

Vegetation Response to 2014 Pulse Flow in the Lower Colorado Delta Region

Background

As part of an agreement between the US and Mexico, an approximated 130 million cubic meters (105,000 acre-feet) of water was released to Mexico in March, 2014. The agreement, known as Minute 319, was to release an experimental flow through the Morelos Dam and down the riverbed. On March 23rd, water was released through the dam. Though most of the water was soaked into the ground in the first few miles, a portion of the flow did make it to the delta. Water had flown on the areas targeted for restoration and the revived vegetation and surrounding ecosystem along the route to the sea.

The Minute 319 pulse flow was the result of significant cooperation between a large group of partner organizations and agencies in the U.S. and Mexico. There has been little vegetation along the river since the last time natural flood touched the delta in 2000. The region has seen little improvement over the years. Scientists have been monitoring the lower Colorado River Delta's vegetation and hydrological response to the pulse flow after the release of pulse flow and have seen significant improvement in the amount of vegetation as a result of the release of pulse flow.

Objectives

- To clearly define the project area of concern for the investigation of vegetation response to 2014 pulse flow.
- To measure vegetation response over the project area by calculating Normalized Difference Vegetation Index (NDVI) using Landsat 8 data.
- To compare vegetation maps from year 2013 to 2015 to get an idea of the state of vegetation over the project area before and after the pulse flow.

Methods

Data sources

For this study, satellite images over the project area was needed. NASA/USGS satellite Landsat 8 images were downloaded using the earth explorer tool from the USGS website. Landsat 8 is a joint project of NASA and the U.S. Geological Survey (USGS).

Projection used

The following is the projection data for all the features that were used to work in the ArcMap environment. The projection data were not changed from the Landsat 8 data which is a preset for optimal projection over the project area.

Spatial reference	WGS_1984_UTM_zone_11N
Projection	Transverse_Mercator
False_easting	500000.0
False_northing	0.0
Central_meridian	-117.0
Scale_factor	0.9996
Latitude_of_origin	0.0
Linear Unit	Meter (1.0)
Geographic Coordinate System	GCS_WGS_1984
Angular Unit	Degree (0.0174532925199433)
Prime Meridian	Greenwich (0.0)
Datum	D_WGS_1984

Software environment

For the analysis, ArcMap and ArcCatalog of ArcGIS software suite were used. To calculate the NDVI (Normalized Difference Vegetation Index), the raster calculator in map algebra toolbox from the ArcMap environment was used.

Analysis

Delineation of the project area

The project area is digitized over a National Geographic base map of the world. The editor toolbar in ArcMap was used to do the digitizing. The Colorado Delta project area is divided into 6 regions starting from Upper Limitrophe and going through Lower Colorado Delta area before ending up at the Gulf of California. The minute- 319 pulse flow was released from the Morelos Dam which is situated at Yuma, California.

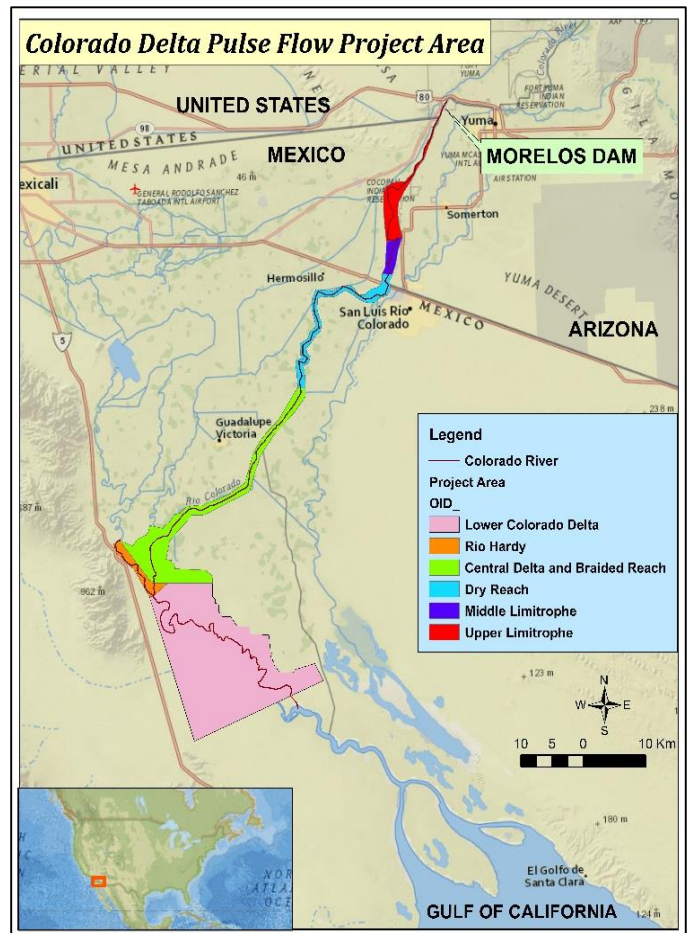


Figure 1: Digitized Colorado Delta Pulse Flow Project Area

Measuring vegetation response using NDVI

Normalized Difference Vegetation Index or NDVI maps are being used in agriculture, forestry, ecology and more. NDVI is an index describing vegetation by showing the difference between near-infrared (which is strongly reflected by vegetation) and red light (which is absorbed by vegetation). One particular use of NDVI is the detection of vegetation over land area. NDVI could also work as an indicator of drought intensity.

NDVI is calculated from the visible and near-infrared light reflected by vegetation. Healthy vegetation (left) absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light.

Unhealthy or sparse vegetation (right) reflects more visible light and less near-infrared light. The numbers on the figure are representative of actual values, but real vegetation is much more varied.

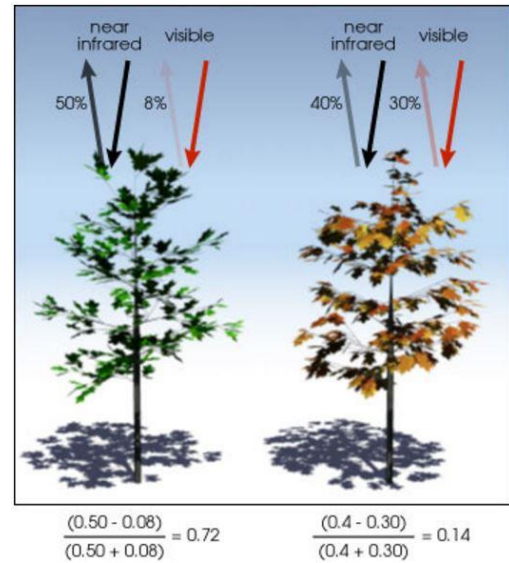


Figure 2: NDVI calculation (picture taken from NASA Earth Observatory Website)

So, the formula for calculating NDVI is:

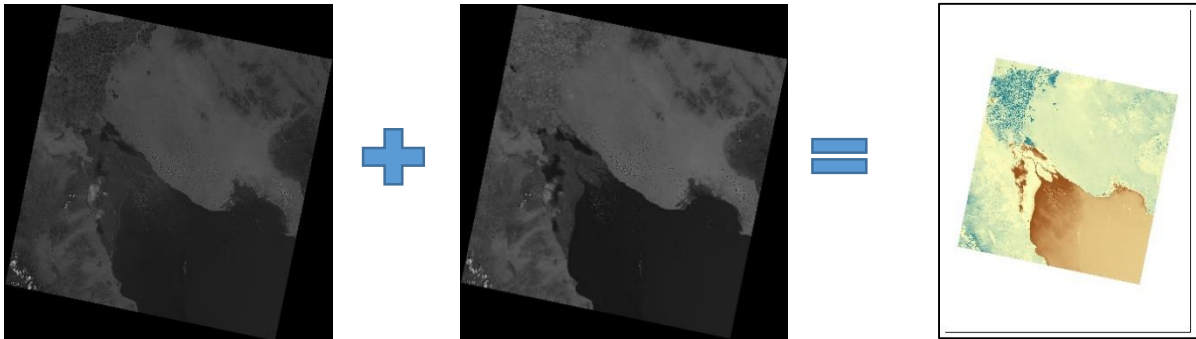
$$\text{NDVI} = \frac{(\text{NIR} - \text{red})}{(\text{NIR} + \text{red})}$$

To calculate NDVI in ArcGIS, the first step is to collect the satellite images, NIR and red band, which will be needed for calculation. Landsat 8 images were used for NDVI calculation.

Below is a full list of Landsat 8's bands:

Band Number	Description	Wavelength(μm)	Resolution
1	Senses deep blues and violets	0.433–0.453	30m
2	Visible blue	0.450–0.515	30m
3	Visible green	0.525–0.600	30m
4	Visible red	0.630–0.680	30m
5	Near Infrared or NIR	0.845–0.885	30m
6	shortwave infrared, or SWIR	1.560–1.660	30m
7	shortwave infrared, or SWIR	2.100–2.300	30m
8	Panchromatic- combines visible colors	0.500–0.680	15m
9	Very thin wavelengths- clouds	1.360–1.390	30m
10	Thermal infrared, or TIR	10.6–11.2	100m
11	Thermal infrared, or TIR	11.5–12.5	100m

For NDVI calculation, band 4 and 5 were used. In ArcGIS, a sequence of operation was performed to get the final output: Arc Toolbox > Spatial Analyst Tools > Map Algebra > Raster Calculator. In Raster Calculator, the formula applied was: $(B5-B4) / (B5+B4)$. Applying the formula produced the NDVI raster.



Alternatively, the NDVI calculation can also be performed by the NDVI function in the image analysis window.

Results

NDVI calculation was performed for the same project area for a comparison of vegetation maps from year 2013 to 2015 dated from pre-pulse flow to post-pulse flow condition. The comparison of NDVI images clearly shows a greener delta region in August 2014 just after the pulse flow of March 2014. This is indicative of a greener delta region just after the pulse flow.

No.	Coverage area of the satellite image	Condition	Date taken
1	Colorado Delta Region	1 year before pulse flow	August 12, 2013
2	Colorado Delta Region	Few months after the pulse flow	August 15, 2014
3	Colorado Delta Region	1 year after the pulse flow	August 23, 2015

Now most of the water was soaked into the ground in the first few miles. But a portion of the flow did make it into the lower Colorado delta region which is comprised of the Central Delta and Braided Reach, Rio Hardy and Lower Colorado delta in the project map. The comparison of the NDVI images clearly show an increase in vegetation as a

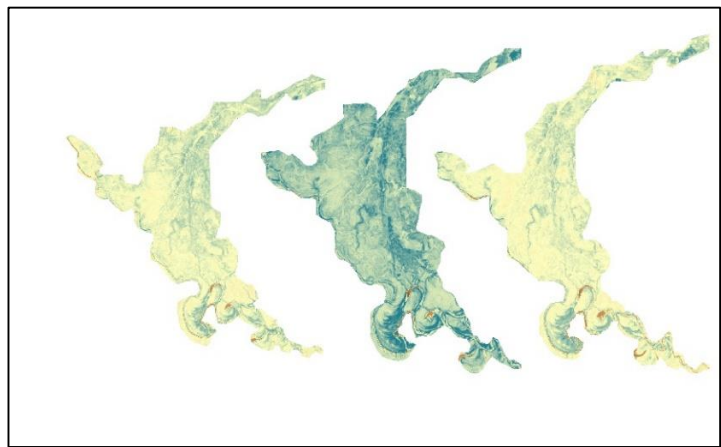


Figure 3: Resulting NDVI images of the Lower Colorado Delta region in 2013, 2014 and 2015

result of the march 2014 pulse flow release. The 2015 image shows a dried up delta region similar to the one in 2013 which indicates that flow needs to be sustained in that region for long term impacts to vegetation, biodiversity and groundwater.

The difference in NDVI values between 2013 and 2014 images shows sites where vegetation response was more pronounced

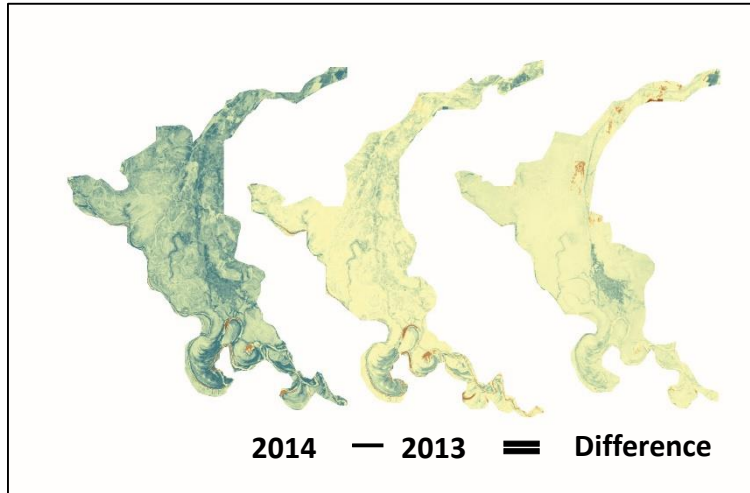


Figure 4: Resulting NDVI image from subtracting the NDVI values of 2013 image from 2014 image

A comparison of the mean NDVI values of the pixels from 2014 and 2013 NDVI rasters revealed an increase of 16.35%.

$$\text{Year to year increase in mean NDVI value} = \frac{\text{Mean}_{2014} - \text{Mean}_{2013}}{\text{Mean}_{2013}} = \frac{0.1210 - 0.1040}{0.1040} * 100 = 16.35\%$$

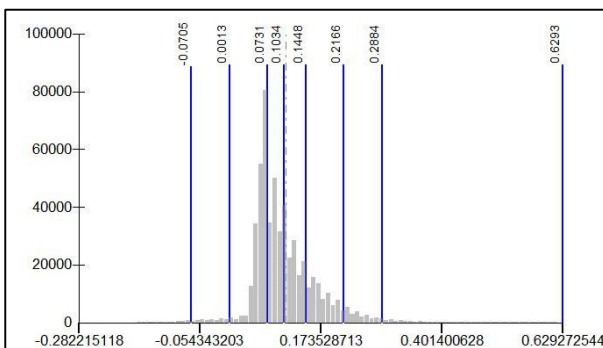


Figure 5: Mean NDVI values of pixels from 2013 image (classified with 1 standard deviation)

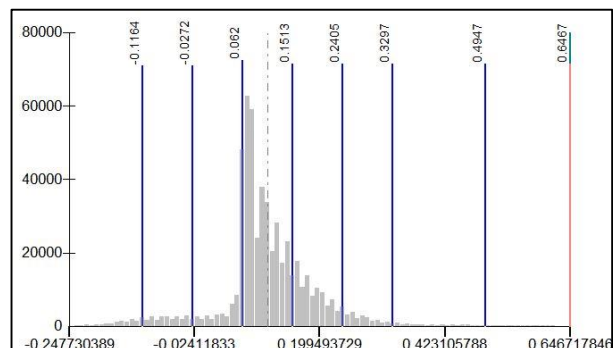


Figure 6: Mean NDVI values of pixels from 2014 image (classified with 1 standard deviation)

Conclusion

- The increase in vegetation after the pulse flow in 2014 was noticeable from the comparison of NDVI images of the Lower Colorado Delta Region.
- Researchers from NASA calculated a 43 percent increase in green vegetation along the route wetted by the flow, called the inundation zone, and a 23 percent increase in greening of the riparian zone, or the river banks. In this analysis, an overall increase of 16.35% was found in mean NDVI values which supports the findings of NASA researchers.
- The 2015 dried up image of the Lower Colorado Delta is indicative of the need for a sustainable flow to maintain a greener delta.

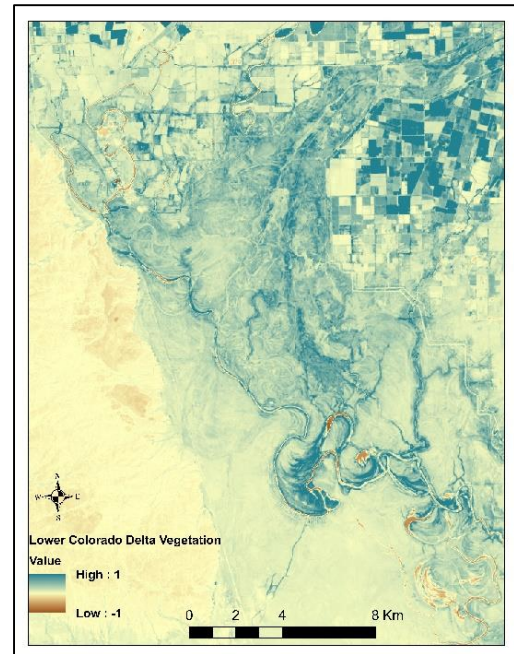


Figure 7: NDVI Map layout of the Lower Colorado Delta in 2014

Future Work

In the future, the impact of the pulse flow will be more evident as different organizations from both sides of the border prepare progress reports. Currently the changes to groundwater, plants, birds, fish and wildlife are being tracked by researchers. Impacts to pre-existing and proposed restoration projects in the surrounding area will, no doubt, be one of the factors that will decide the success of the pulse flow. Future flows, including base flow volumes totaling 65 mcm (52,696 acre-feet) are also to be delivered to new and pre-existing restoration areas during the term of Minute 319 through December 31, 2017.

Appendix

Data sources:

Landsat 8 image band 4 and 5 downloaded from NASA/USGS Earth explorer website:

<http://earthexplorer.usgs.gov/>

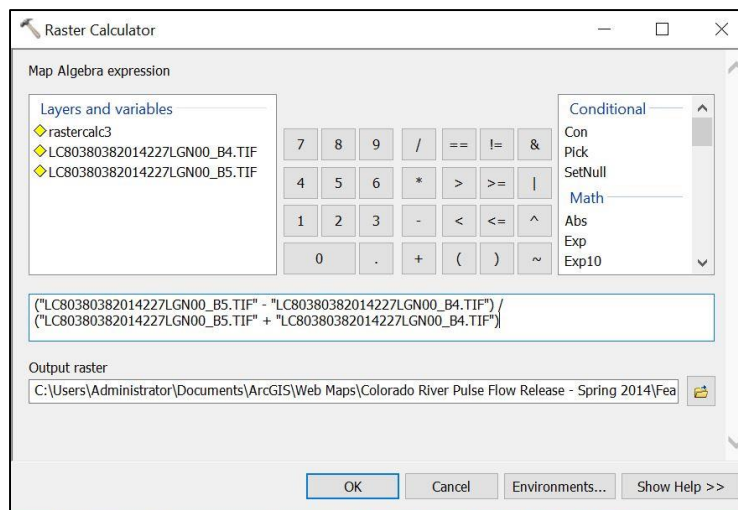
Procedures followed:

Creating NDVI maps in ArcGIS

There are two ways to calculate NDVI values in ArcGIS. Using the Raster Calculator or using the Image Analysis window. Both methods are provided here.

Raster Calculator Method

After adding both the raster images for Landsat 8 band 4 and band 5, go to Arc toolbox>Spatial Analyst>Map Algebra>Raster Calculator and perform the following simple calculation:



Alternative Method: Image Analysis

Step 1: Enable Image Analysis Toolbar

Enable the Image Analysis Toolbar (Windows > Image Analysis). The image analysis window will be displayed in ArcMap.

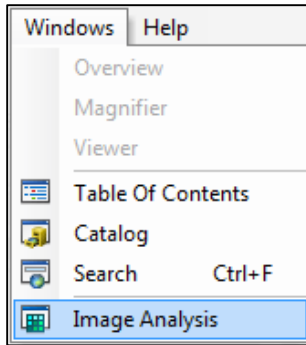


Image Analysis Toolbar

Step 2: Check Scientific Output Properties

Under image analysis options, select the red band and the near infrared band.

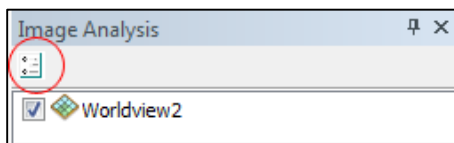
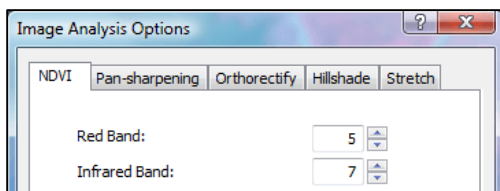


Image analysis toolbar options

For Worldview-2 imagery, under the NDVI tab – the red band is “band 5” and the NIR band is “band 7”.

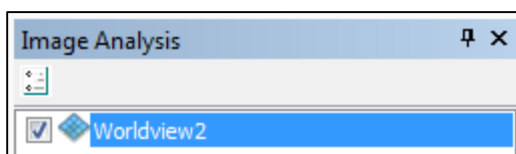


NDVI band selection

Optionally select “Scientific Output” so your values range from -1 to 1.

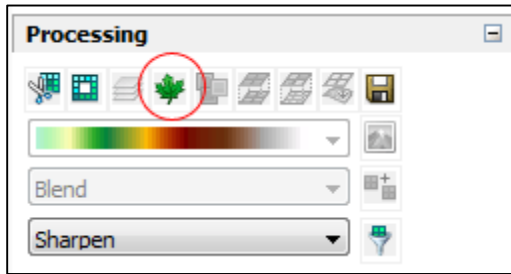
Step 3: Click NDVI Icon

Highlight your layer by clicking it.



Highlight your image

Under properties, select the NDVI icon which looks like a leaf.

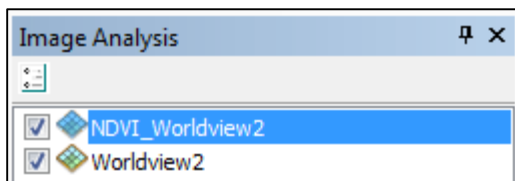


NDVI button

This will create temporary layer in the table of contents.

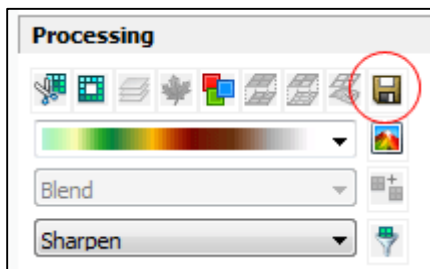
Step 4: Export Raster

Highlight the new NDVI layer that you want to export by selecting it in the image analysis toolbar.



Highlight NDVI raster

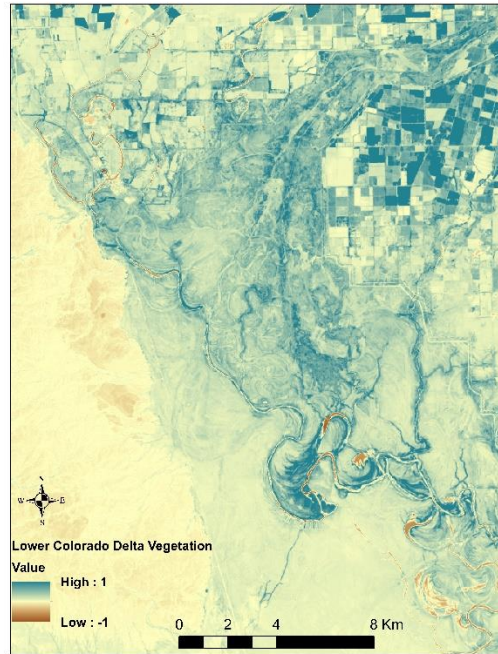
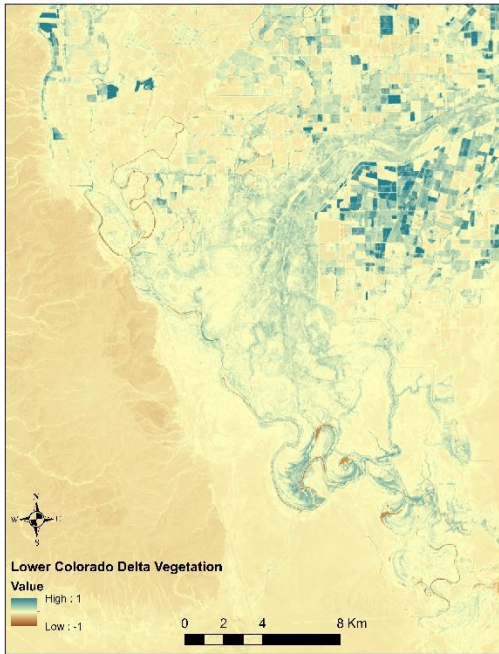
Right click layer, and export raster to save into memory.



Export raster

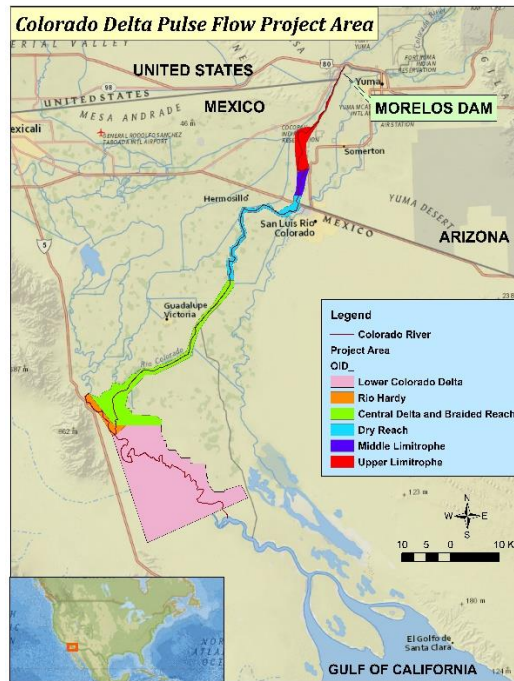
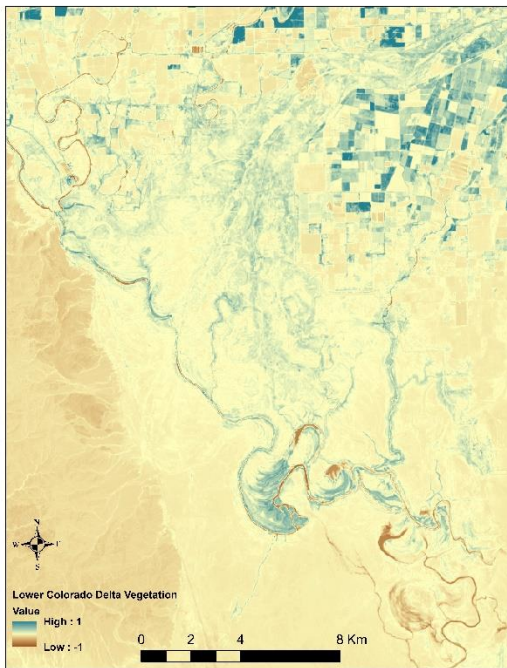
High positive NDVI values (green) means high vegetation. Urban and water will have negative NDVI values (yellow and red).

A total of 4 maps were produced in ArcGIS:



NDVI Map layout of the Lower Colorado Delta in 2013

NDVI Map layout of the Lower Colorado Delta in 2014



NDVI Map layout of the Lower Colorado Delta in 2015

Digitized Colorado Delta pulse flow project area