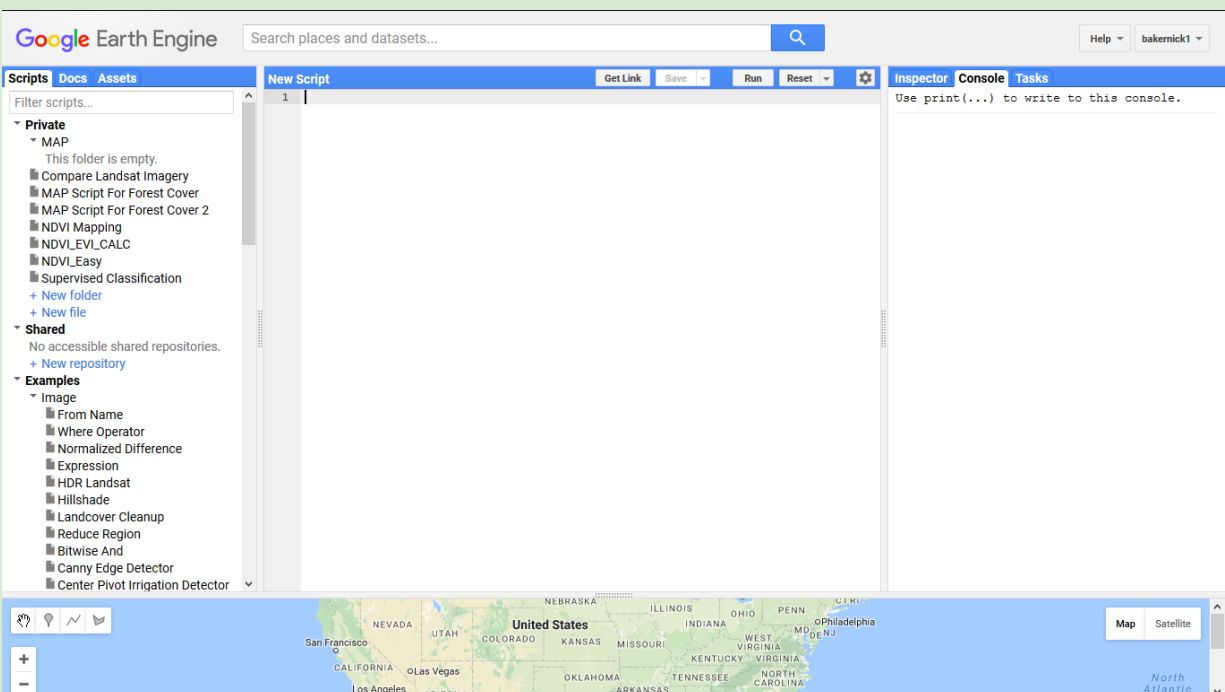
Creating an NDVI image for Analysis using Landsat 8 imagery

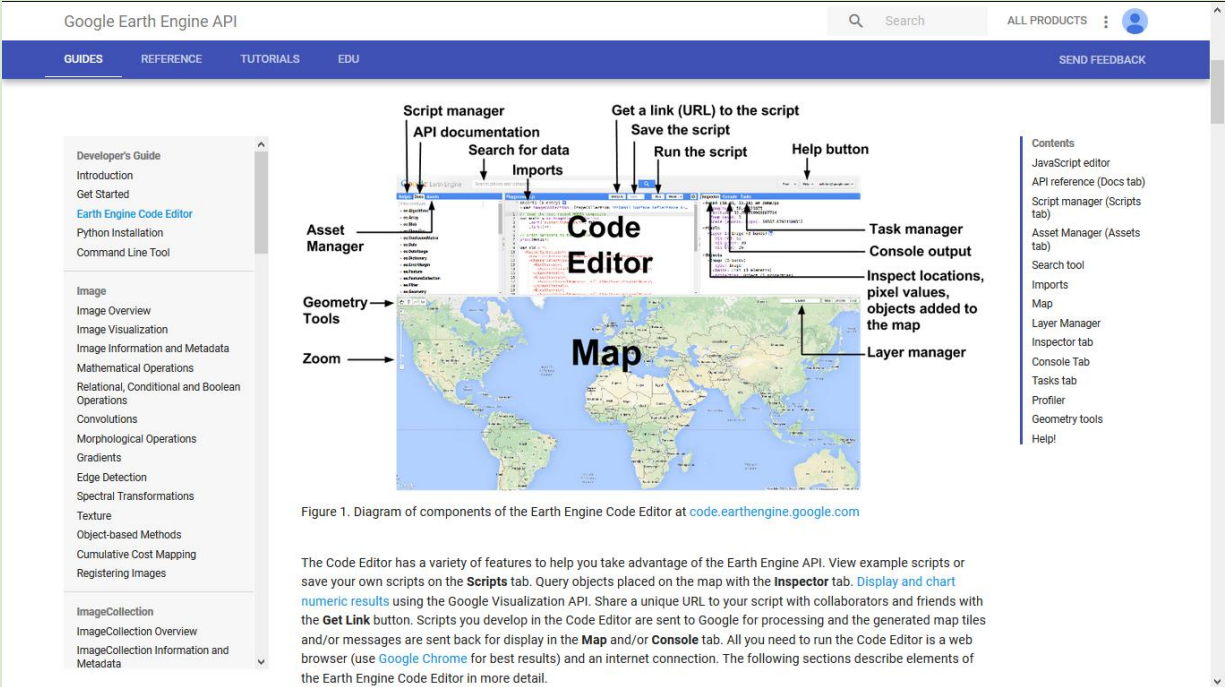
Please note: you will need a Google Account to get started.

Familiarize yourself with the API and Open a new page for the API:

- Follow the tutorials from Google at: <https://developers.google.com/earth-engine/getstarted>
- Navigate to the following page to begin creating a new script for the NDVI.
<https://code.earthengine.google.com/>

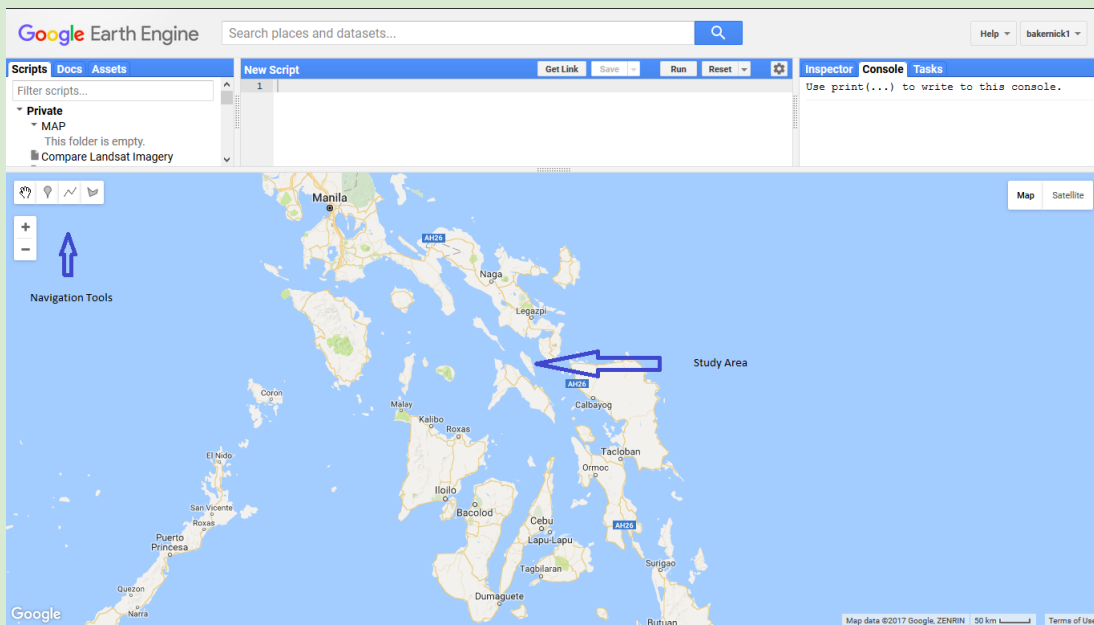
Within the screenshot below you will see four main panes to the website. The Code Editor is broken into three parts, the Scripts Docs and Assets, The Script Editor, and Inspector Tasks and Console. The Map is in the fourth window.





Determine the Study Area:

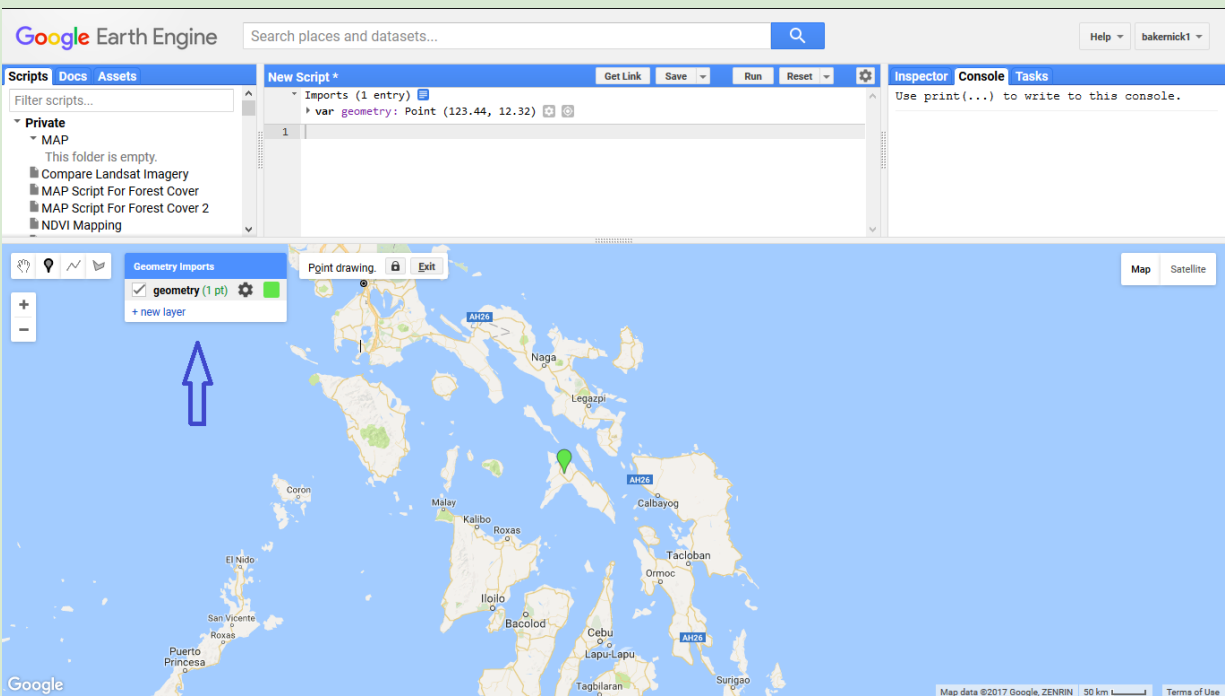
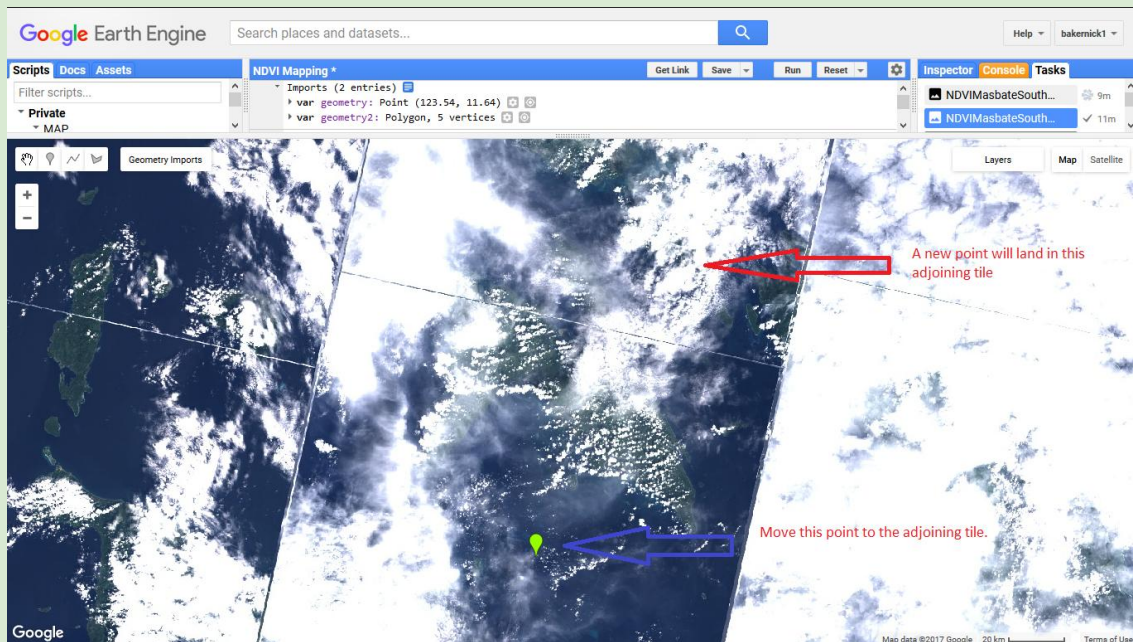
- In the Map Pane of the Window, use the navigation tools to center the map over your area of interest.



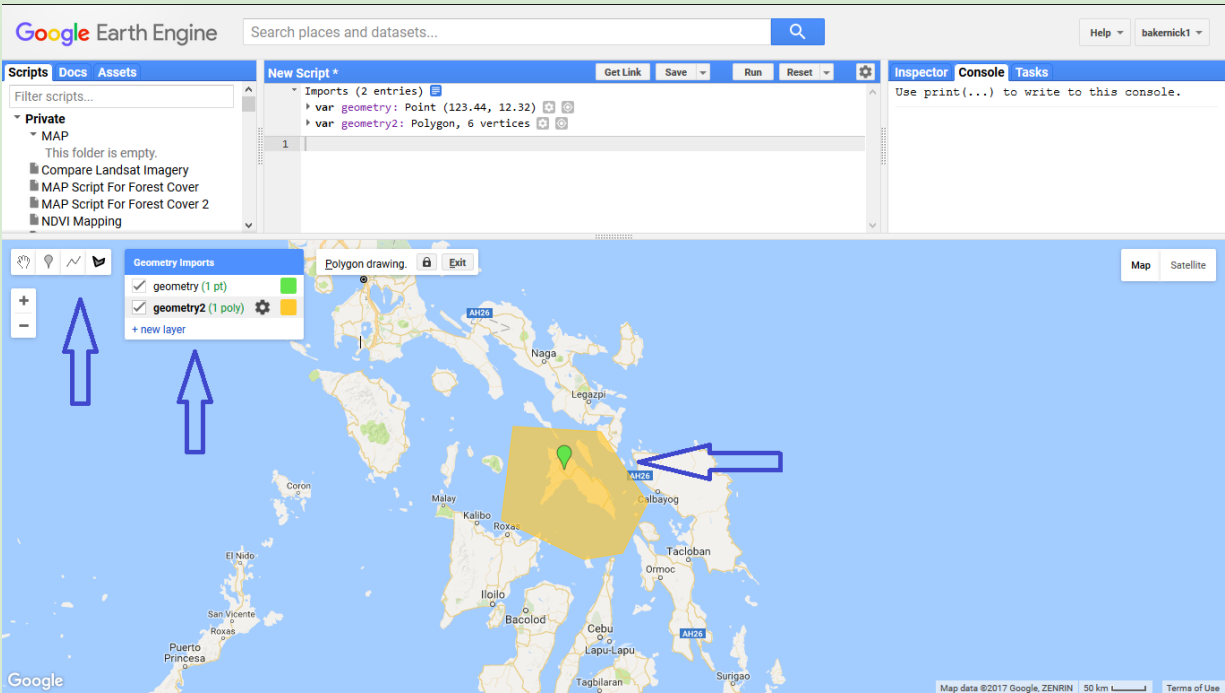
Establish two Geometry Imports to Use within the Code

- Use the Create Point Shape tool to select the center of the study area for the NDVI analysis.
- This will automatically create a “Geometry Import Layer”
- Each Geometry needs a new layer.

Note: You will need to move the Geometry Point to cover more than one Landsat Tile when extracting data from a larger study area.



- Geometry Imports in Layers can be Points, Lines, or Polygons
- Hover over “Geometry Imports” to create a new layer.
- Use the Create Shape Polygon Tool to create the Export Image Boundary



You're now ready to add the Java Code to the Code Editor Pane

- Open the Notepad file `GoogleEarthEngine_NDVI_Java.txt`
- Select All text
- Copy text
- Paste text into Code Editor

Adjust the dates within the code:

- `var temporalFiltered`
- `var landsat201X`
- `var median`
- `var image`

Please note Landsat 7 and 8 data will be processed in the Collection 1 archive only. For data from 1999-present use either 7 or 8 where available.

Google Earth Engine Search places and datasets... Help bakernick1

Scripts Docs Assets

Filter scripts...

- Private
 - MAP
 - This folder is empty.
 - Compare Landsat Imagery
 - MAP Script For Forest Cover
 - MAP Script For Forest Cover 2
 - NDVI Mapping
 - NDVI_LVL_CALC
 - NDVI_Easy
 - Supervised Classification
 - + New folder
 - + New file
- Shared
 - No accessible shared repositories.
 - + New repository
- Examples
 - Image
 - From Name
 - Where Operator
 - Normalized Difference
 - Expression
 - HDR Landsat
 - Hillshade
 - Landcover Cleanup
 - Reduce Region
 - Bitwise And
 - Canny Edge Detector
 - Center Pivot Irrigation Detector
 - Clamp
 - Connected Pixel Count
 - Download Example
 - From Name Landsat8

NDVI Mapping * Get Link Save Run Reset

```

Imports (2 entries)
var geometry2: Polygon, 5 vertices
var geometry: Point (123.69, 12.82)
https://developers.google.com/earth-engine/tutorial_api_06
1
2
3 // Call in the Landsat Imagery
4
5 var l8 = ee.ImageCollection('LANDSAT/LC8_L1T_TOA');
6
7 // Filter Bounds for the Study. Adjust as needed after NDVI is created.
8 var spatialFiltered = l8.filterBounds(geometry);
9 print('spatialFiltered', spatialFiltered);
10
11 // Set the Filter Dates for the Imagery you would like to search through for
12 // Landsat 8
13 var temporalFiltered = spatialFiltered.filterDate('2013-01-01', '2013-12-31');
14 print('temporalFiltered', temporalFiltered);
15
16 // This will sort from least to most cloudy.
17 var sorted = temporalFiltered.sort('CLOUD_COVER');
18
19 // Get the first (least cloudy) image.
20 var scene = ee.Image(sorted.first());
21
22 // Centers the Map in the Map Pane Display
23 Map.centerObject(scene, 9);
24 Map.addLayer(scene, {}, 'default RGB');
25
26 // Sets the Visual Parameters for the Bands
27 var visParams = {bands: ['B4', 'B3', 'B2'], max: 0.3};
28 Map.addLayer(scene, visParams, 'true-color composite');
29
30 // Filters the date collection for Landsat 201X
31
32 var landsat201X = l8.filterDate('2013-01-01', '2013-12-31');
33 Map.addLayer(landsat201X, visParams, 'l8 collection');
34
35
36 // Get the median over time, in each band, in each pixel.
  
```

Inspector Console Tasks

- ChangetoYourDesiredN... RUN
- NDVIMasbateNorth201... ✓ 12m
- NDVIMasbateNorth201... ✓ 11m
- NDVIMasbateSouth20... ✓ 12m
- NDVIMasbateSouth20... ✓ 11m
- NDVIMasbateSouth20... × 8m
- NDVIMasbateSouth2013 ✓ 11m
- Older tasks

Google Earth Engine Search places and datasets... Help bakernick1

Scripts Docs Assets

Filter scripts...

- Private
 - MAP
 - This folder is empty.
 - Compare Landsat Imagery
 - MAP Script For Forest Cover
 - MAP Script For Forest Cover 2
 - NDVI Mapping
 - NDVI_LVL_CALC
 - NDVI_Easy
 - Supervised Classification
 - + New folder
 - + New file
- Shared
 - No accessible shared repositories.
 - + New repository
- Examples
 - Image
 - From Name
 - Where Operator
 - Normalized Difference
 - Expression
 - HDR Landsat
 - Hillshade
 - Landcover Cleanup
 - Reduce Region
 - Bitwise And
 - Canny Edge Detector
 - Center Pivot Irrigation Detector
 - Clamp
 - Connected Pixel Count
 - Download Example
 - From Name Landsat8

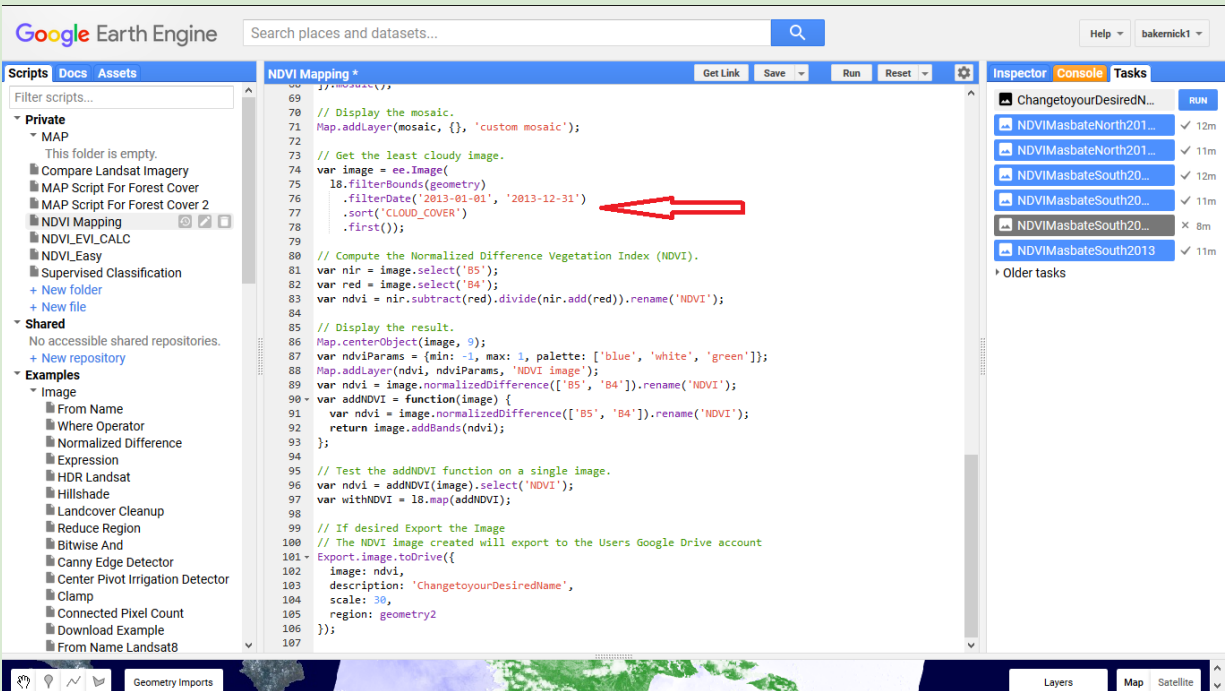
NDVI Mapping * Get Link Save Run Reset

```

35
36 // Get the median over time, in each band, in each pixel.
37 var median = l8.filterDate('2013-01-01', '2013-12-31').median();
38
39 // Make a handy variable of visualization parameters.
40 var visParams = {bands: ['B4', 'B3', 'B2'], max: 0.3};
41
42 // Display the median composite.
43 Map.addLayer(median, visParams, 'median');
44
45 // Load or import the Hansen et al. forest change dataset.
46 var hansenImage = ee.Image('UMD/hansen/global_forest_change_2015');
47
48 // Select the land/water mask.
49 var datamask = hansenImage.select('datamask');
50
51 // Create a binary mask.
52 var mask = datamask.eq(1);
53
54 // Update the composite mask with the water mask.
55 var maskedComposite = median.updateMask(mask);
56 Map.addLayer(maskedComposite, visParams, 'masked');
57
58 // Make a water image out of the mask.
59 var water = mask.not();
60
61 // Mask water with itself to mask all the zeros (non-water).
62 water = water.mask(water);
63
64 // Make an image collection of visualization images.
65 var mosaic = ee.ImageCollection([
66   median.visualize(visParams),
67   water.visualize({palette: '000044'}),
68 ]).mosaic();
69
70 // Display the mosaic.
71 Map.addLayer(mosaic, {}, 'custom mosaic');
72
73 // Get the least cloudy image.
  
```

Inspector Console Tasks

- ChangetoYourDesiredN... RUN
- NDVIMasbateNorth201... ✓ 12m
- NDVIMasbateNorth201... ✓ 11m
- NDVIMasbateSouth20... ✓ 12m
- NDVIMasbateSouth20... ✓ 11m
- NDVIMasbateSouth20... × 8m
- NDVIMasbateSouth2013 ✓ 11m
- Older tasks



Exporting the Image:

There are many options for Exporting images. You can review other options at:

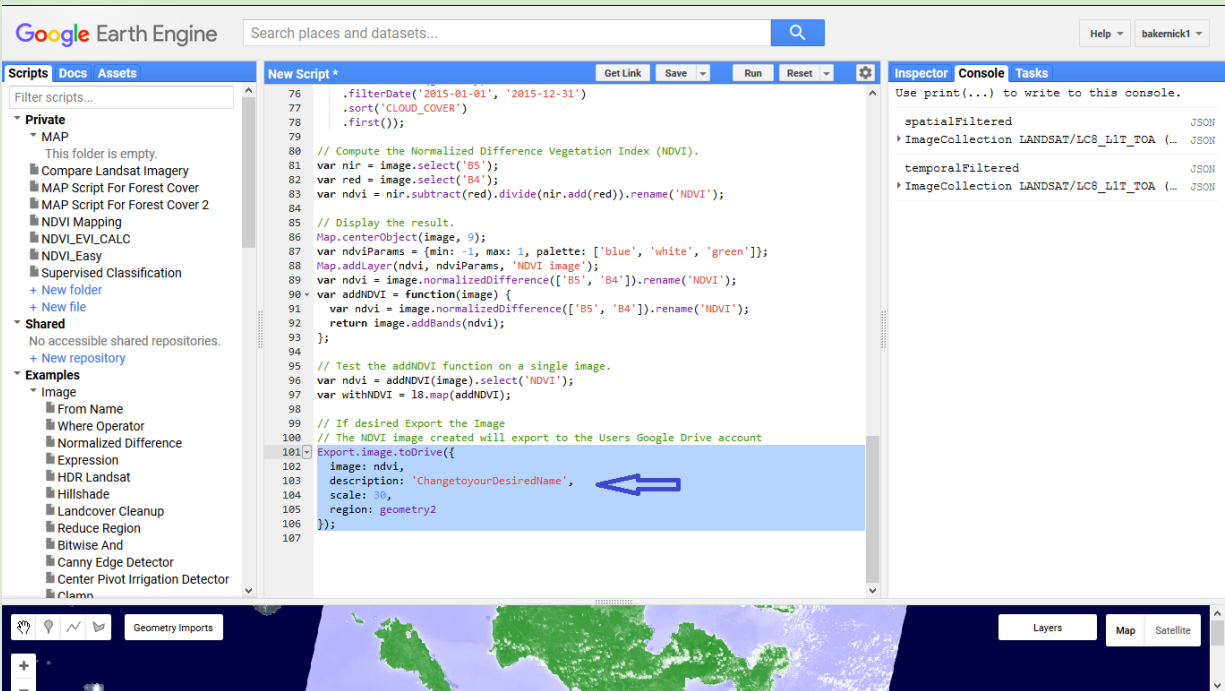
https://developers.google.com/earth-engine/tutorial_api_07

- The end of the code sample refers to the Export command.
- If desired, change the Export Image Name to a file name that makes sense to you!
- The image to be exported is generated from the “geometry2” which you defined earlier.

```

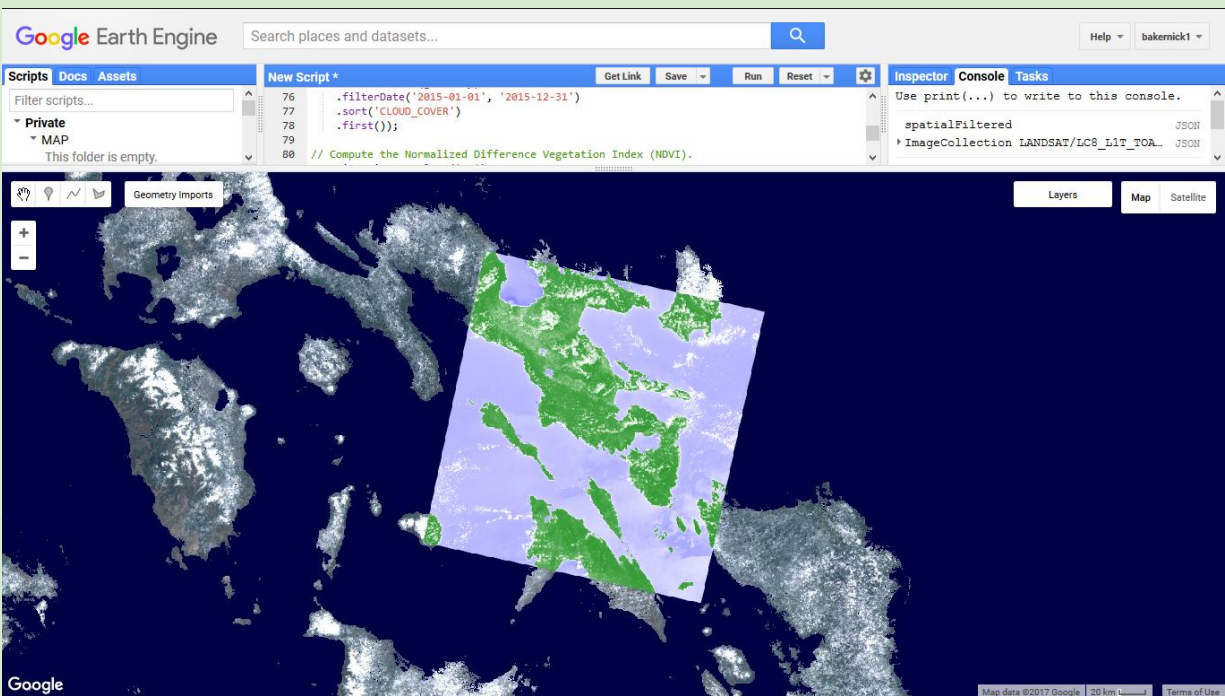
Export.image.toDrive({
  image: ndvi,
  description: 'ChangetoyourDesiredName',
  scale: 30,
  region: geometry2
});

```



Success! You now have a NDVI image, and a TIFF file to use in a GIS platform.

Please note, the Geometry selection is a bit finicky and may require you to run the analysis multiple times choosing different points to gain all of your study area desired.



*Data management tip: include the date in the file name. Make sure the name makes sense to you and it will be easy to file and search for the image

Using Google Earth Engine Generated NDVI in ArcMap:

- Open Your Google Drive Account, this is the same account you used to log into Google Earth Engine
- Navigate to your image.
- Download the image.
- Open ArcCatalog (if need be)
- Create a File Geodatabase.
- Add the NDVI TIFF file from your Google Drive Account.
- Follow the Analysis Workflow, step 3 Desktop ArcGIS for Forest Change from multiple NDVI layers.

Desktop ArcGIS

ArcGIS offers a friendly user interface and it is clicks away from MODIS data, a FOS Satellite imagery collection by NASA. The Time Slider function allows users to see a daily time lapse and chose the imagery that suits the purpose of the project. Saving the target imagery for NDVI Calculations is also possible in easy steps. ESRI offers the option to import layers and maps in a variety of compatible formats and can be used interchangeably with QGIS and GEE. To automate some of the work, classify NDVI data using Ground Truth and Visual data and let ESRI's Assisted Learning tool do the rest.

1 - Classifying Imagery Rasters

Now that you have all scenes with calculated NDVI in one raster layer, the next step is classify your data. There are a few ways to do it. As explained previously, vegetation will be in the higher ranges of NDVI values. The results we tested showed mangroves with NDVI values from 0.2 and above. It is possible to classify the NDVI raster simply by value ranges and export the selected values.

The [Interactive Supervised Classification tool](#) is available in ArcGIS Image Classification toolbar with Spatial Analyst license. The tool provides a user friendly interface and workflow to classify raster data using the maximum likelihood process. It allows users to classify the data using other layers and imageries as reference maps.

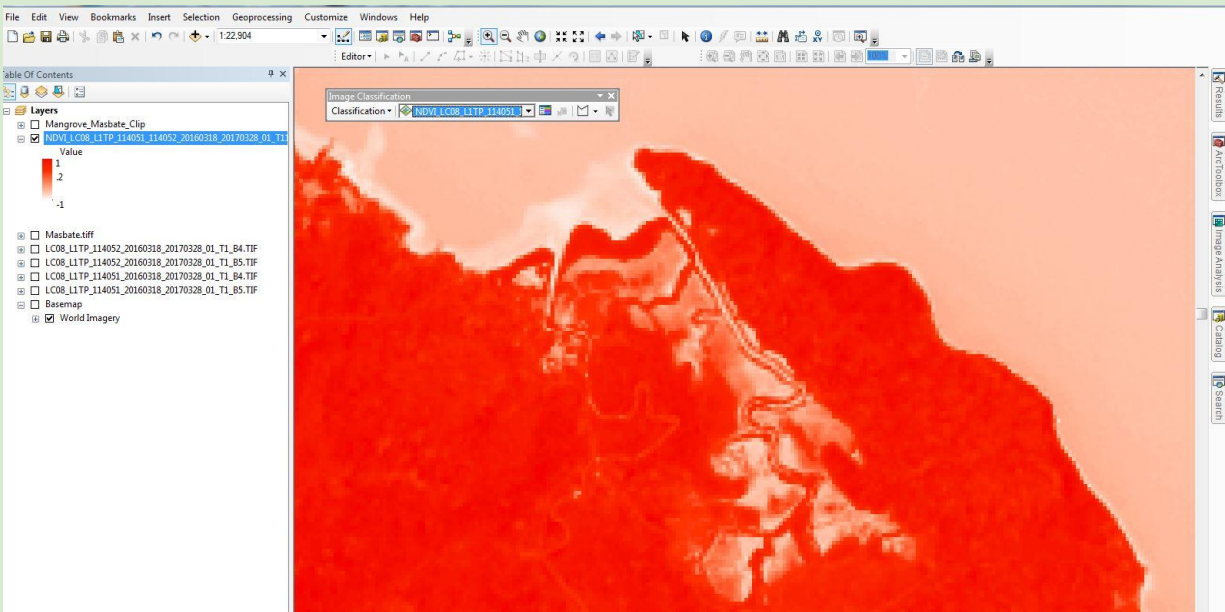
The tool could be particularly useful for [crowdsourcing](#) since the classification files can be easily stored, transferred, and used with different rasters. Collaborators abroad are able to contribute with a simple polygon shapefile (.shp) that can be created using FOS QGIS. Polygons with ground truth data can be used as reference maps to classify imagery. Other sources such as [PhillGIS.org](#) also provide polygon layers representing mangroves and water bodies.



Using the Interactive Supervised Classification

On the menu bar, go to Customize >>Extension and make sure the Spatial Analyst extension is check.


To open the Image Classification toolbar, got to Customize >> Toolbars >> Image Classification.

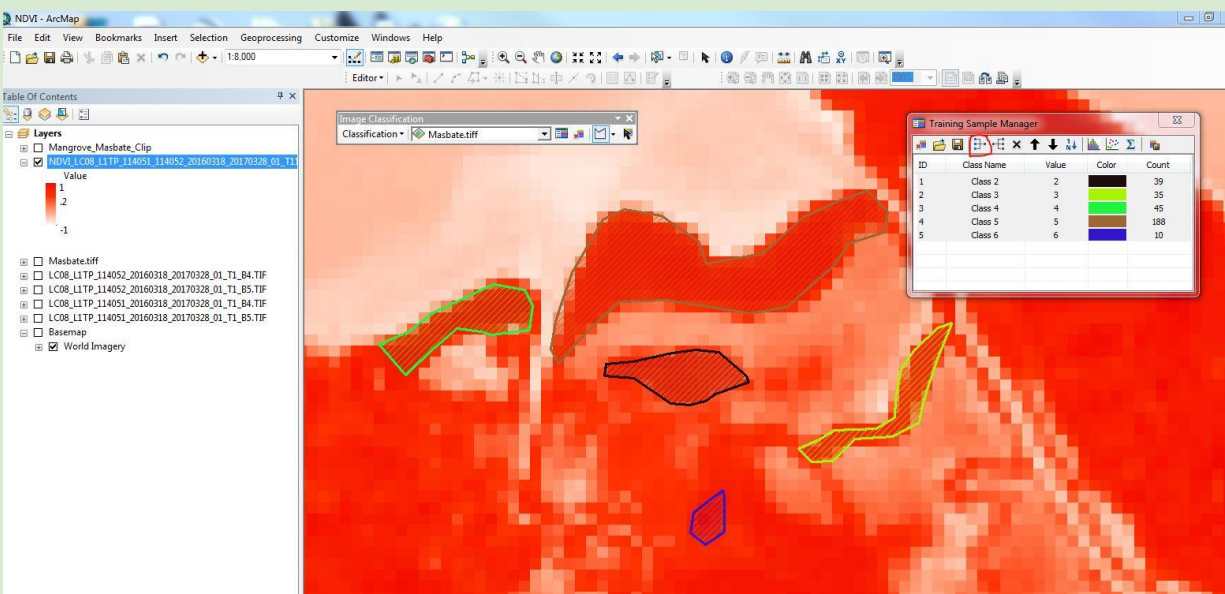
On the Image Classification Toolbar, select the NDVI layer you want to classify.



On the Image Classification toolbar, click on "Training Sample Manager"  and "Draw Polygon"  icons to create polygon features based on their classification.

Create polygons for all areas where mangrove is present by clicking on its boundaries. Double click to finish a polygon. Use base maps, WMS, other rasters and shapefiles as reference to classify the NDVI data.

After creating the polygons for mangrove, select all polygons on the Training Sample Manager and click on "Merge Training Samples" icon .



All polygons representing mangrove have been merged into one class. Name the class "Mangrove"

Repeat the steps for other land features such as water, shrimp ponds, build up areas, other vegetation types.

Once all classes are created, save your sample by as a shapefile. Note that shapefiles can also be uploaded as the training layer.



On the Image Classification toolbar, click on the classification drop down menu and chose "Interactive Supervised Classification". A new classified raster appears on your table of contents. Right click on the image, and go to Data>>Export Data to save the raster.

Other resources: [ArcGIS Help, Tutorial](#)

- Creating a polygon shapefile (.shp) in QGIS
- On the menu bar, go to Layer>>Create layer>>New Shapefile Layer
- Chose the type and coordinate and click ok. Chose the name and destination folder for the new layer. Click ok
- The new layer is loaded to the Layers Panel.

Click on Edit >>Add feature on the menu bar and draw polygons or points reflecting on classifications of sampled areas. To finish a polygon, right click and assign a unique id.

Send this easy workflow to your peers and use the sampled polygons and the training layer shapefile.

Other resources: [QGIS Help, Tutorial](#)

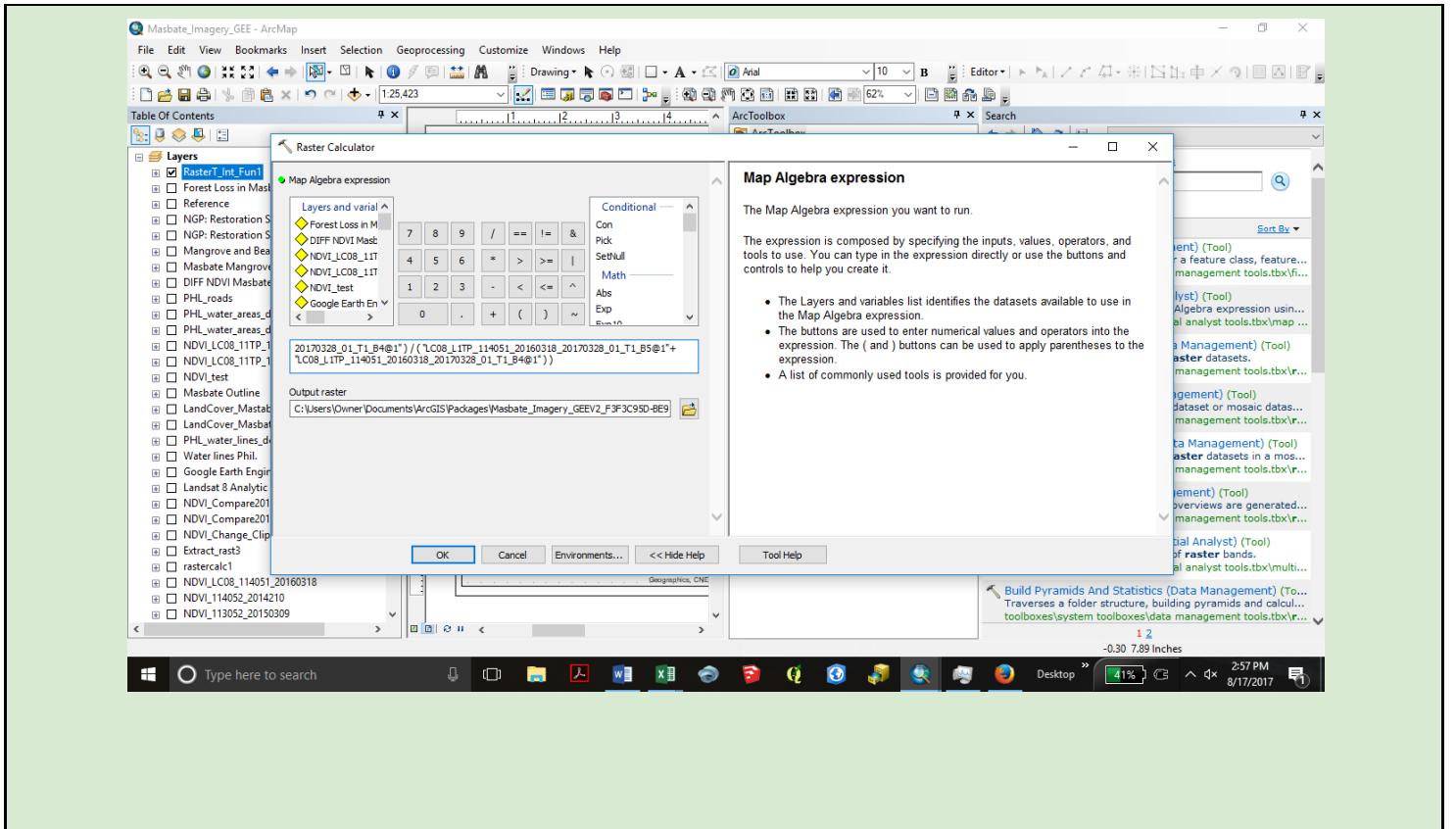
2 - Calculating NDVI

Now that you have downloaded the images, the next step is to calculate the NDVI and create a mosaic with the raster bands.

This calculation yields values ranging from -1 to 1. High values indicate the presence of vegetation, where any negative values are mainly generated from clouds, water, and snow, and values near zero are mainly generated from rock and bare soil. Very low values (0.1 and below) of NDVI correspond to barren areas of rock, sand, or snow. Moderate values (0.2 to 0.3) represent shrub and grassland, while high values (0.6 to 0.8) indicate temperate and tropical rainforests. b) Calculating NDVI using ESRI's WMS "Landsat 8 Analytic" in ArcMap.

Calculating NDVI with Raster Calculator ArcMap

- Load B4 and B5 for all desired scenes the NDVI. A good practice is to do sets of same date at the same time in order for the final NDVI mosaic to reflect one temporal scene.
- Open the Raster Calculator
- Generate this formula for all Landsat data
- $$\frac{("LC08_L1TP_114051_20160318_20170328_01_T1_B5@1" - "LC08_L1TP_114051_20160318_20170328_01_T1_B4@1")}{("LC08_L1TP_114051_20160318_20170328_01_T1_B5@1" + "LC08_L1TP_114051_20160318_20170328_01_T1_B4@1")}$$
 See the screenshot below
- Choose the Output extent
- Click "OK"
- The New NDVI will appear in the Map
- Confirm that the values fall between 1 to -1
- Repeat for another Landsat image for the same area at a different time frame.



Calculating NDVI with ArcGIS Image Analysis Toolset

1 - Load B4 and B5 for all desired scenes

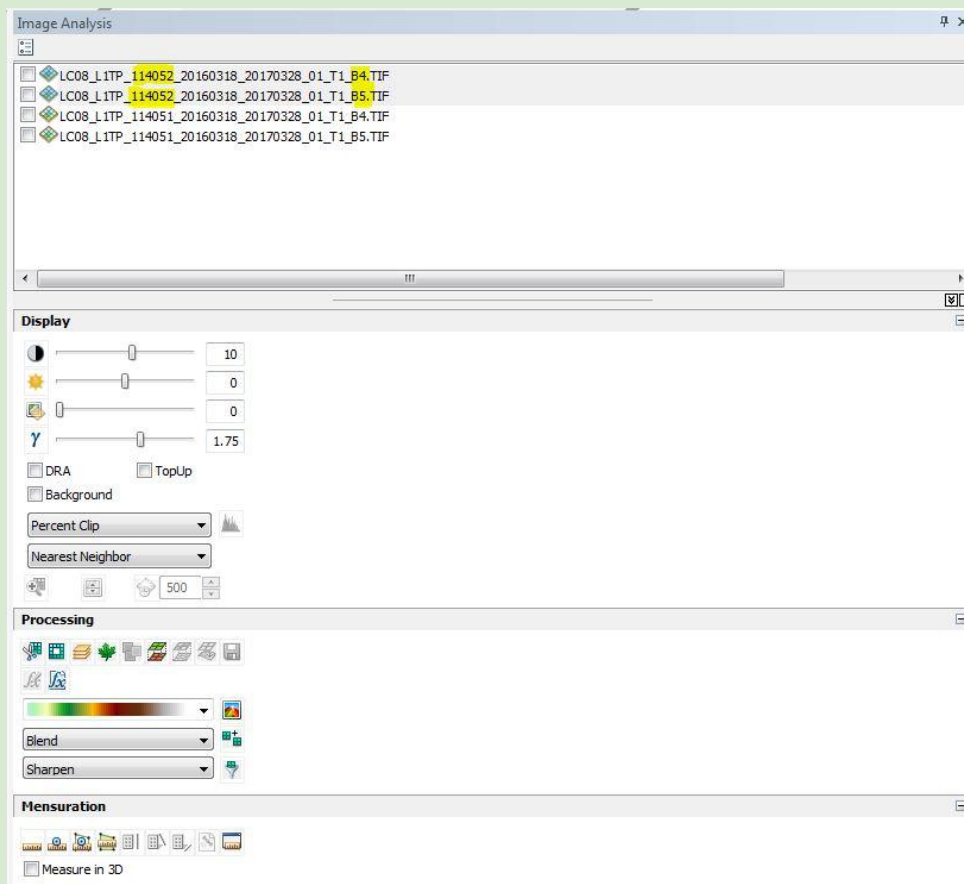
On section "Data>>Landsat>>Downloading Landsat 8 Data" you have learned how to download Landsat 8 scenes and that each raster in the package represents one band. Now you will upload band 4 (B4) and band 5 (B5) from all scenes you have downloaded to calculate the NDVI. A good practice is to do sets of same date at the same time in order for the final NDVI mosaic to reflect one temporal scene.


Open ArcGIS and drag and drop rasters corresponding to band 4 and 5 of each scene.

2- Calculate NDVI for each scene

Open Image analysis (Windows>>Image Analysis).

On Image Analysis, select a combination of band 4 and band 5 of each scene, one scene at the time. To select a scene, click on its name, not the check box. The scenes must be in increasing order as shown below.



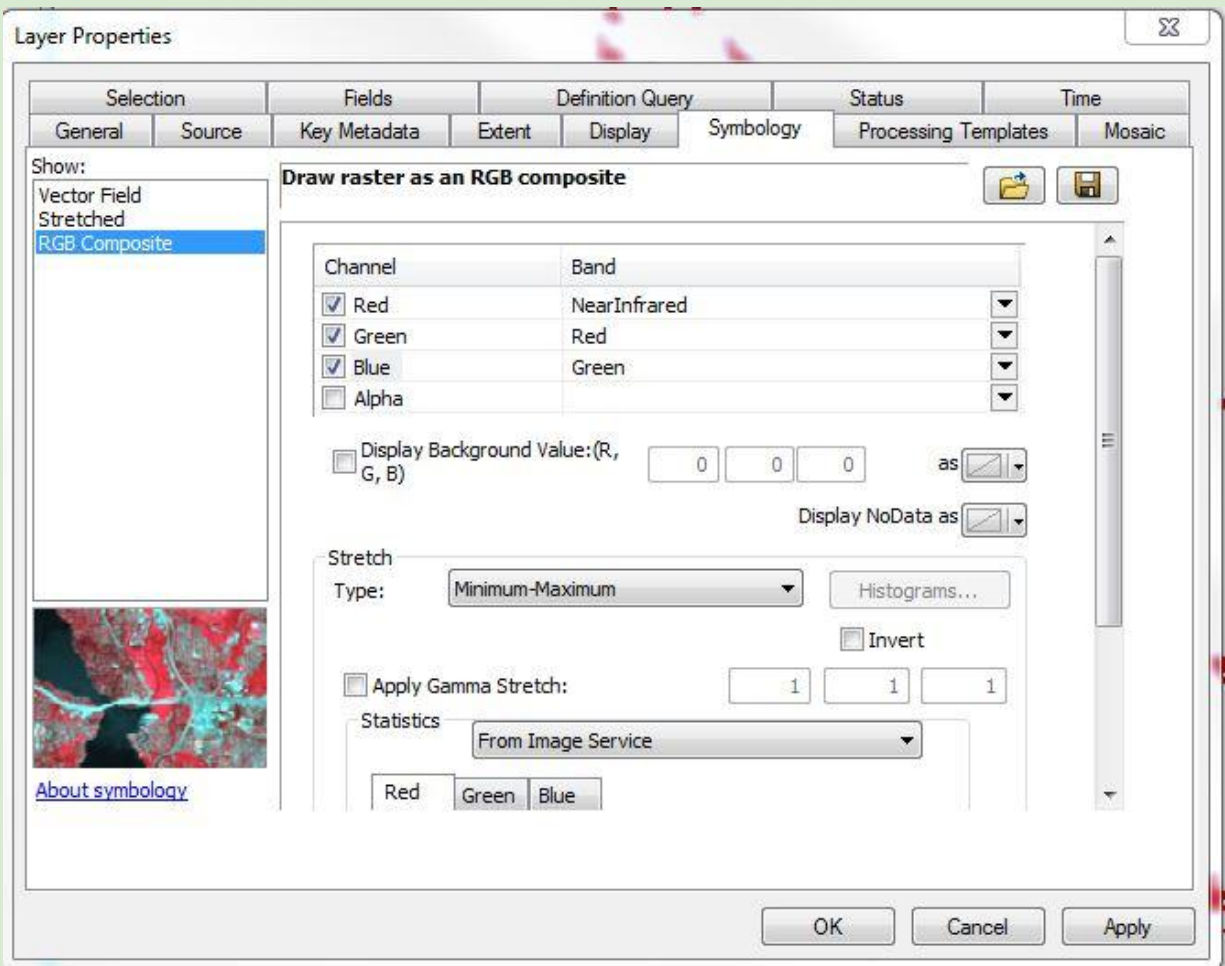
Once B4 and B5 of the first scene have been selected, click on "NDVI"  on the "Processing" tab of Image Analysis. Repeat this step for all scenes.

You now have one raster layer that represents the calculated NDVI for each of the Landsat 8 scenes downloaded.

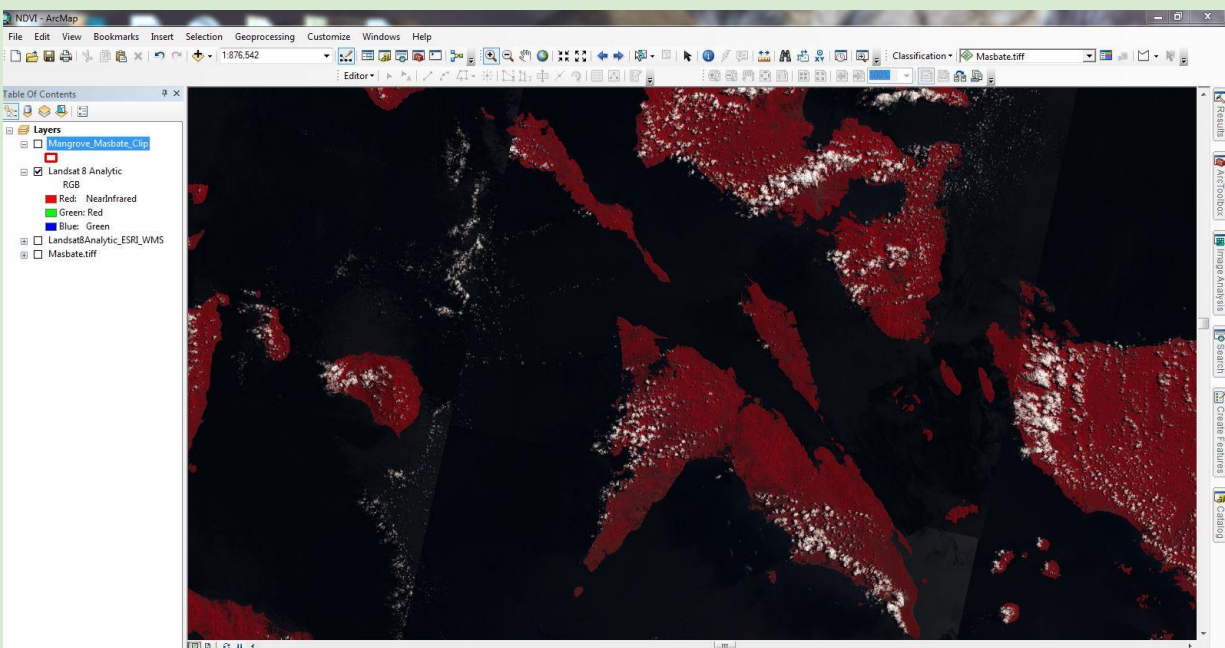
Calculate NDVI using saved Landsat 8 ArcGIS WMS

Please refer to "Data>>Landsat>>Downloading Landsat 8 ArcGIS WMS" workflow for instruction on how to save ESRI's Landsat 8 Analytic scenes.

The Landsat 8 Analytic WMS has 8 bands. To display NIR colors, set the red color to NIR, the green color to red and the blue color to green band.



Vegetation is now displayed in red.



Next, you will use the Image Analysis toolset to calculate NDVI. Click on Image Analysis Options icon and on the NDVI tab select only "Scientific Output"

On the Image Analysis window, select the Landsat 8 Analytic TIFF you have saved and click on the NDVI icon



to calculate NDVI.

ArcGIS Help, [Tutorial](#)

3 - Calculating forest change using NDVI rasters


After calculating the NDVI for Landsat scenes of multiple years, it is possible to find pixels that changed value (decrease and increased) using Image Analysis Toolset. Using the "Difference Function", it is possible to create a raster with the difference in NDVI value for each pixel. Using the "Remap Function" create a raster with specific values of change. For example, if MAP wishes to know which areas had an NDVI decrease of more than 0.3, simply set the maximum value to -0.3 and 0.3. The raster will yield pixels in which the NDVI increased or decreased by 0.3 between the two scenes.

Using Image Analysis to calculate change

Load two rasters of the same extent and calculate NDVI (see session ArcMap>>Calculate NDVI)

Load the NDVI rasters in ArcMap and open the Image Analysis toolset (Windows>>Image Analysis)

Select the two NDVI layer by clicking on the layers - not checking the box (hold Ctrl to select multiple layers)

Click on the "Difference" icon  to calculate the difference. A new Difference Raster layer will be created and uploaded to the TOC.

In Image Analysis window, select the new difference layer and click on "Add Function" icon



Right click on "Arithmetic Function" and got to "Insert Function>>Remap Function" to open the Rater Function Properties window.

On the Remap tab, set the minimum value to the lowest value of the Difference Raster layer and the maximum to the negative difference of NDVI you are trying to detect (decrease). On the next line, set the minimum value to the highest value of the Difference Raster and the maximum to the positive difference value (increase).

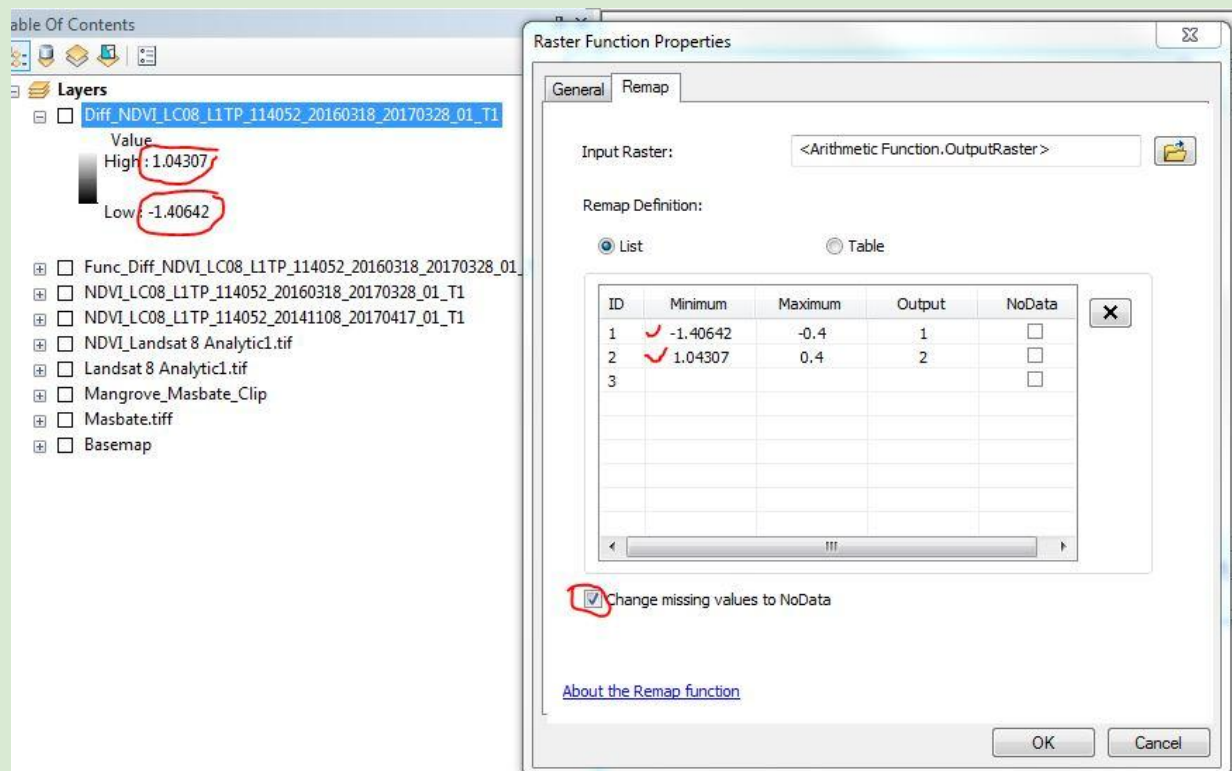
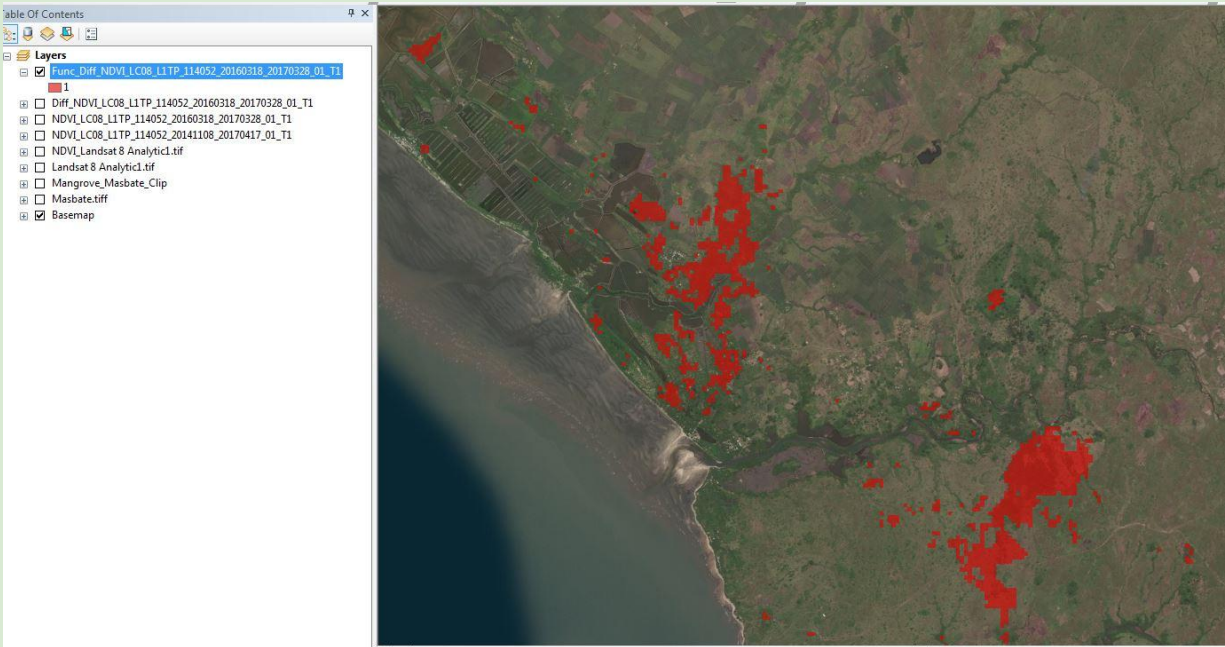


Table of Contents

- Layers
 - Diff_NDVI_LC08_L1TP_114052_20160318_20170328_01_T1
 - Value
 - High: 1.04307
 - Low: -1.40642
 - Func_Diff_NDVI_LC08_L1TP_114052_20160318_20170328_01_T1
 - NDVI_LC08_L1TP_114052_20160318_20170328_01_T1
 - NDVI_LC08_L1TP_114052_20141108_20170417_01_T1
 - NDVI_Landsat 8 Analytic1.tif
 - Landsat 8 Analytic1.tif
 - Mangrove_Masbate_Clip
 - Masbate.tiff
 - Basemap

Click ok to create a new temporary layer where pixels of value 1 experienced a decrease in NDVI and 2 an

increase by .04.



ArcGIS Help, [Tutorial](#)

QGIS

With all of the workflows the overview steps initially provided above to scope the project apply for the QGIS workflow as well. Given the brief timeframe of the project the steps below were not vigorously examined as though run with the Google Earth Engine or ArcGIS. QGIS provides a very similar platform for calculating and analyzing NDVI layers for forest change. There are a couple of ways to calculate the NDVI in QGIS. Note: for Landsat 8 imagery the NIR Band is Band 5, and the Red Band is Band 4, whereas for Landsat 7 imagery Band 4 is the NIR, and Band 3 is the Red Band.

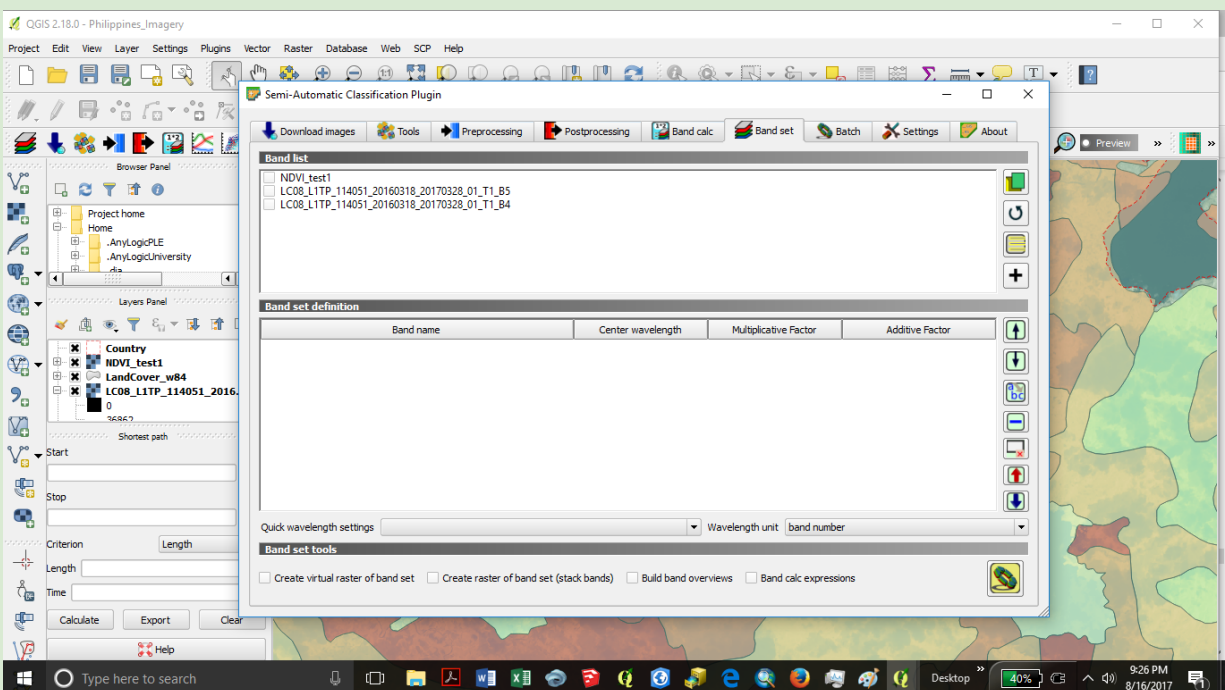
Semi-Automatic Classification Plugin

If there ever was a tool that had it all this would be the one. This plugin has many handy built in features:

- Gives the user the ability to download Landsat Data
- Classifier for Raster Datasets
- NDVI calculation with Band Calculator
- Multiple tools for Raster Calculations
- Preprocessing image tools
- Built-in Raster Calculator for Landsat Bands

Again given the time constraints of the project, please navigate to the following link for the classifier plugin and workflow. <https://fromgitors.blogspot.com/p/semi-automatic-classification-plugin.html>.

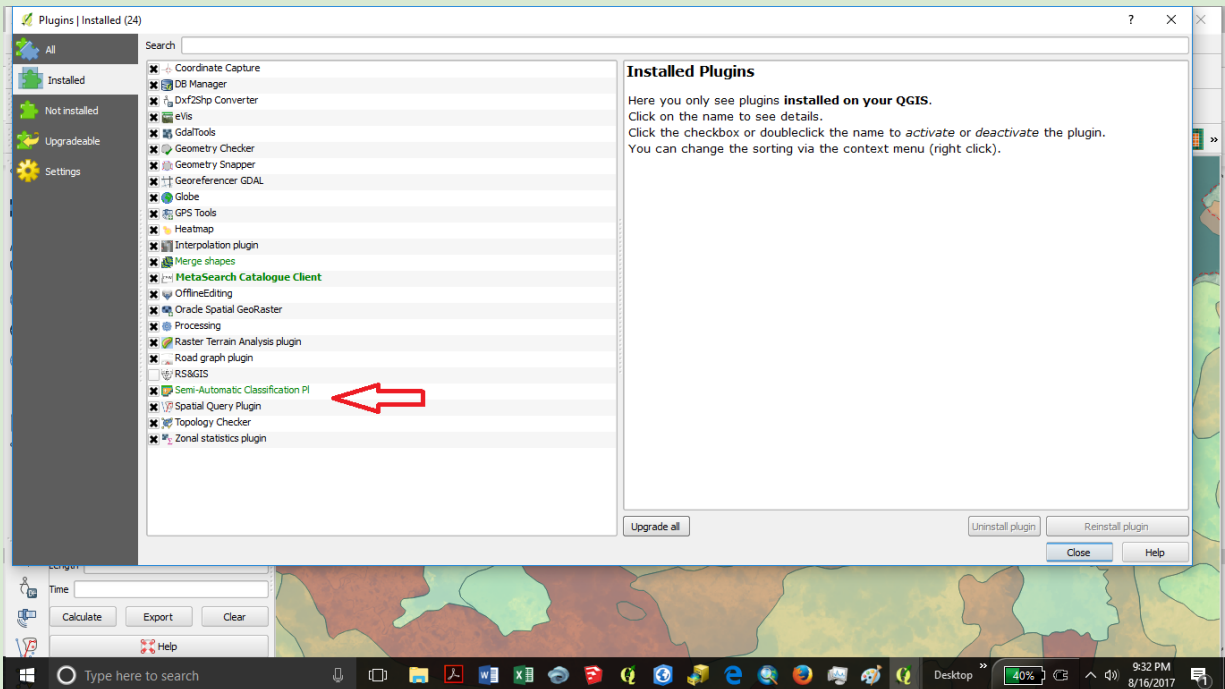
http://semiautomaticclassificationmanual-v5.readthedocs.io/en/latest/tutorial_1.html



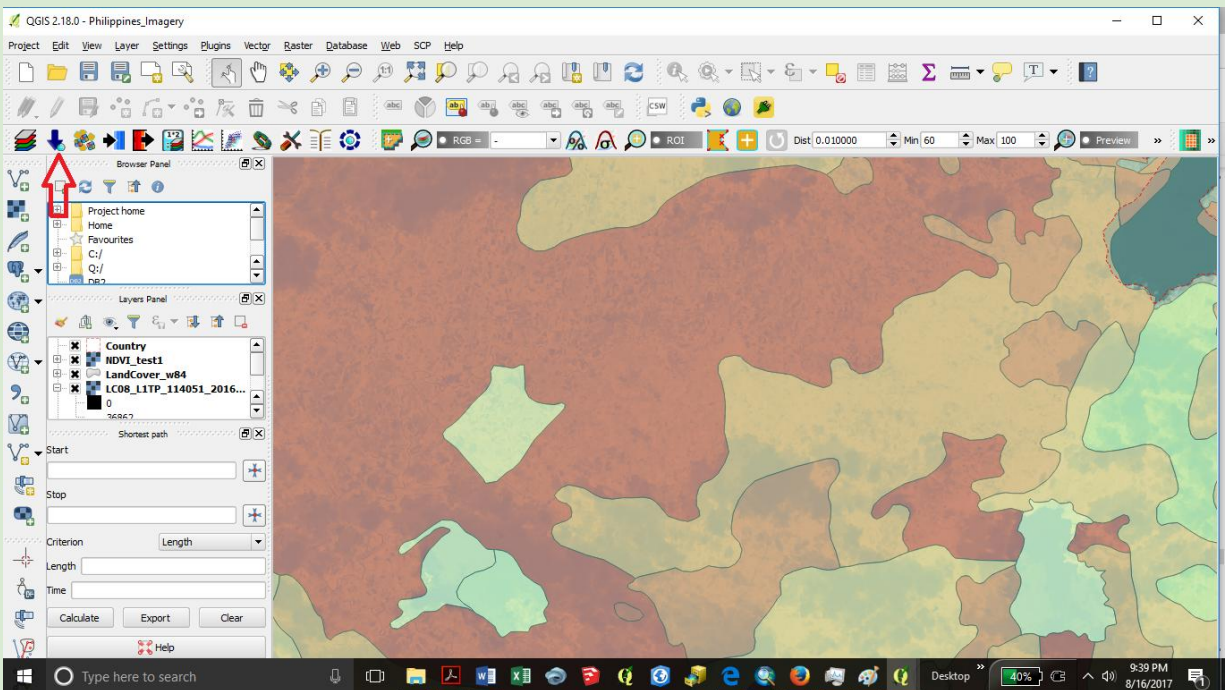
Adding the Semi-Automatic Classification Plugin

- Open QGIS
- Check to see if the Semi-Automatic Classification Plugin is enabled. Navigate to the “Plugins” menu, and select “Manage and Install Plugins.”
- In the “Installed” Tab it will be listed, and the box to the left needs to be checked.
- If it is not listed click on the “Not Installed” tab, scroll down to “Semi-Automatic Classification”, and

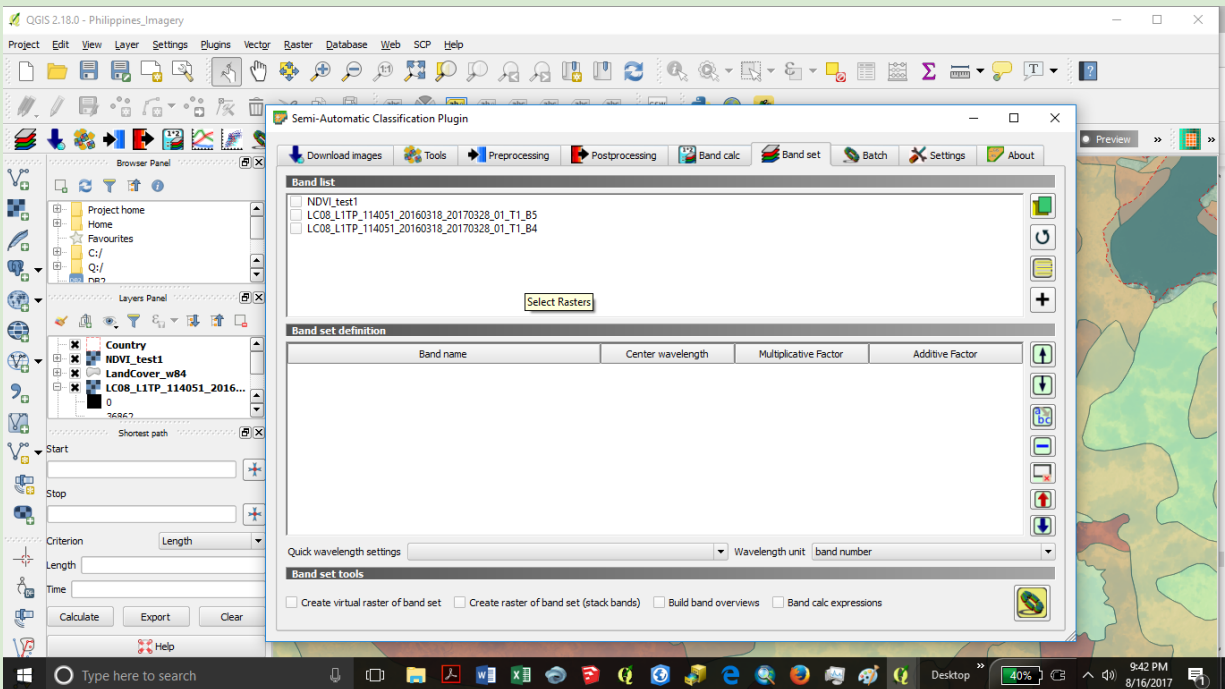
follow the prompts within the window to add it to QGIS.



- Once installed return back to the main window. You will see the following



- Click on the toolbar and the window will open.



The Classifier Tool:

The Classifier tool in the Semi-Automatic Classification Plugin contains very similar steps like ArcGIS. Use the Classifier tool in order to define the Mangrove Forest Cover from Landsat imagery. The classifier allows the user to gain perspective on the overall distribution of the Mangrove in the study area. The classified mangrove layer will be used in the analysis of the workflow.

- Given time constraints navigate to to: http://semiautomaticclassificationmanual-v5.readthedocs.io/en/latest/tutorial_1.html
- Follow the prompts to create a classified image for Mangrove Forests.

Using QGIS to calculate NDVI

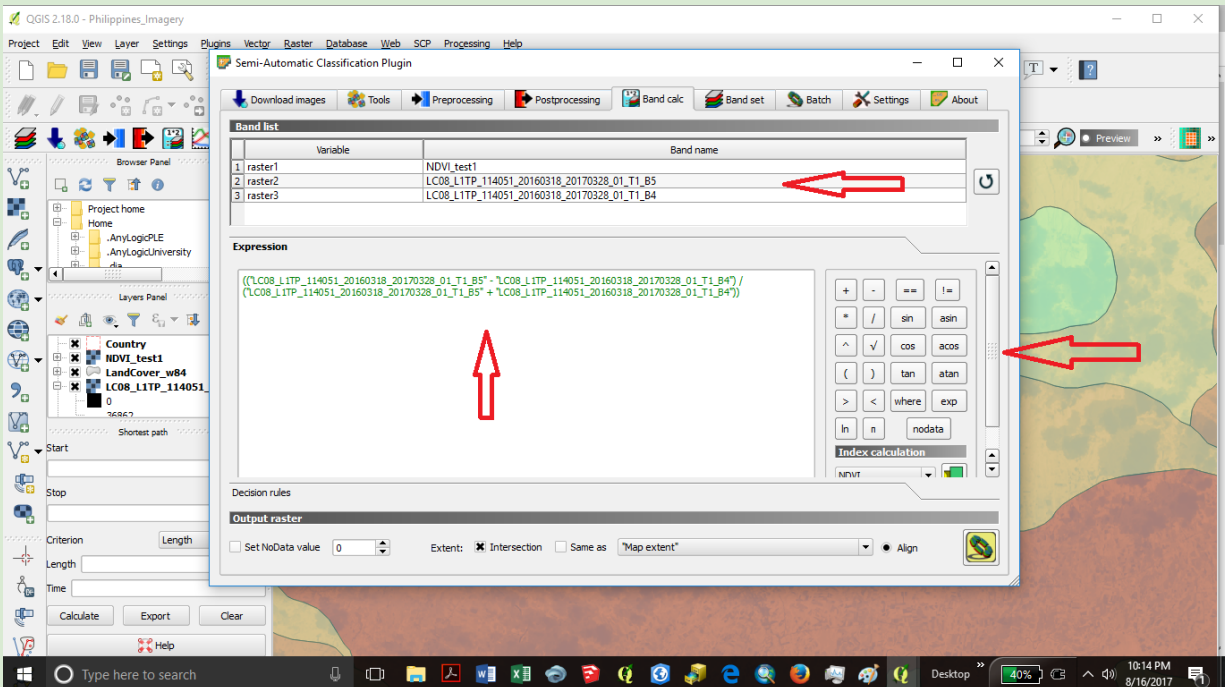
Method 1.Semi-Automatic Classification: Band Calculator

- Load B4 and B5 for all desired scenes the NDVI. A good practice is to do sets of same date at the same time in order for the final NDVI mosaic to reflect one temporal scene.
- Select “Band Calc” from the Menu Bar
- Generate this formula for all Landsat data

```
(("LC08_L1TP_114051_20160318_20170328_01_T1_B5@1"-
"LC08_L1TP_114051_20160318_20170328_01_T1_B4@1") / (
"LC08_L1TP_114051_20160318_20170328_01_T1_B5@1"+
```

"LC08_L1TP_114051_20160318_20170328_01_T1_B4@1"))

- See the screenshot below
- Choose the Output extent
- Click "Run"
- A new window to save the NDVI Raster will open
- Give the new NDVI Raster a name, click save
- The NDVI raster layer will be added to the Layers Panel
- Confirm that the values fall between 1 to -1
- Repeat for another Landsat image for the same area at a different time frame.



See Below for the Image Analysis

Analysis:

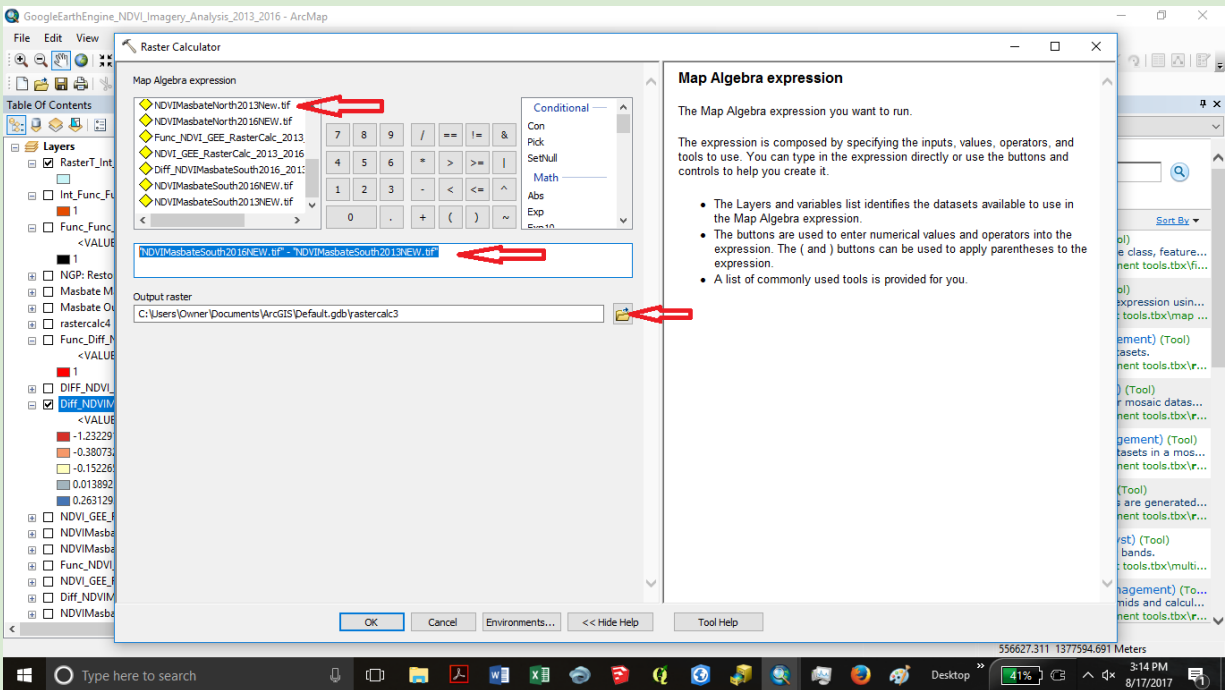
For all Workflows analyses outlined above, ArcGIS and QGIS work equally well for analysis, where all steps outlined can be performed in either platform.

NDVI Analysis for Mangrove Forest Loss with ArcMAP, QGIS, and Google Earth Engine output:

This step compares the two raster layers, and creates shapefiles in order to compute the total loss for the given study area. These shapefiles were also used in the Story Map outlined below.

Method 1. Raster Calculator for Comparing the two images

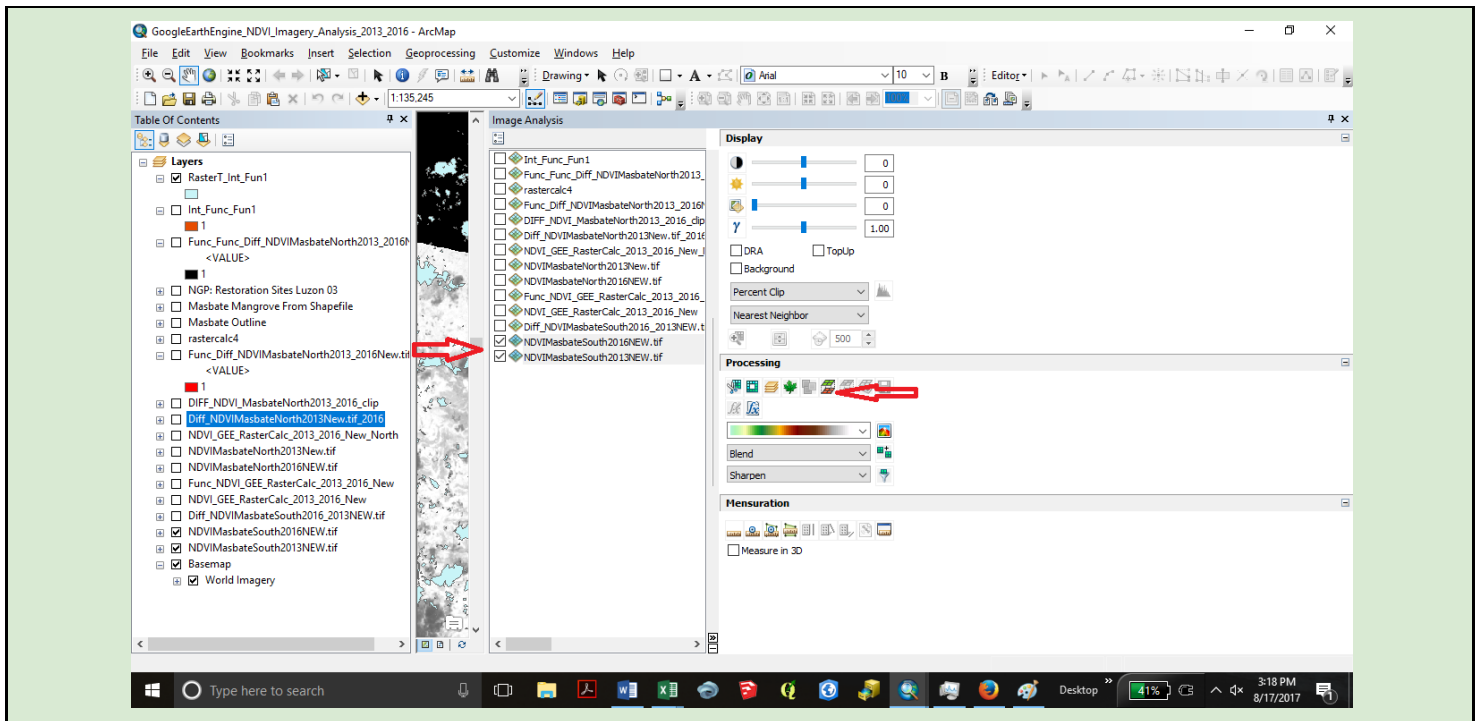
- Open the Raster Calculator




- Select the NDVI layers for comparison, most recent year first subtracted from previous year's data.
- Enter the following Equation, (of course choose your NDVI layers)
- "NDVIMasbateSouth2016NEW.tif" - "NDVIMasbateSouth2013NEW.tif"
- Choose the output raster location

Method 2. Image Analysis: Use the Difference Calculator

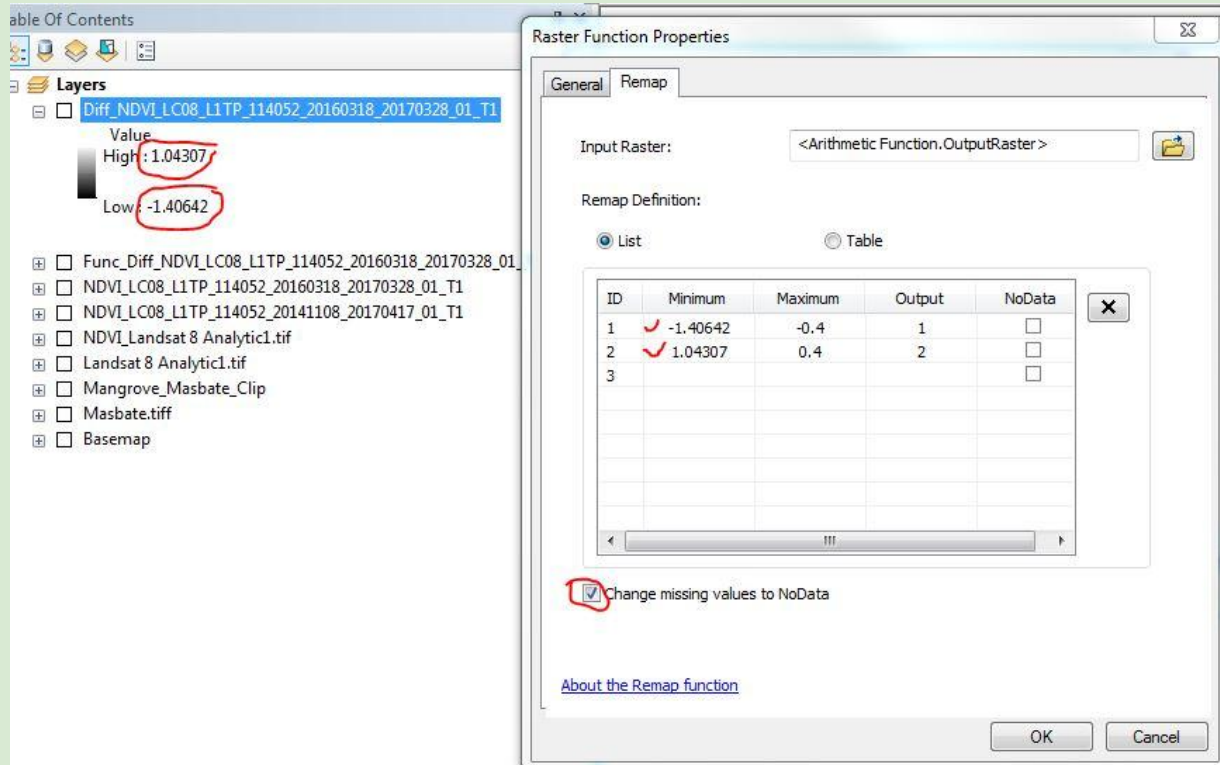
- Open the Image Analysis Window



- Select the two NDVI for analysis
- ****Please Note**** The Layers for NDVI Raster layers must be placed in the Table of Contents in the order from most recent year to oldest year for analysis.
- Click on the Difference Button 
- ****Please Note**** The Layers for NDVI Raster layers must be placed in the Table of Contents in the order from most recent year to oldest year for analysis.
- In Image Analysis window, select the new difference layer and click on "Add Function" icon



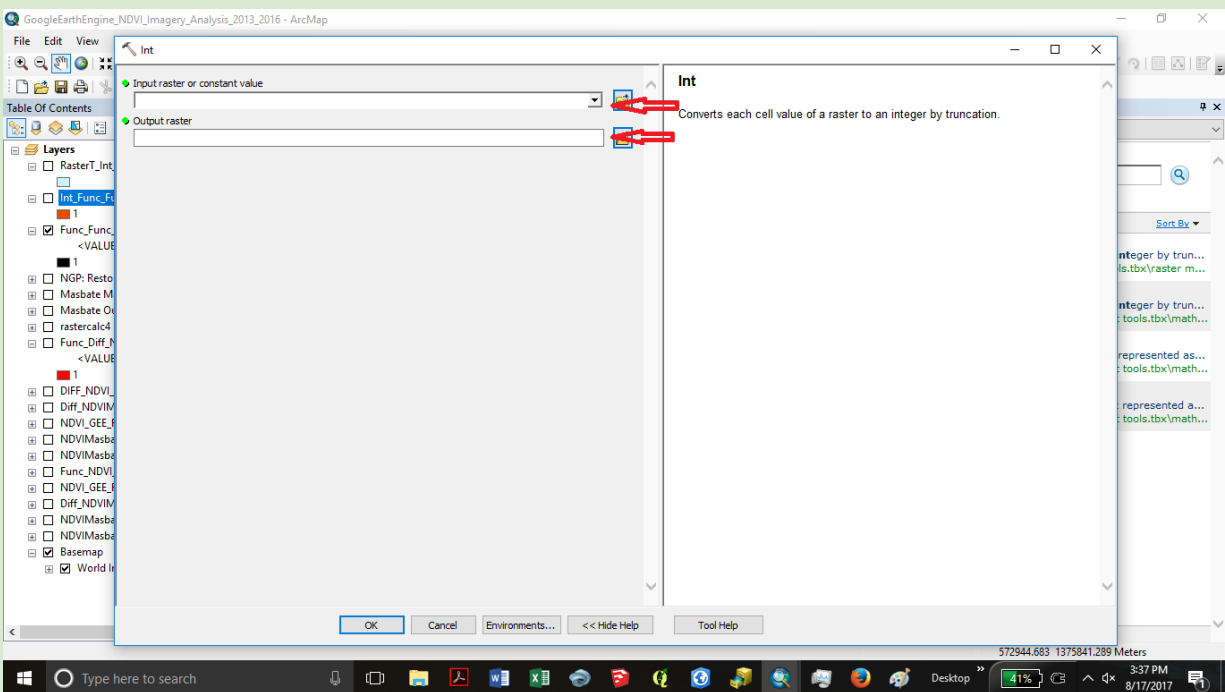
- Right click on "Arithmetic Function" and got to "Insert Function>>Remap Function" to open the Rater Function Properties window.
- On the Remap tab, set the minimum value to the lowest value of the Difference Raster layer and the maximum to the negative difference of NDVI you are trying to detect (decrease). On the next line, set the minimum value to the highest value of the Difference Raster and the maximum to the positive difference value (increase).



Click ok to create a new temporary layer where pixels of value 1 experienced a decrease in NDVI and 2 an increase by .04.

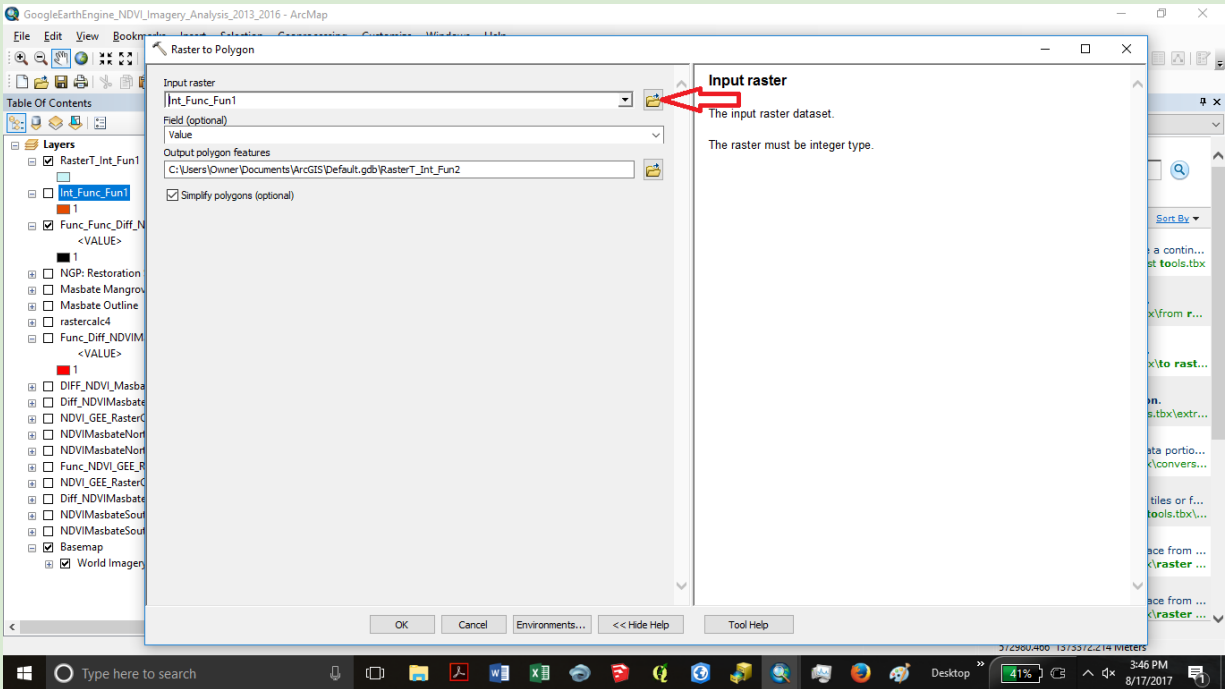
Use the INT Function: This step will allow the user to export the Raster as a Shapefile

- Select the Raster
- Select the Output Raster



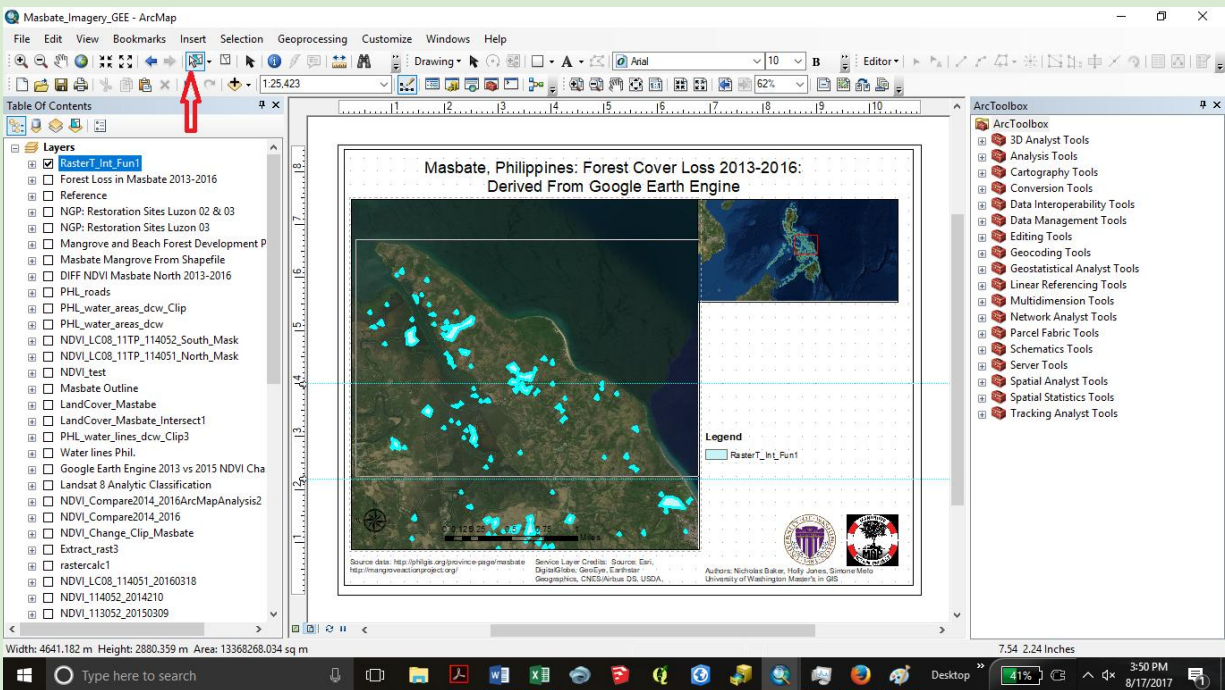
Convert The INT file to Shapefile

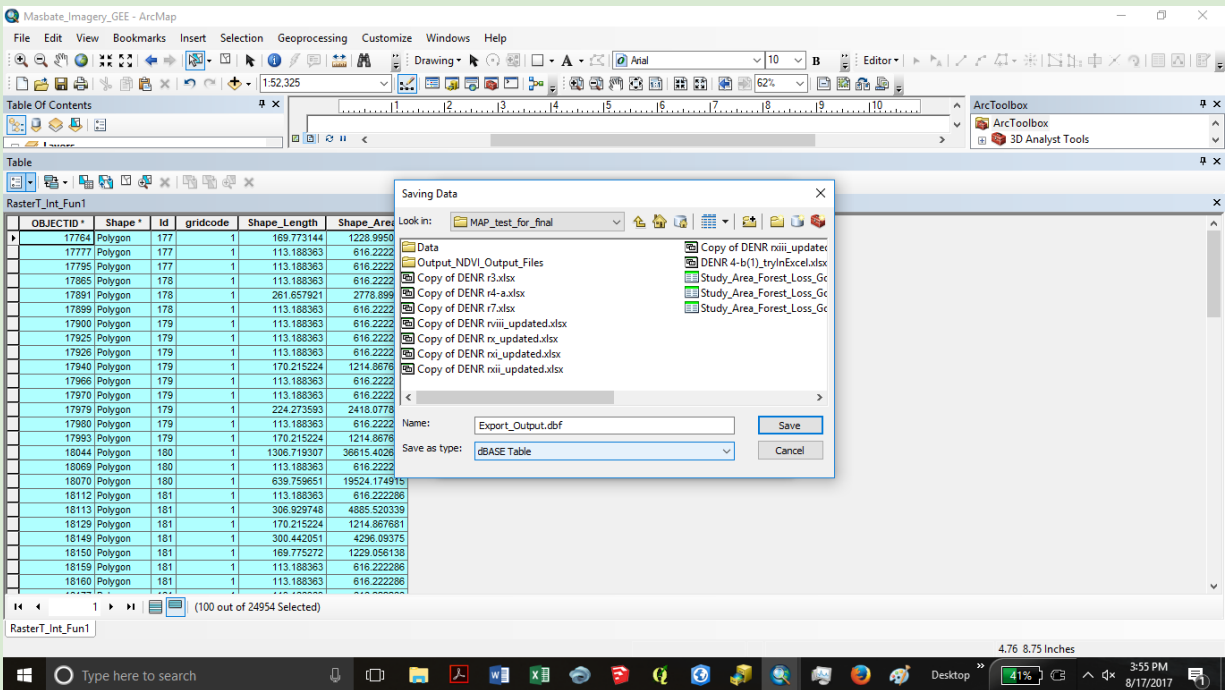
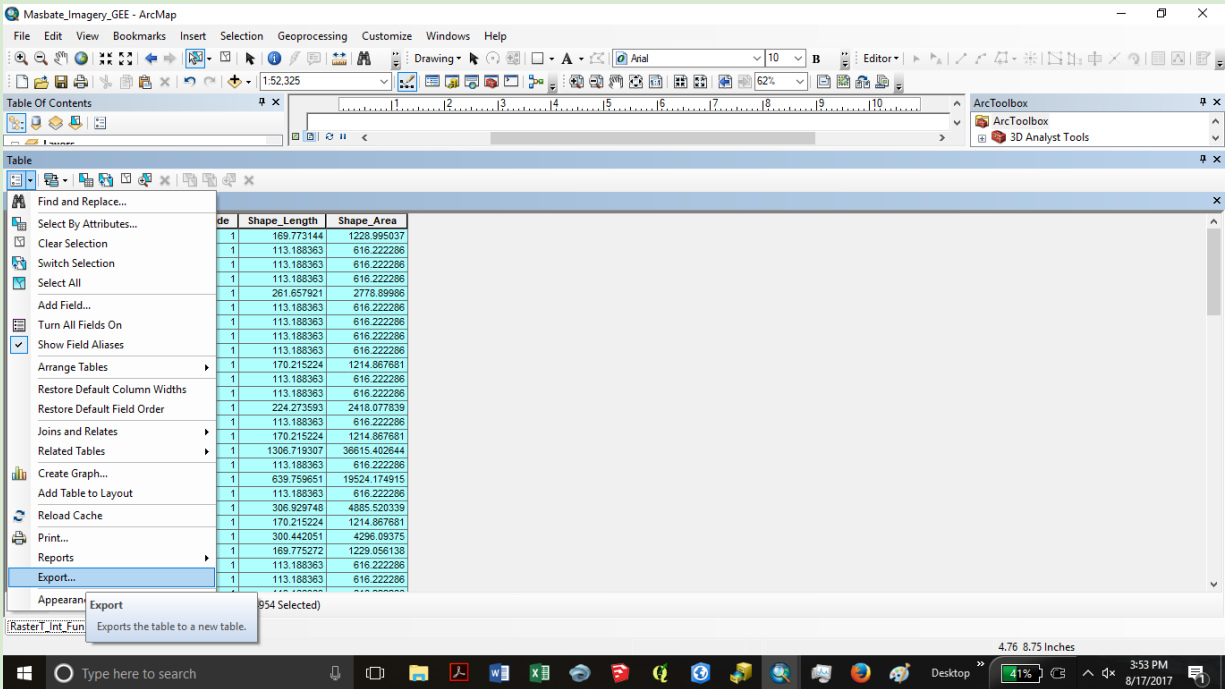
- Use the Raster to Shapefile



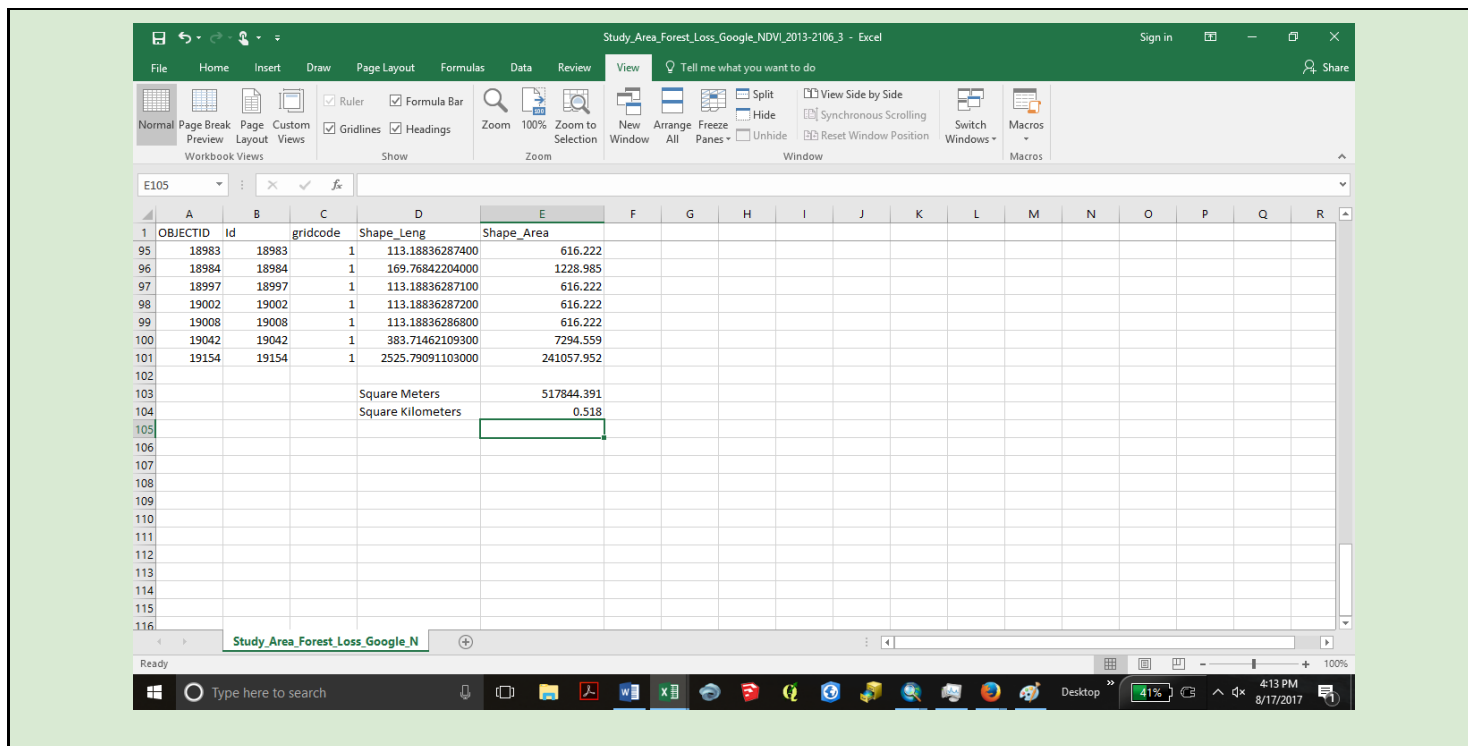
Calculate The Forest Loss By Area

- Use the Export by Mask Tool to Clip the Forest Loss to the desired Study Area
- Or Use the Select By Attributes on the Map to Select the Loss Area you would like to Ex
- Open the Attribute Table for The Forest Loss Polygon Shapefile
- The highlighted data will show up in blue (see screenshot)
- Export the data as a dbf file to open in Excel





- Open the file in Excel
- Use the SUM tool to add up the Forest Loss
- For the above example we had a loss of 0.517844 kilometers



Assessment analysis report of selected restorations sites in the Philippines: Collate secondary and primary data into a 'roadmap' for mangrove restoration practitioners.

- Determine if NGP reforestations were successful for mangroves in selected sites
- Using socio-ecological clues, including shrimp farming, determine why sites were successful or why not.

Map package with layers related to the topic and formatted mangrove data (and metadata). Static and online maps: Create roadmap to enable MAP to determine the success of projects and continue to adapt resources around mangrove restoration.

- **Connect MAP to the right sources through outreach**, with MAP's consent, including FOS satellite imagery provider and others.
- **Demonstrate solutions and technologies** that are currently being used to assess vegetation and how accessible they are.

Path solutions directing MAP the best course of action to expand the focal scale and attend to restoration centers in different countries

4. Results

From any software platform you choose, and analysis option you run, you will end up at the same place. NDVI's were calculated using Landsat 8 imagery in Google Earth Engine, The idea behind the multiple workflows is to accommodate the user and not restrict them to a proprietary software platform. For the analysis workflow above, we chose to look at the Masbate Province of the Philippines. An area on the east coast, just south of the City of Masbate, on the island of Masbate for It's vicinity to the urban area, forest, and shrimp / aquaculture farms was chosen. The resulting loss in the map above is 0.517844 kilometers.

Please note, the access to data has been rather challenging for this project. Known restoration sites with areas as polygons would allow for the actual measurement of losses in the forest cover based on the NDVI.

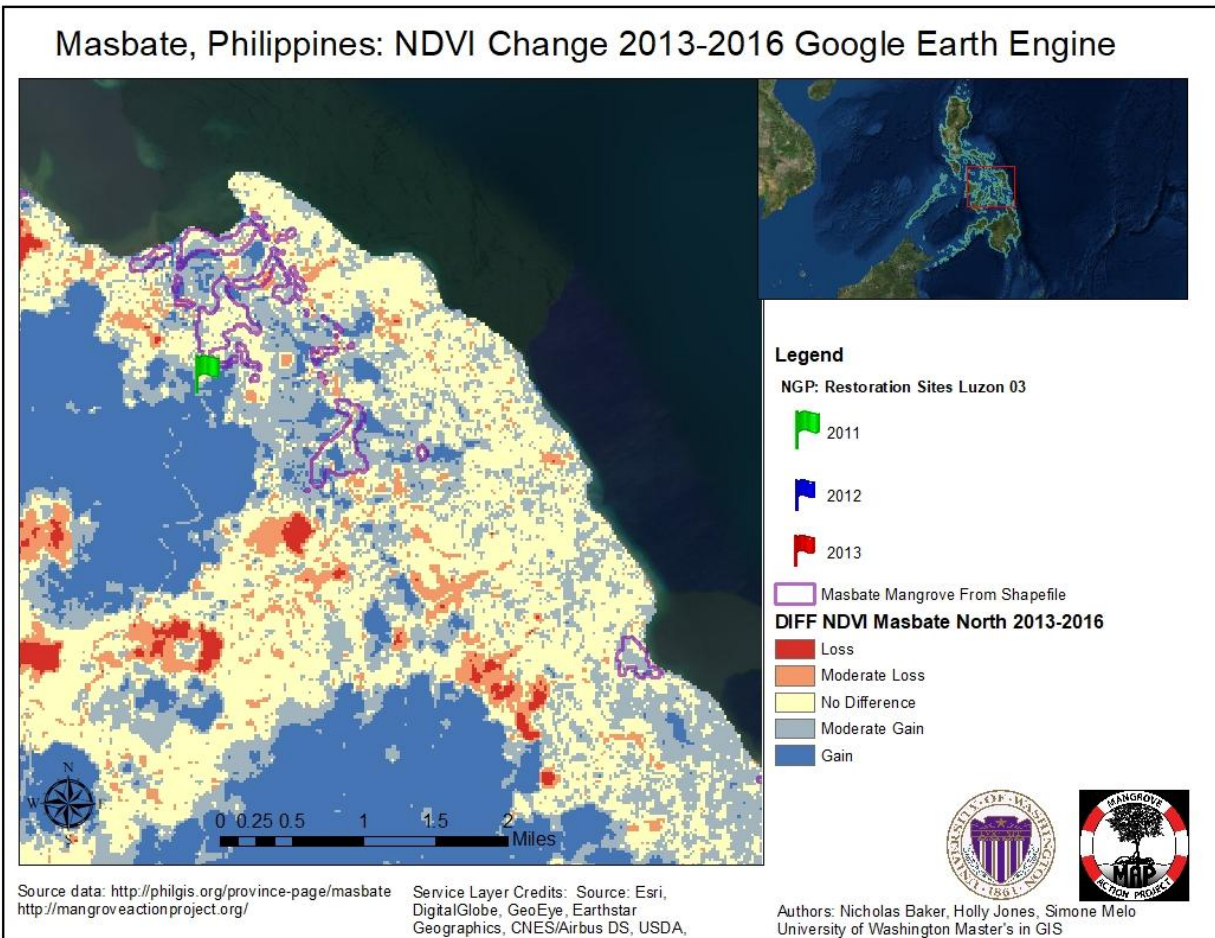


Figure 15

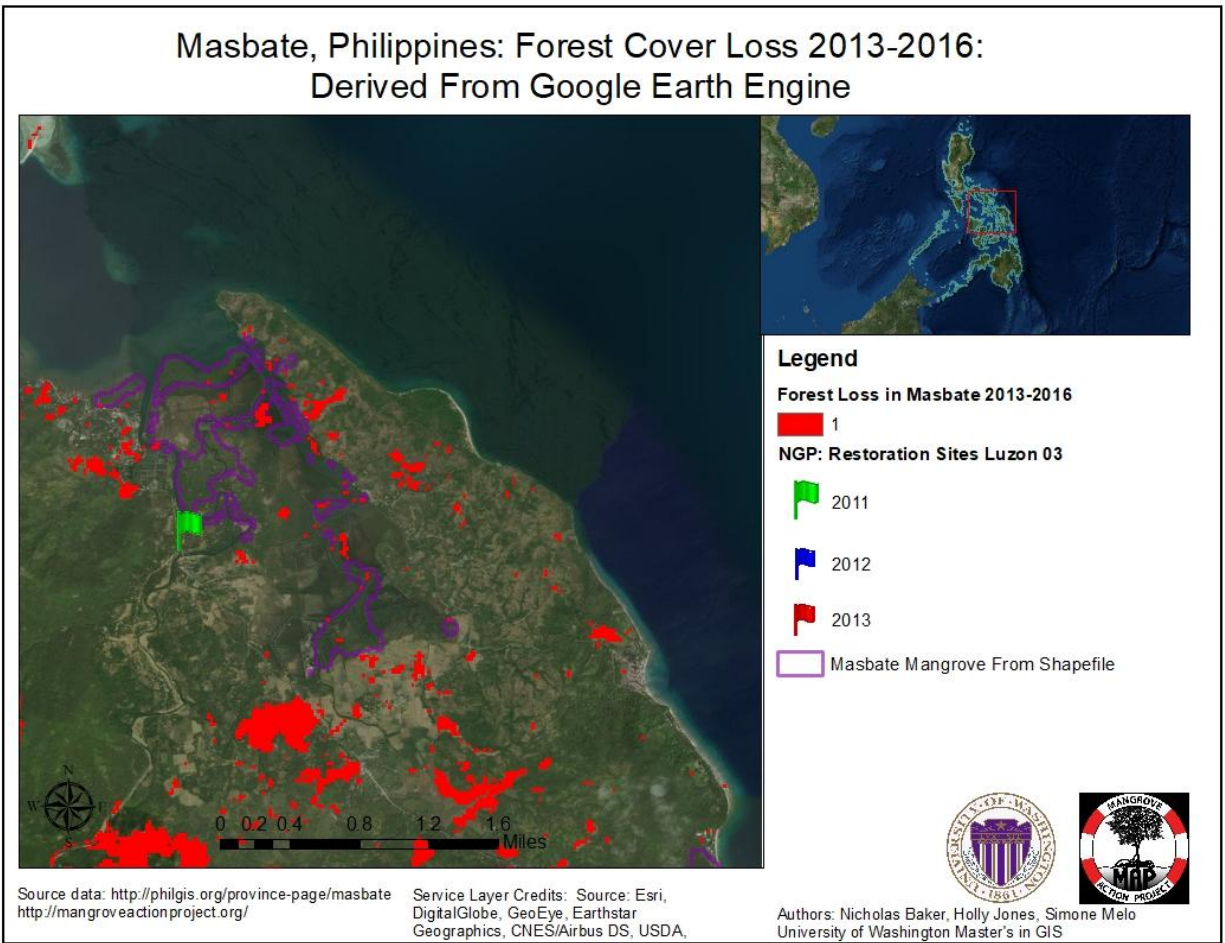


Figure 16

5. Conclusion / Discussion

What's Next for MAP?

Socio-economic Cost Benefit Analysis

In order to expose the importance of mangroves and draw public attention to increase conservation efforts, we recommend a full socio-economic analysis of this environmental service. It would be valuable to design a uniform comparable value system that allows the full cost benefit analysis of the service.

The analysis can be done using spatial data, statistics, surveys and others. Some of the economic factors that are connected to the service are the revenue from shrimp farm and fisheries, property value in coastal areas, water quality and costs related to healthcare, recreational value. Any other benefit this service provides to society, being economic, social or environmental, can be added to the analysis. Ultimately, the cost benefit analysis will result in numbers in a scale that the public can relate to, including a dollar amount.

The cost benefit analysis has the potential to get other groups involved once it becomes clear “what is the benefit of mangrove service” to their specific purpose or community.

ArcGIS Online and ESRI Story Map

The results of analysis have been published to ArcGIS Online and made public to be accessed by both MAP and the general public in an effort to increase the amount of open data on mangrove health and restoration projects in the Philippines. While the island of Masbate in the Philippines was the focus of this project, the workflow is universal and can be used for evaluation globally.

Additionally, an ESRI Story Map has been published publicly to be used as an educational tool for both MAP and the general public. The ownership of the Story Map will be transferred to MAP at the conclusion of the Capstone Project so that it can be maintained and expanded.

The main goals / themes of the Story Map include:

- Discussion of the importance of mangrove forests
- Explanation of the distribution of mangrove forests globally
- Identification of current restoration sites in the Philippines
- Depiction of the NDVI analysis to be understood by general public

Partnerships

In order to increase the reach of the conservation and restoration projects, we encourage MAP to outreach to other organizations that are interested to contribute to these efforts. Several data providers and tech companies and organizations dedicate some of their resources to conservation work. A great example of successful partnership is the [Global Forest Watch](#), an NGO that created an elaborated system to remotely monitor forests all around the world using imagery and technologies such as machine learning algorithms.

Start ups like [Planet.com](#) provide daily high resolution satellite imagery and can be a potential resource; however, it is a challenge to work with its developing infrastructure. Also, these are usually costly services and Planet recommended data [resellers](#) as MAP needs are relatively infrequent. Data and technological solutions providers are occasionally open to partnerships that will decrease the price of the service. Data exchanges such as imagery for ground truth data can also be a potential bond for partnerships.

6. Business Case and Implementation Plan

The workflows proposed to MAP provides a low-cost solution to locating critical areas of mangrove habitat, and outlines the workflow for downloading satellite imagery for the use in a NDVI vegetation analysis. The tools proposed are free and / or open source. Or, in the case of ArcGIS, the software is available free of cost to non-profits. The only cost to MAP in this process is the labor involved in implementing the workflow.

MAP currently evaluates the health of mangrove forests with on-the-ground field surveys. Utilizing NDVI and Landsat 8 imagery allows for preliminary assessment to be done at a fast pace remotely. These tools can locate mangrove forests where the tree cover is increasing or decreasing and can also identify shrimp farming operations. Once critical areas have been identified, field surveying can commence to assess the accuracy of the data and make more nuanced site assessments, noting species, plant sizes and other important attributes. Utilizing the technology available to the Seattle office to prioritize regions which require field surveying will maintain low operating costs in the Seattle office and more efficient use of labor in field surveying abroad. This solution is not limited to use in the Philippines, or SE Asia and can bolster MAPs plans to expand to Latin America and other regions.

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