

How to use the Africa Regional Data Cube (ARDC) for investigation of water extent, water quality, coastal change, vegetation indices and the development of cloud-free mosaics. The following case studies show how to create several products and understand the details of the output.

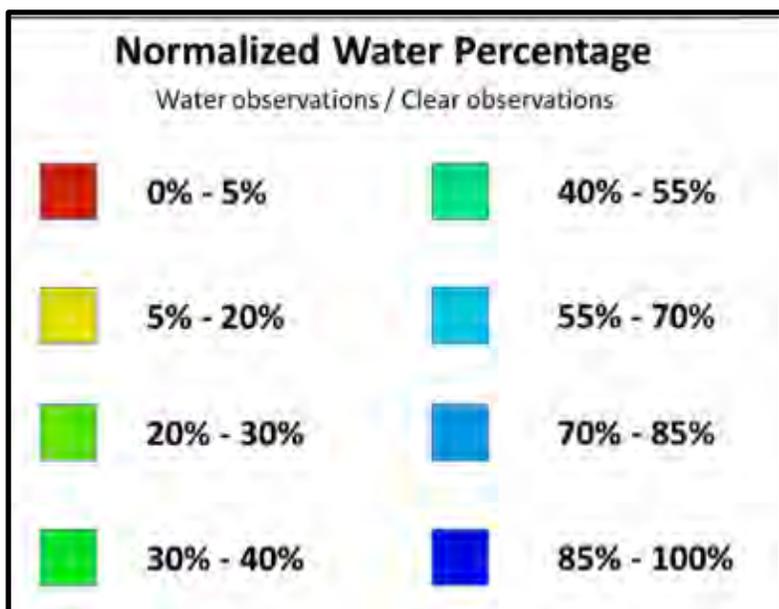
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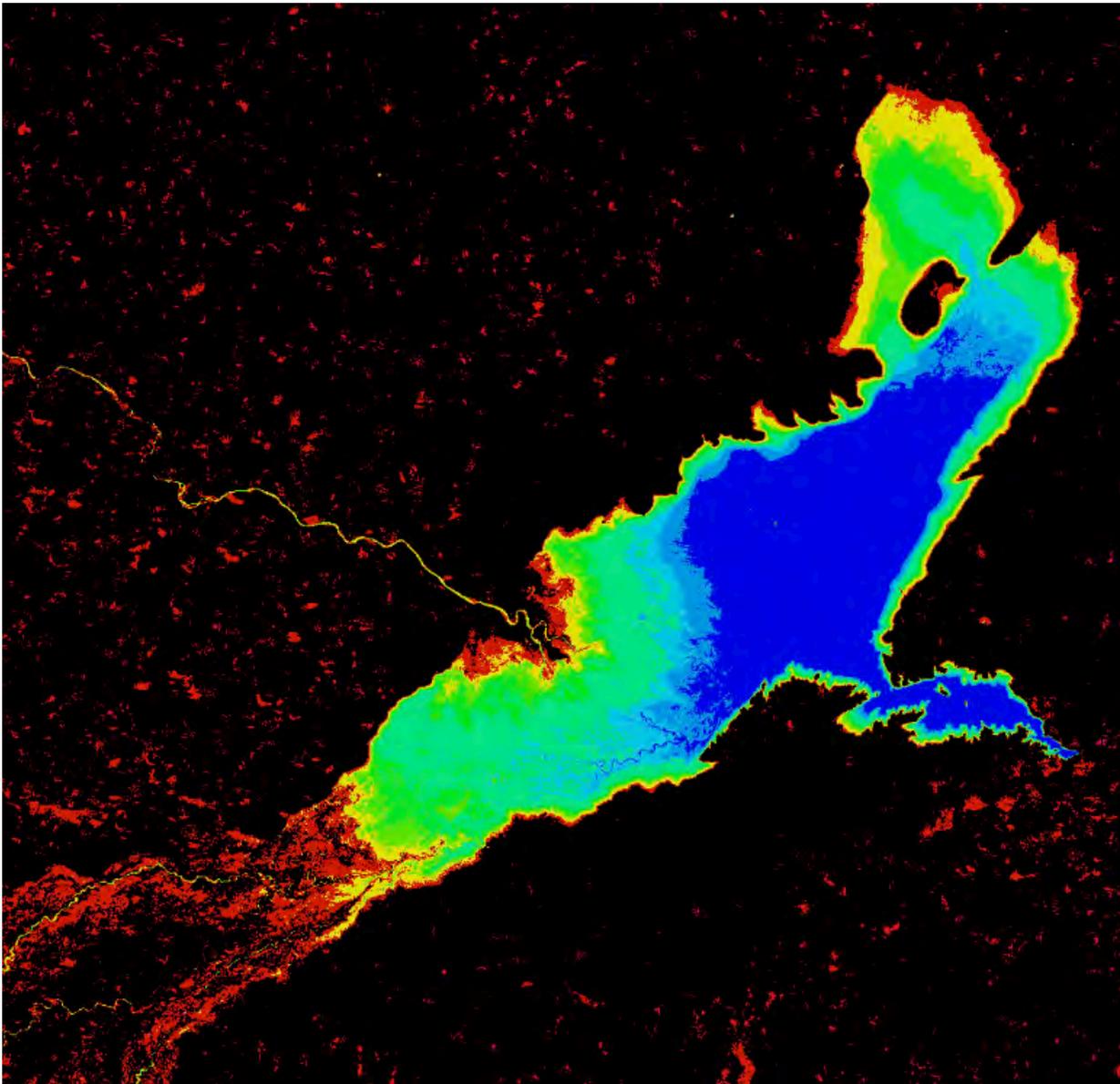
**Website:** <http://54.146.168.223>

**Case #1: Menu:** Tools > Water > Water Detection > Tanzania

The user needs to select a region and then select the parameters from the "Data Selection" menu. It is usually best to select a long start and end date to gather water information for entire time series. The product is based on the Water Observation from Space (WOFS) algorithm, developed in Australia. The results can be used to identify regions of periodic flooding, flood risk and the times of historic flooding.

Below is the legend for the WOFS product. The colors represent the percent of time a pixel has experienced water out of all of the clear observations. Regions of rare water will be red and yellow colors. Regions of persistent water (rivers, lakes, etc.) will be dark blue.

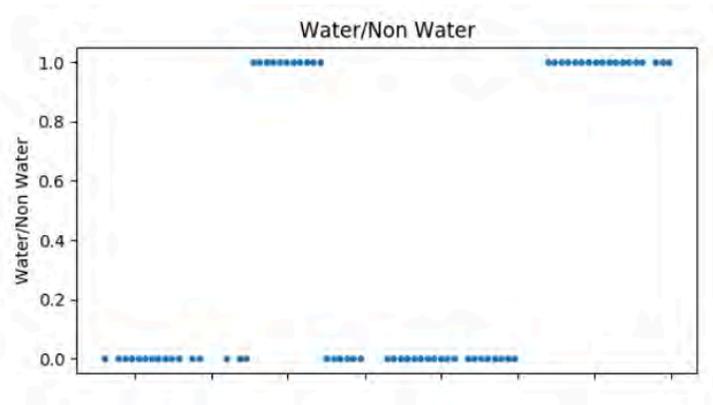
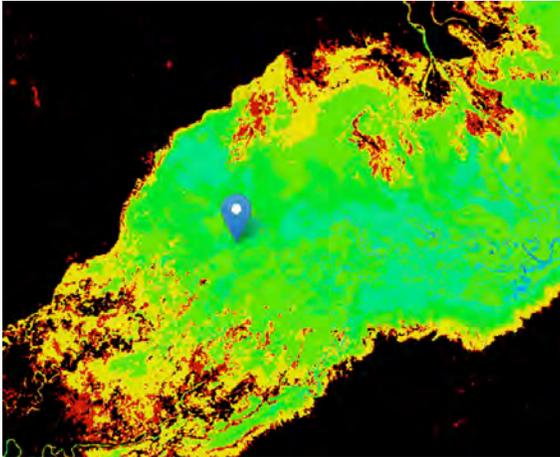




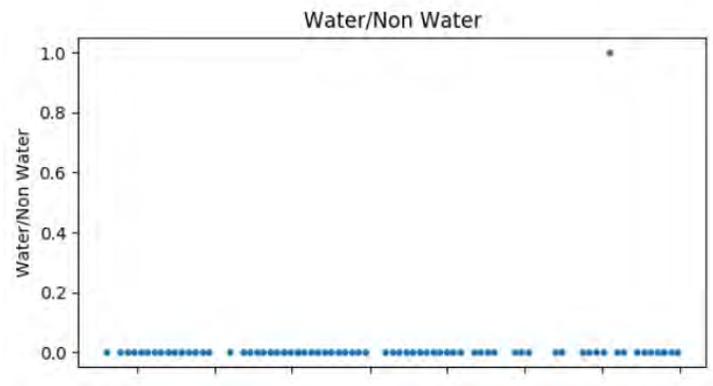
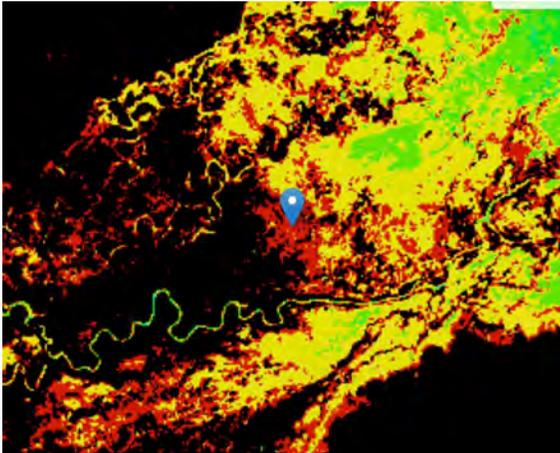
WOFS Water Extent for the Mtera Reservoir from Apr-1999 thru Dec-2016 (17 years).

These water extent products can be used as a flood risk map, as the colors show the historic extent of water over the spatial region and allows identification of areas that have seen periodic or rare flooding.

The pixel-dropper can be used to assess any single location in the final product. An example is below.



The results above suggest this location experienced water during two time periods. These were mid-2014 and after Feb-2016.

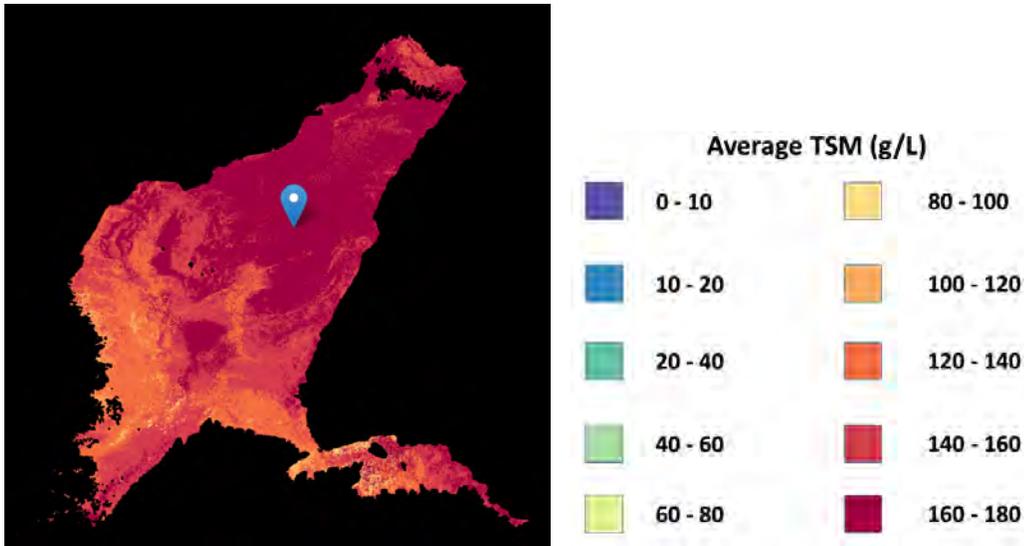


The results above show an area that experienced water only 1 times in a 4-year period (2013 thru 2016). This event occurred in mid-2016.

**Case #2: Menu: Tools > Water > Water Quality TSM**

Select the Tanzania cube and then select an inland water body where you might think the water is used for drinking water supplies. Similar to above, select a region and time period. This analysis will use a simple single-band algorithm to predict Total Suspended Matter (TSM) in the water. It is believed that TSM is a proxy for water quality and represents the "cleanliness" or "turbidity" of the water. Though many scientists believe that Landsat cannot accurately measure TSM, there is known value in the results when viewing spatial differences in TSM and time series variations in TSM. In general, Landsat-8 is better than Landsat-7 for water quality, as the signal-to-noise is better for L8.

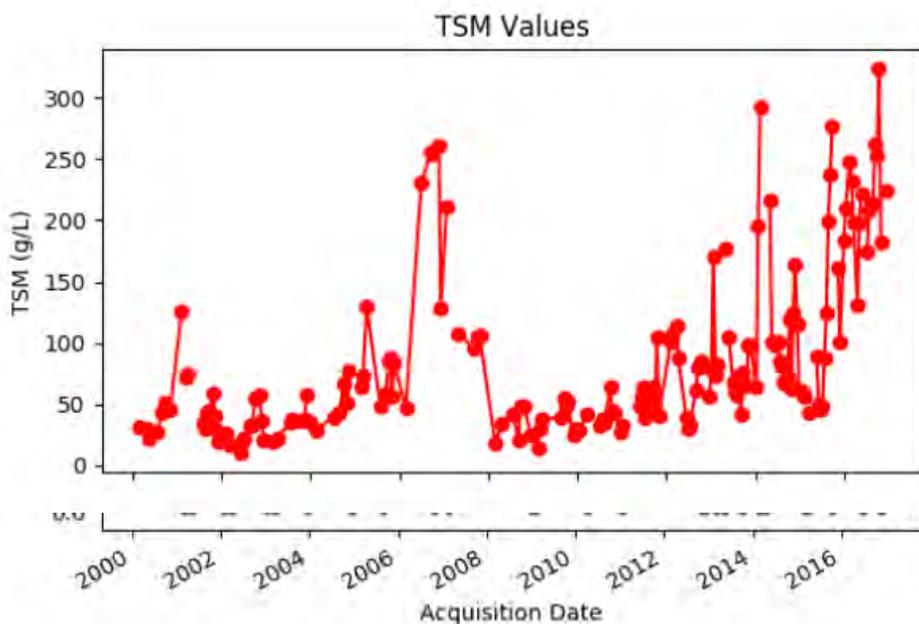
Select a "Result Type" and run an analysis. A sample output is shown below.



The example above is TSM Variability from Apr-1999 to Dec-2016 over the Mtera Reservoir. Only the pixels where there is constant water are used for the analysis.

It is possible to view a single pixel to see the variability in TSM values over time. Use the "Marker Tool" to look at any single pixel location. This tool is located in the top-left of the map and looks like a small "marker". A 2-D plot will be generated to show the time series TSM result for the selected pixel. Below is the example output from the marker on the product shown above. In this case it appears there was an extreme event of high TSM in 2006 but it recovered within 2 years. Starting in 2013, there appears to be a large increase in TSM that has not recovered.

Try this same analysis for a water body in your region and use this information to determine how you might take water quality samples or monitor the impact of a water management change.



### Case #3: Menu: Tools > Water > Coastal Change

Select the Tanzania cube and then select a region on the coast. This product will show two different types of results. One is the coastal boundary change (old vs. new) and the other product is the coastal change (water vs. land). Below are two example outputs near the city of Dar es Salaam. The two types of output products can be changed using the "Results" tab. The color legend can be used to see the changes in the coastal boundary and where the land-water interface has changed.



The coastal changes from 2000 to 2015 (15 years) along the Dar es Salaam inlet are shown above. Inside the inlet there are some regions that have experienced a change from water to land (green) and outside the inlet there are signs of coastal erosion from land to water (red).

### Case #4: Menu: Tools > General > Custom Mosaic

In order to closely analyze land data, it is often best to create a **cloud-free mosaic** and then export that image as a GeoTIFF for analysis in a more powerful tool, such as QGIS. The following steps show an example of creating a cloud-free mosaic for a region.

The term "**mosaic**" is used to describe a time-series product that combines that removes clouds and creates a new spectral representation of the region for the selected time period. In some cases the mosaic will use "real" pixels from the time series, but in other cases it might create a new synthetic product that is a statistical median of each band in the time series.

(1) Pick a region for your mosaic by clicking on the top-left corner and then dragging your mouse to the bottom-right corner of the region. You should see a shaded box on your screen. Check the LAT and LON boundaries of your cube and try to keep the region to less than 1deg x 1deg. This will make the execution faster for everyone. As you move around the map, you can also see the LAT-LON position in the upper-right corner of your screen.

(2) Select a Start and End data for your mosaic. Pick ONE year within the range of dates for your cube. The system will default to the range of dates that are available. You can also pick shorter time periods for seasonal mosaics.

(3) Pick a "Result Type". You might start with a "true color" image first, which is the typical Red-Green-Blue (RGB) output. There are also several other false color outputs that can be interesting to identify certain land features. Try a few of them to see the differences in these RGB combinations.

NIR-SWIR1-SWIR2 or NIR-SWIR1-RED = Land appears in shades of orange and green, ice stands out as a vibrant magenta color, and water appears in blue.

SWIR1-NIR-RED = Good for vegetation analyses

SWIR2-NIR-GREEN = This band combination was used for the global Landsat mosaic created by NASA.

SWIR1-NIR-BLUE = Useful for the monitoring of agricultural crops, which appear as a vibrant green. Bare earth appears as magenta color and non-crop vegetation appears as more subdued shades of green.

NIR-RED-GREEN = Vegetation is red, with healthier vegetation being more vibrant. This is commonly used when looking at vegetation, crops and wetlands.

(4) Pick a "Compositing Method" which is the basis for building the mosaic. You will see Least/Most Recent Pixel, Min/Max NDVI, and Median. For your first mosaic, you should try the Most Recent Pixel, as it will select the most recent cloud-free pixel in the time series. For your second case, you should try the "Median Pixel" as it will select the "middle" value of each band in the time series, which is a synthetic product, since it is a statistical quantity of the band data.

NOTE: NDVI and Median mosaics take longer to run as they are "synthetic" products and require statistical calculation. The True Color RGB image will look "dark" on the UI screen. You can export the PNG image and then use Photoshop to create a "brighter" image as shown in the example below.

(5) Pick a "Generate Time Series Animation" choice, if desired. This will produce an animation file that will allow you to see each of the images in the time series stack which are the basis for the mosaic product. Scene = this will give you a scene by scene look. Cumulative = this will give you a cumulative look at the mosaic as it filters for clouds over the time series. It is suggested to use the SCENE selection as this is a nice way to view the available data for each scene in the time series. NOTE: SCENE is not possible with median mosaics, but should be used for least/most recent pixel mosaics.

NOTE: If the user selects a time series animation of the scenes, it will take MUCH longer to complete the analysis. To download the animated GIF file, the user needs to go to the OUTPUT tab, pick the job that ran the animation, and then select the "time series animation" output product. These files can get VERY large.

(6) Select the "SUBMIT" button when are ready to run your analysis. The "Running Tasks" window will show you the progress of your analysis. It make take a few minutes, so be patient. Once complete, you will see the final mosaic (cloud-filtered) on the main screen.

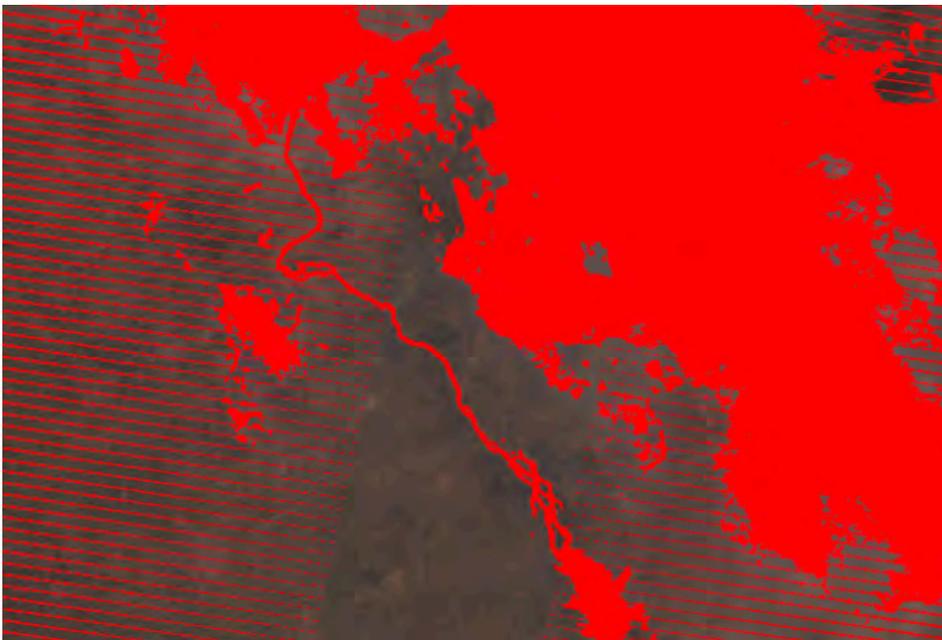
**EXAMPLE:**

True Color RGB, Max NDVI, Landsat-8,  
Year 2017 - Mount Kenya National Park

(7) Select the HISTORY tab on the top-left menu to see a history of your analysis cases. By clicking on any of the listed tasks you can see the details of analysis and load past results into the screen.

(8) Select the RESULTS tab on the top-left menu to see the details of the underlying scenes that were used for the mosaic. You will see an "Acquisition List" that shows details for each of the scenes in the mosaic. For example, you can see the "clean pixel percentage", which is the same as 1-Cloud%.

In addition, any one of these individual scenes can be loaded for viewing. Try one! When a scene or mosaic is selected the user can also check the "Highlight No Data" box to color the no-data or clouds as RED in the image. An example is shown below.



(9) Select the OUTPUT tab on the top-left menu to choose a variety of output products. Once a result is selected there will be a drop-down list of possible outputs, such as PNG, animations and GeoTIFF. Try downloading a PNG file (flat image), a GeoTIFF (to view in QGIS or ArcGIS) and a time series animation (GIF file). For each one, you will need to press the "Download Selected" button to download the final result. Be sure to download and view a GIF animation file as it is interesting to see the variations in cloud cover, Landsat-7 banding and scene edges as you go thru the time slices in the data cube.

In addition, when a product is selected you will see a list of details for the mosaic. This includes the run time, the number of scenes in the image, the pixel count and the clean pixel percentage (% cloud free), Lat-Lon range, time range and composite method. This is valuable information.

(10) Repeat the steps above with variations in the selections. For example, try a different region, time period, false color mosaic output, or compositing method.

#### **Case #5: Menu: Tools > Land > Spectral Indices**

This section of the training manual is meant to address spectral indices. These are mathematical combinations of the Landsat spectral bands (red, green, blue, infrared-IR, shortwave infrared #1 (SWIR1), and shortwave infrared #2 (SWIR2)). These band combinations allow unique identification of land features and make it easier to study differences in land classes and time series variations due to seasons or land change.

Similar to the previous cases, the user first selects a region, selects a time period, and selects a satellite (L7 or L8). Then the user must select one of the 6 spectral indices and a compositing or mosaic method, similar to case #4. Below is a summary of the available spectral indices and how they might be used for land analyses. All of these parameters are quite common and more information can be found using typical "Google" queries.

#### **(a) NDVI = Normalized Difference Vegetation Index**

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

This is the most common vegetation index and measures "greenness". Healthy vegetation (chlorophyll) reflects more near-infrared (NIR) and green light compared to other wavelengths. But it absorbs more red and blue light. The range of values is -1.0 to 1.0.

- 1.0 to 0.0 > Rocks, sand or snow (no vegetation)
- 0.0 to 0.2 > Non-green plants or dead vegetation
- 0.2 to 0.6 > Moderate green plants, shrubs or grasslands
- 0.6 to 0.9 > Dense and dark vegetation, typical of forests

#### **(b) NDWI = Normalized Difference Water Index**

$$\text{NDWI} = \frac{\text{GREEN} - \text{NIR}}{\text{GREEN} + \text{NIR}}$$

This index correlates well with the existence of water. The range of values is -1.0 to 1.0.

- 1.0 to 0.0 > Bright surface with no vegetation or water content
- ~ 1.0 > Consistent water such as lakes or rivers

(c) **NDBI = Normalized Difference Build-Up Index**

$$NDBI = \frac{(SWIR - NIR)}{(SWIR + NIR)}$$

This index correlates well with the existence of urbanized areas. The range of values is -1.0 to 1.0.

-1.0 to 0.0 > No urbanization

0.0 to 1.0 > Urbanization

(d) **EVI = Enhanced Vegetation Index**

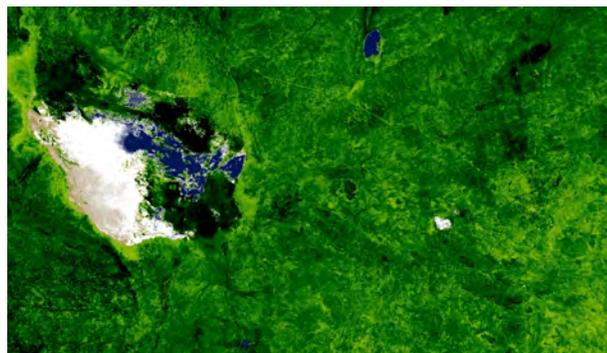
$$EVI = 2.5 * \frac{(NIR - RED)}{(NIR + C_1 * RED - C_2 * BLUE + L)}$$

Where, C1 = 6.0, C2 = 7.5, L = 1.0

The enhanced vegetation index (EVI) was developed as an alternative vegetation index to address some of the limitations of the NDVI. The EVI was specifically developed to: (a) be more sensitive to changes in areas having high biomass (a serious shortcoming of NDVI), (b) Reduce the influence of atmospheric conditions on vegetation index values, and (c) correct for canopy background signals. EVI tends to be more sensitive to plant canopy differences like leaf area index (LAI), canopy structure, and plant phenology and stress than does NDVI which generally responds just to the amount of chlorophyll present.

The range of EVI values are -1.0 to 2.5.

Left (Google Earth), Right (EVI Product)



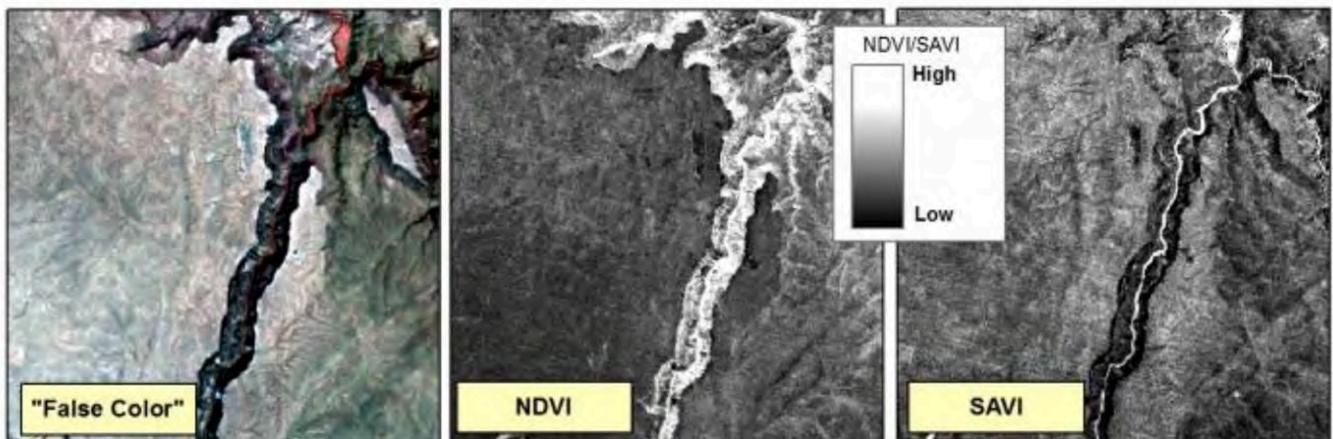
(e) **SAVI = Soil Adjusted Vegetation Index**

In areas where vegetative cover is low (i.e., < 40%) and the soil surface is exposed, the reflectance of light in the red and near-infrared spectra can influence vegetation index values. This is especially problematic when comparisons are being made across different soil types that may reflect different amounts of light in the red and near infrared wavelengths (i.e., soils with different brightness values). The soil-adjusted vegetation index was developed as a modification of NDVI to correct for the influence of soil brightness when vegetative cover is low. The SAVI is structured similar to the NDVI but with the addition of a “soil brightness correction factor,”

$$SAVI = \frac{NIR - RED}{(NIR + RED + L)} * (1 + L)$$

L = 0.5 for Landsat Surface Reflectance Products

where NIR is the reflectance value of the near infrared band, RED is reflectance of the red band, and L is the soil brightness correction factor. The value of L varies by the amount or cover of green vegetation: in very high vegetation regions, L=0; and in areas with no green vegetation, L=1. Generally, an L=0.5 works well in most situations and is the default value used. When L=0, then SAVI = NDVI.



NDVI and SAVI calculated from a Landsat TM5 image of southwestern Owyhee County, Idaho. This image shows a section of the South-Fork Owyhee River canyon. Notice how the NDVI image has high index values in the rocky river canyon, suggesting much more vegetative cover than is actually there. The SAVI for the canyon gives a much better approximation of the amount and cover of vegetation in the canyon as well as in the upland.

(f) **NBR = Normalized Burn Ratio**

$$NBR = \frac{(NIR - SWIR)}{(NIR + SWIR)}$$



**Case #7: Menu:** Tools > Land > Fractional Cover

Vegetation fractional cover represents the exposed proportion of Photosynthetic Vegetation (PV), Non-Photosynthetic Vegetation (NPV), and Bare Soil (BS) within each pixel. This product is useful for natural resource management, modeling carbon dynamics and assessing land cover change in time series. The fractional coverage algorithm uses a linear unmixing technique developed by Juan P. Guerschman (CSIRO).

