**QGIS-FIRE MAPPING TOOL (FMT3) USER GUIDE**

**Version 2.1**

**September 9, 2025**

**Contents**

[Document History: 2](#_Toc573467118)

[Background 3](#_Toc1972885724)

[Pre-Requisites 4](#_Toc162015405)

[QGIS Installation and setup 5](#_Toc1124253992)

[Satellite Assessment of Fire Effects: Concepts 8](#_Toc1475012189)

[A. Fire Assessment Strategies 9](#_Toc1460806091)

[B. Peak-of-Green 13](#_Toc1028679086)

[QGIS-FMT3: Step-by-Step 13](#_Toc586401050)

[Glossary of Terms 30](#_Toc988948249)

[References: 31](#_Toc2004160172)

[Appendix #1 Assessing Peak of Green Using NDVI Curves 31](#_Toc1374559598)

[Appendix #2: Adjusting Image Origin Coordinates: 33](#_Toc1648003734)

**Appendix #3: Event-ID Naming Convention: ..................................................................................... 34**

# Document History:

|  |  |  |
| --- | --- | --- |
| **Document Version** | **Publication Date** | **Change Description** |
| Version 1.0 | December 4, 2018 | Original release |
| Version 2.0 | October 31, 2024 | Updated to add capability to process Sentinel imagery, for contemporary versions of QGIS, and to remove dependency on the USGS ESPA system. Minor text edits were made to improve readability and consistency. |
| Version 2.1 | September 9, 2025 | Updated preferences GUI to include layers the user would like to add to the QGIS project. |

# Background

The “bird’s-eye view” provided by satellite imagery allows for visual assessment of an entire burned area. When combined with field plot information, it provides a more complete understanding of the fire’s effects (i.e., the “burn severity”), or the first order effects upon vegetation, soils, and the landscape. The establishment of the National Park Service (NPS)/US Geological Survey (USGS) Burn Severity Mapping project in the early 2000s began as a satellite assessment of fire effects on NPS lands. This set the stage for the Monitoring Trends in Burn Severity project (MTBS), which began in 2006 with a mandate from the Wildland Fire Leadership Council (WFLC) to establish a consistent methodology for assessment and documentation of fires and their effects across all land ownerships. The archive of Landsat imagery provided the necessary data to support the effort to assess over 50,000 fires from 1984 to the present. At its inception, the MTBS project recognized that it did not have the resources to map ALL fires, so the project established minimum scar size thresholds of 500 acres in the eastern and 1,000 acres in the western U.S. The project was eventually overwhelmed with the addition of thousands of prescribed fires from state records. Because local land managers likely cannot wait that long for information, prescribed fires are therefore only mapped on federal lands.

The development of this fire assessment plug-in for QGIS 3.x.x, the Fire Mapping Tool (FMT3), is meant to address the needs of local fire managers who may need to determine the effects of smaller fires or who cannot wait for an MTBS assessment to be published. This plug-in will also allow local fire managers to utilize the same type of satellite-based imagery and derivative information used by Burned Area Emergency Response (BAER) teams. This tool mimics the Event Mapping Tool (EMT) developed by the US Forest Service (USFS) Geospatial Technology and Applications Center (GTAC; Salt Lake City, UT) and used by the USFS and USGS MTBS teams. Additional functions have been added and utilization of open-source software via QGIS allow for free distribution.

# Pre-Requisites

This user document presumes the reader has some basic knowledge of remote sensing concepts and geographic information systems processing. The fire assessment processes are implemented on the open source QGIS platform (https://www.qgis.org/). After downloading and installing QGIS 3.x.x, a beginner user should spend a few hours completing some web based QGIS tutorials to learn how to load and manipulate raster and vector datasets:

5. Getting Started — QGIS Documentation - <https://docs.qgis.org/testing/en/docs/user_manual/introduction/getting_started.html#sample-session-loading-raster-and-vector-layers>. Use an internet search to locate other tutorials, (inclusion of websites mentioned below does not constitute endorsement):

[QGIS resources · QGIS Web Site](https://www.qgis.org/resources/hub/) - [https://www.qgis.org/resources/hub/](https://www.qgis.org/resources/hub/%20) <http://www.qgistutorials.com/en/>

There are YouTube videos: go to [www.youtube.com](http://www.youtube.com) and search “QGIS”

To properly use this tool, you need to get a basic understanding of how to visually enhance raster (satellite) images, digitize and edit vector files (shapefiles), and color-code gray scale images. QGIS is constantly updated, and new plug-ins and on-line tutorials may not show the latest features.

>>>>>

**Note: This plugin tool automates many image-processing steps but cannot replace the analyst skills required to accurately interpret, assess, and map fire effects. These skills are developed through a repeated process of comparing satellite imagery with information and knowledge gathered from field experiences. By gaining this experience, an analyst will improve the accuracy of their assessments.**

To better understand how to assess burned area and burn severity using remotely sensed satellite indices, users should explore the references below that discuss the Normalized Burn Ratio (NBR), Differenced Normalize Burn Ratio (dNBR), and Relative dNBR (RdNBR).

# QGIS installation and setup

**Prerequisites:**

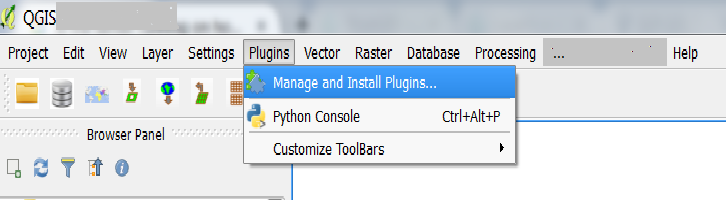
1. QGIS (Tested on Version 3.34.9), available at <https://qgis.org/>
2. Activated QGIS Plugins
   1. DB Manager (Included with standard QGIS v3.x.x installation and must be enabled).
   2. Processing (Included in standard QGIS v3.x.x installation and must be enabled).
   3. MetaSearch Catalog client (Included in standard QGIS v3.x.x installation and must be enabled).
3. Compatible with operating systems that are supported by QGIS v3.x.x (Tested on Microsoft Windows 11)
4. Recommended system requirements:
   1. Operating System: Windows 11
   2. Memory (RAM): 1GB of RAM required
   3. Hard Disk Space: 500MB of free space required
   4. Processor: 1.6GHz processor or faster

**Unresolved Issues:**

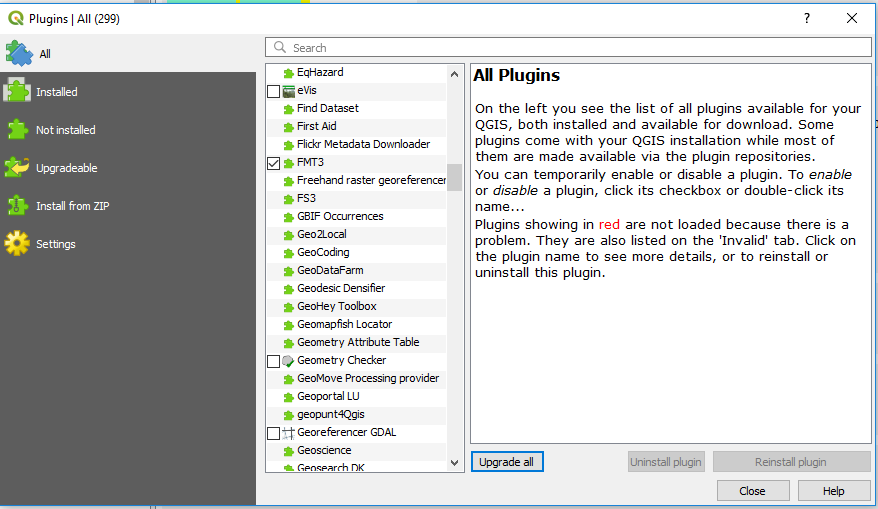
Unresolved issues include any known issues that are not severe in terms of limiting the tool performance enough to warrant the delay of the release. Change Requests have been added to correct them in a future release. These items are listed below:

**Plugin Setup:**

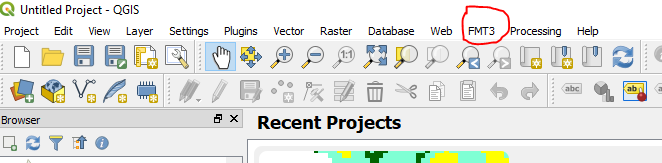
1. Download/acquire the QGIS FMT3 plugin, available via the MTBS website (<https://mtbs.gov/qgis-fire-mapping-tool>).
2. Open QGIS application and under plugins click on “Manage and Install Plugins”
3. Go to “Install from Zip” , select the downloaded zipped file, and click “Install Plugin”.
4. Inside the directory: C:\Users\<user\_name>\AppData\Roaming\QGIS\QGIS3\profiles\default\python\plugins\FMT3, rename FireInfo\_repo.sqlite to FireInfo.sqlite
5. Inside the directory, rename your “config\_repo” file to “config”.
6. Open QGIS application and under plugins click on “Manage and Install Plugins”



1. Now open “Manage and Install Plugins” and click on “All” which should show a list of all available plugins (If the FMT3 plugin doesn’t appear in the list, verify that you have it installed in the correct folder (see step 2), close the window and restart QGIS)

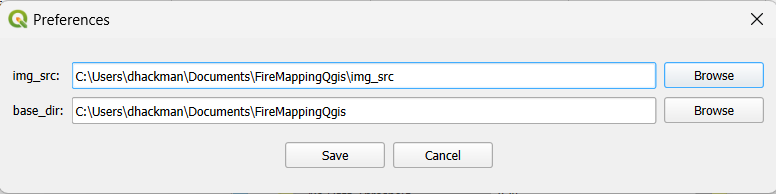


1. From the list select “FMT3”, “DB Manager”, “MetaSearch Catalog Client” and “Processing” and close the dialog. The “FMT3” plugin should now show in the menu bar (may need to restart QGIS).



**Configuration and Folder Settings:**

1. The user needs to edit the ‘img\_src’ and base\_dir’ lines to show the path to their choice of storage location. To do this open the FMT tool via the FMT3 menu bar. In the FMT tool, click “Change Preferences” under the preferences menu bar. Although the string snippet 'C:\Users\<user>\Documents' is suggested, the data folder can be placed in any accessible location. .
2. Note: In the preferences dialog box you have the option to add custom vector and raster layers, as well as custom WMS layers. The layers you choose here will appear in the mapping project. These layers can be used as a reference when mapping or for anything the user would like. The layers will be added when you run the “Fire Prep” step as described below in the user guide.



1. Copy the “FireMappingQgis” data folder into the location the user has defined in the previous step. This folder has the data directory structure that is required for the tool to function.
   1. For example:

Image Source: <userdefined>\FireMappingQgis\img\_src\Landsat\(PathRow)

Image Proc: <userdefined>\FireMappingQgis\img\_proc\Landsat\

Event Prods: <userdefined>\FireMappingQgis\event\_prods\fire\

Templates: <userdefined>\FireMappingQgis\templates\

The plugin is now ready for use.

# Satellite Assessment of Fire Effects: Concepts

This conceptual overview assumes that the user knows when and where a fire has occurred and wants to use satellite imagery to evaluate the extent and the variation of fire effects within the perimeter. The amount of change observed between pre- and post-fire Landsat or Sentinel images is the basis of the evaluation. Landsat satellites record light reflected from each 30-m patch of the earth’s surface in several spectral “bands” such as blue, green, red, infrared, etc. Each 30-m “pixel” is a spectral average of all the “stuff”: rocks, trees, roads, grass, crops, etc. inside the pixel. Sentinel satellites will give you the choice of either 30-m or 20-m resolution. In wildland environments there are pure pixels of forest, shrubs grass, etc. and “mixed” pixels consisting of mixed land cover types.

This document provides a brief overview of the concepts related to satellite assessment of fires and burn severity. These procedures follow protocols used by the Monitoring Trend in Burn Severity project (MTBS, <https://www.mtbs.gov/>). See a comprehensive review of fire assessment including field sampling in the USDA Forest Service General Technical Report (USDA Forest Service Gen Tech. Rep RMRS-GTR-164-CD. 2005) which can be found at:

<https://www.frames.gov/documents/projects/firemon/FIREMON_LandscapeAssessment.pdf>

After knowing the date and location of a fire, the general process is:

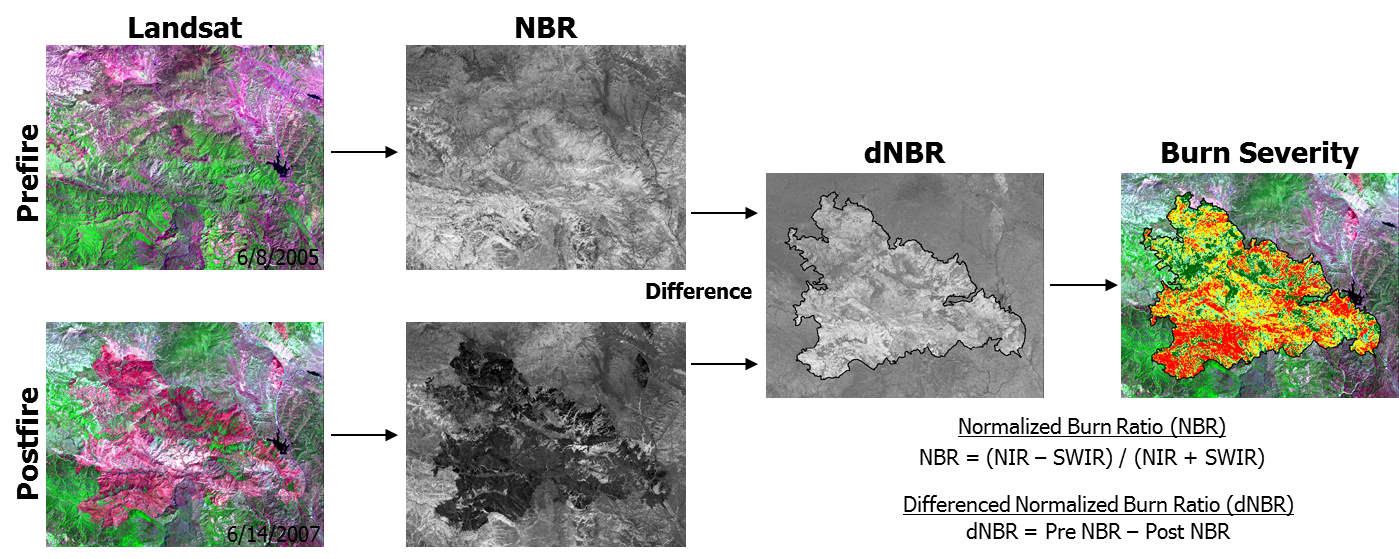
* Determine the assessment strategy
* Evaluate “Peak-of-Green” and order candidate Landsat or Sentinel imagery
* Preprocess the candidate Landsat or Sentinel imagery
* Select the best-matched scenes for the assessment
* Generate the “change” image (pre-fire image ─ post-fire image)
* Evaluate the change image to estimate burn severity

## Fire Assessment Strategies

With location and date information, an analyst can begin a search for suitable Landsat imagery. For larger fires, low-resolution browse imagery available via GloVis ([https://glovis.usgs.gov](http://glovis.usgs.govh/)) or EarthExplorer (<https://earthexplorer.usgs.gov/>) is sufficient. The search for smaller fires on Landsat imagery for may require the use of LandsatLook Viewer/Services ([https://Landsatlook.usgs.gov/](https://landsatlook.usgs.gov/)), which offers higher resolution browse imagery. There are limitations to both applications which are discussed in more detail below. When searching for a landsat image, keep in mind that you can use either level 1 or level 2 imagery. Sentinel-2 imagery may also be used. This imagery is acquired more frequently than Landsat imagery, however the Sentinel-2 image footprint is much smaller. You can find Sentinel-2 imagery here: <https://browser.dataspace.copernicus.eu/>. You can use either level 1 or level 2 Sentinel-2 imagery

If the fire scar is not visible at the reported location within a cloud-free image acquired shortly after the ignition date, it is possible that fire is too small, the effects are minimal/under the canopy, or the reported location or ignition date is incorrect. The analyst should examine the surrounding area on the scene to determine if a burned area is visible in the immediate area (within 5-10 km), or in subsequent acquisitions. If the burned area is visible in an immediate post-fire image, then the analyst needs to determine which additional pre-fire images may be needed to assess the severity of the fire.

In multispectral imagery, the red, near infra-red, and shortwave infra-red spectral bands are useful for assessing vegetation condition and fire effects. The assessment of burn severity is based upon evaluating the amount of change that has occurred due to fire. This requires the comparison of pre- and post-fire images acquired at similar stages of phenology. For each scene, the Normalized Burn Ratio (NBR) is created and the post-fire NBR image is subtracted from a pre-fire NBR image to create a differenced NBR, (dNBR) which is used to assess the amount of vegetation and soil changes resulting from fire (see figure 1).



**Figure 1**: Creation of the dNBR. Larger dNBR values correspond to greater burn severity.

Each Landsat satellite acquires imagery of the entire earth every 16 days. Currently (and several times in the past), two Landsat satellites are in orbit and collecting imagery (i.e., Landsat 8 and 9). The orbits of these sensors are configured so that complete collections of the Earth’s surface collected every 8 days. There are two Sentinel-2 satellites that work together to image the entire Earth every 5 days. These two satellites orbits are 180 degrees from each other, with each satellite revisiting the same area every 10 days. There are many image choices, and selecting the best imagery is important. The best imagery depends upon several factors related to the land cover type and season of the burn that leads to a preferred assessment strategy.

Determining the preferred assessment strategy:

The preferred assessment strategy for a burned area is based on the **interplay** of the land cover type(s), persistence of the fire scar, seasonality, and soil moisture conditions (e.g., forest fire vs grassland, early season vs late season, upland vs wetland, etc.). The best assessment strategy will consider the combination of these factors; see the general guidelines below:

There are two assessment strategies, initial and extended. Initial assessments use post-fire scenes acquired within a couple weeks or months after the fire is out. Extended assessments use scenes acquired after an interval of time during which delayed mortality and survival, or recovery become apparent. Generally, this is the peak-of-green in the following year. However, for late winter/early spring fires, the next peak of green may occur during the same calendar year as the fire.

Repeated assessments conducted in subsequent years allow for monitoring the development of fire effects and/or recovery. Ongoing monitoring of fires is outside the scope of the MTBS project. Performing yearly assessments of an individual fire is a viable option for local fire managers because the imagery is free for download. The only cost is the time it takes to conduct the assessment.

* 1. Extended Assessment

Extended assessments (EAs) can show delayed mortality and vegetation recovery. EAs require a post-fire scene acquired at the **peak-of-green** during the growing season following the fire. A pre-fire scene acquired at the peak of green before the fire is also required. Matching the seasonal timing (vegetation phenology) of the imagery is important. The objective is to match the phenology and other parameters (sun illumination angles) between the pre- and post-fire images as closely as possible. The pre-fire scene date should be within 45 days the post-fire scene acquisition day (i.e. a June-June pairing is better than a June-August paring). In addition, the pre-fire scene should be within a few years of the post-fire scene and be without any obvious changes like thinning or clear cuts. This helps to ensure that changes detected within the burned area are primarily the result of the fire rather than other physical or ecological factors that may contribute to misleading results. Image pairing can be challenging due to seasonal variability and cloud cover. It is important to evaluate several combinations of pre- and post-fire imagery to determine the best image pair (See section below: “Determine dNBR offset value”).

* 1. Initial Assessment

Use Initial assessments (IAs) for vegetation types in which the fire scar fades quickly and is no longer visible in an extended assessment Landsat scene. These are typically fires in grasslands and the southeastern US that revegetate quickly, or in arid shrublands where the scar fades quickly as the ash and char disappear. Choosing scenes for an initial assessment also requires the previously mentioned level of effort to match the phenology and dates of the pre- and post-fire imagery.

* 1. Single Scene (SS) Assessment

For burn severity mapping, the best way to assess the effect of fire on the vegetation is to compare pre- and post-fire Landsat scenes. However, lacking a suitable pre-fire image, a single scene (SS) assessment is the next best option. Each assessment strategy, initial or extended, uses just the post-fire NBR image. However, a dNBR assessment is generally preferred over an NBR assessment. The post-fire NBR best shows change in homogeneous vegetated settings, variations in the NBR are probably related to differences in the amount of vegetation burned.

* 1. Perimeter Scenes

If a ground-collected perimeter is not available, then use an immediate post-fire scene to delineate the burned area perimeter. Also known as a ‘perimeter scene’ it will improve the accuracy of the delineated perimeter when compared to an extended post-fire image. Fires may continue to spread beyond a ground-collected perimeter or post-fire green-up may cause the full extent of the burned area to fade from the extended post-fire scene.

Preferred strategy: Land cover types and regional guidelines

The assessment strategy generally depends upon to how long the fire scar persists on the landscape, which is dependent on the land cover type and climatic (moisture) conditions. Local users have a better understanding of the local cover types and local effects of fire. If the burn scar persists during the following growing season, an extended assessment is used. Generally, MTBS uses an extended assessment to map western conterminous U.S. (CONUS) forest and Alaskan fires. Grasslands and some shrublands tend to recover and green-up quickly after a fire, requiring an initial assessment.

Use Google Earth - <https://www.google.com/earth/about/versions/> to view recent and historical high-resolution aerial photography that may accurately show land cover types within a burned area.

1. Southwestern Fires

In the first year of the MTBS project, extended assessments were used for all fires. However, feedback and mapping experience showed that the rapid disappearance of burn scars in the Southwest and the Southeast necessitated the use of an initial assessment. In areas characterized by low rainfall and sparse vegetation biomass, it can be difficult to distinguish burned areas from the surrounding unburned and senesced vegetation after only a few weeks. Initial dNBR assessments should be used if suitable pre- and post-fire imagery are available. Riparian environments may be assessed with a dNBR but be aware of local phenology and moisture/flooding conditions when identifying pre- and post-fire scene pairs.

1. Southeastern Fires

The climate of the Southeast, including Florida, South Carolina, Georgia, Alabama, Mississippi, Louisiana, and coastal Texas, is characterized as humid subtropical with rapid vegetation growth. Burned areas in this region tend to be re-vegetated within a few months requiring the use of initial assessments. Use post-fire scenes acquired within 45 days of the fire.

Very high soil moisture or periodic flooding characterizes woody wetlands or herbaceous wetlands. Year-to-year moisture variability makes it difficult to select matching post- and pre-fire fire imagery. These areas may require the use of a single scene assessment unless pre-fire and post-fire scenes are found with matching soil moisture conditions.

1. Wetland Fires

A single scene NBR may be necessary for wetland fire assessments. Wetland refers to intermittently submerged landscapes or those with very wet soils for some portion of the year, in which the vegetation may dry out sufficiently to carry a fire (even over standing water).

Southeast wetlands may have multiple growing seasons, rapid re-growth, and seasonal flooding, which makes finding suitable matching scenes for these fires difficult (i.e., matching phenology, sun illumination angles, and soil moisture conditions). Wetter soils in a post-fire scene will tend to lower the dNBR values (the burn severity “signal”) when used with a drier pre-fire scene (and vice versa). If moisture conditions between the pre- and post-fire scenes are similar, then a dNBR assessment is appropriate. Review several pre- and post-fire scenes scene combinations to determine the best scene pair.

1. Upland Fires

Matching seasonal phenology is the primary concern for scene selection. Upland fires are evaluated using either an initial or an extended assessment: the post-fire scene obtained at or near the peak of green following the fire and the pre-fire scene acquired from a previous year.

1. Grassland Fires

Use Initial assessments to map grassland fires. MTBS assumes that grasslands can only burn at low severity; however, shrubs and trees within a grassland burn may show high severity (complete consumption).

## Peak-of-Green

“Peak of green” is an important concept for burn severity assessments. After a fire is out, the surviving vegetation will begin recovery or eventually die. Selecting a Landsat scene at the peak-of-green following the fire allows discernment of those effects. The USGS Greenness Mapping and Remote Sensing Phenology projects collect daily 1-kilometer Normalized Difference Vegetation Index (NDVI) data acquired by satellite and compile it on a bi-weekly basis to retain the maximum NDVI value. For each land cover category found within the Landsat scene, the bi-weekly average NDVI value is determined and plotted on a graph, showing the timing and magnitude of the peak of green. The curves represent the average NDVI over the entire Landsat scene and can be viewed [by](https://www.mtbs.gov/ndvi-graphs)by) clicking “NDVI Curves” in the FMT tool.

There are many assessment and imagery options for any fire. Once the preferred assessment strategy is determined, use on-line browse images available to help select the appropriate scenes. Scenes acquired at or close to peak-of-green are preferred. One web-based application is available for viewing Landsat imagery. For larger fires (over 3,000 acres), **GloVis** (<http://glovis.usgs.gov>) is sufficient because it provides adequate resolution browse images. To download or browse Landsat imagery, Earth Explorer (<https://earthexplorer.usgs.gov>) is also an option. Sentinel-2 imagery can be downloaded at Copernicus (https://browser.dataspace.copernicus.eu/)

Given low-resolution browse imagery and the generalized nature of the NDVI greenness curves, order several “candidate” pre- and post-fire Landsat images. Having optional imagery on-hand is desirable should there be issues not seen in the browse imagery (a small cloud and shadow in the middle of the fire or less than optimal phenology match). **See Appendix #1** for a detailed discussion about evaluating Peak of Green.

To begin an assessment, use the standard GloVis interface and NDVI curves to review and understand the timeframe (months and years) for pre- and post-fire images. For example, peak-of-green generally falls from June to August. (Note NDVI curve data are only available for Landsat scenes that fall in the conterminous USA).

# QGIS-FMT3: Step-by-Step

Start QGIS and open the fire assessment plug-in by clicking on “FMT3” then select “Fire Mapping Tool.”

**Pre-process Data** button:

The downloaded data are in UTM projection, but at this step, you have the option to project the images to Albers Equal Area. This is the projection used by the MTBS project and outputs will overlay with any existing MTBS products. The images (reflectance, NBR and UTM) are copied to the *landsatID* folder: …/FireMappingQgis/img\_src/landsat /*PPPRRR* */ID /* (“PPPRRR” refers to World Referencing System [WRS2] Path and Row numbers)

To process your downloaded zipped images, place them in the folder: .../FireMappingQgis/raw/landsat or .../FireMappingQgis/raw/sentinel2 for Sentinel imagery. Once the imagery has been placed in their respective folders, click the “Pre-process Data” button on the FMT tool. That will open the dialog box. In the drop-down menu select either “Sentinel-2” or “Landsat”. The download images will then appear below. Select the images you’d like to have processed. If you’d like it reprojected into Albers Equal Area, select the reproject check. Otherwise, once ready, select the “process” button. Will take a few minutes or possibly more depending on how many images you are processing at once. Once done, processed images will be located at ...\FireMappingQgis\img\_src\Landsat\PPPRRR\ID or ...\FireMappingQgis\img\_src\_sentinel2\PPP\PPPRR\sentinel2\ID. The ID will be in both \_20m,\_30m, or \_60m resolution if using Sentinel imagery. You can use whichever resolution you would like; however, all the images must be in the same resolution for the mapping to work.

If you have images processed from the previous version of the FMT tool that you would like to use, those images will need to be reprocessed during this step as well.

After image processing, fire assessment can begin.

1. **Enter Fire Occurrence Information:** Click on **File/Add Fire** and enter the required and optional fire information to create a fire occurrence record. The Event-ID is generated from this information. Note: To determine the Landsat “Path” and “Row” in which the fire occurred, use the GloVis website: enter the latitude and longitude of the fire into the “Lat/Long” entry boxes and click “GO” to display the path and row.

Required fields

* State
* Fire Date
* Latitude
* Longitude
* Path
* Row
* Fire Type
* Acres

Optional fields

* Fire Name
* and others

Clicking **Create Event-ID** adds the information to a SpatialLite database which underpins all subsequent processing.

1. Click **Search** and enter the fire name (or other search criteria) to retrieve the fire record (partial names accepted). All fire record(s) that satisfy the search criteria display in the upper window.
2. Review NDVI curves for Peak of Green: To view the NDVI curves in the QGIS plug-in, a fire record must be displayed and selected in the upper window. Click on the “**NDVI Curves**” button. A browser window will link to a USGS web-service and display the NDVI data (See the QGIS-FMT3 section of **Appendix #12 Assessing Peak of Green using NDVI curves**).
3. Click the “**Create New Mapping**” button, this opens a window where the assessment type is selected: initial, initial (SS), extended, or extended (SS). Then select the Landsat or Sentinel-2 scenes for the assessment. Each mapping may only have Landsat or Sentinel-2. You may not use both types of images in one mapping. For any assessment type, you may enter up to three images defined as pre, post, perimeter (or “supplemental” for single scene assessments). For a single scene, only one image is necessary, for the rest, you must have at least a post-fire and a pre-fire image selected. Finally, click the “**Save Mapping**” button. Note: multiple mappings may be created for an individual fire record… experiment with scene combinations to create the best assessment or conduct initial and extended assessments for the same fire.

Clicking the “**Save Mapping**” button: a mapping record appears in the second widow. Click on the record to select it, which enables the processing interface buttons (“Run Scene Prep”, “Run Fire Prep”, etc). A mapping record must be selected to run a process.

The processing steps need to follow in sequence; however, individual steps may be re-run with different parameters and the original results will be overwritten.

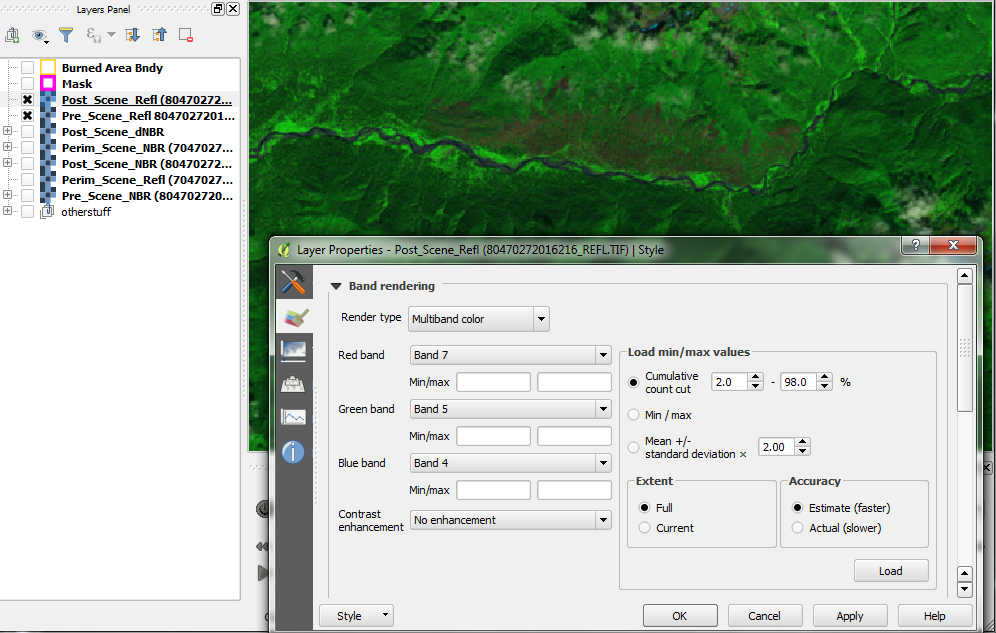
1. **FMT3 STEP: Run Scene Prep**. This step creates a dNBR using the scenes entered. The output is written to the .../FireMappingQgis/img\_proc/landsat/ or .../FireMappingQgis/img\_proc/sentinel2 folder. Click the “Overwrite” box to re-run this step with the same inputs.
2. **FMT3 STEP: Run Fire Prep-** This step creates a mapping folder with the name of the Fire-ID in the FireMappingQgis/event\_prod/fire/year/*fire\_id*/*mapping\_id* folder and fills it with shapefile templates for the fire perimeter and cloud/shadow mask and a .qgz project file. Each mapping for the same fire creates a new *mapping\_id* folder.
3. **FMT3 STEP: DelineatePerimeter-** This step populates the QGIS display with the chosen Landsat imagery, NBRs, dNBR, and shapefile templates. To begin the assessment: 1) enhance the image display, 2) Confirm the accuracy of the registration between the pre- and post-fire imagery, and 3) Delineate the fire perimeter/burned area boundary.

**QGIS Display**: Full resolution data (as opposed to browse imagery) provide the best way to preview candidate scenes and visually evaluate the greenness levels in the vicinity of the fire. This requires scaling the image display histograms, so they are the same for each image. The QGIS program provides a default image “stretch”, and the user may adjust brightness, contrast, and band combinations to improve the visualization of the fire. When interpreting pre-fire and post-fire reflectance images, it is best to display them with the same multiband color stretch, so that the various shades of color represent the same ground conditions on both images. Click on View/Toolbars/Raster toolbar (Figure 3). Highlight the post-fire reflectance image to activate the Raster Toolbar. It offers several different image enhancements based upon the overall image statistics.

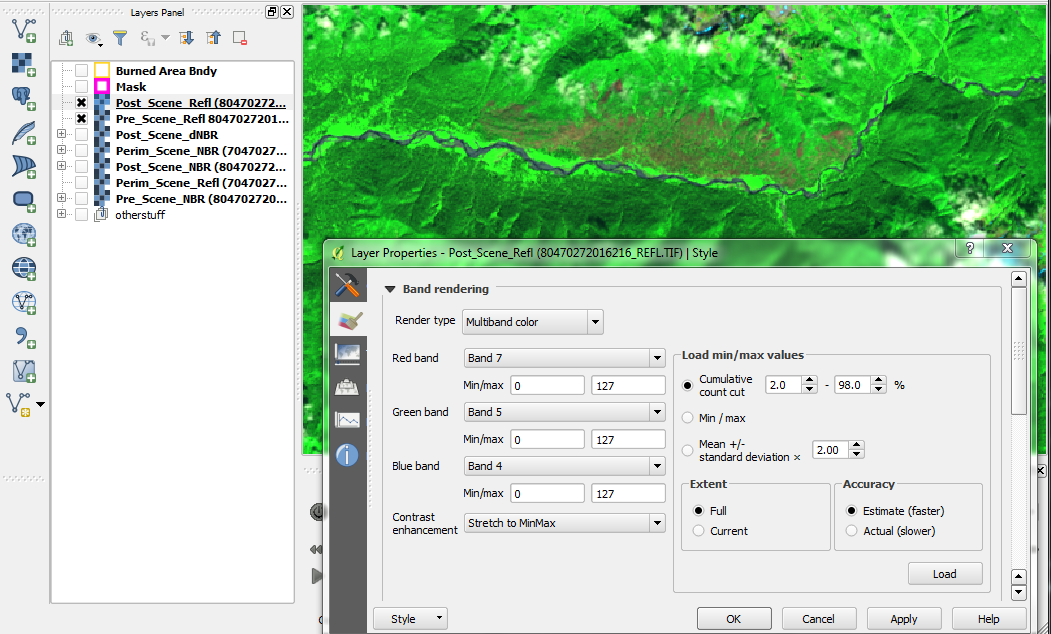


**Figure 2:** Example of QGIS Raster toolbar

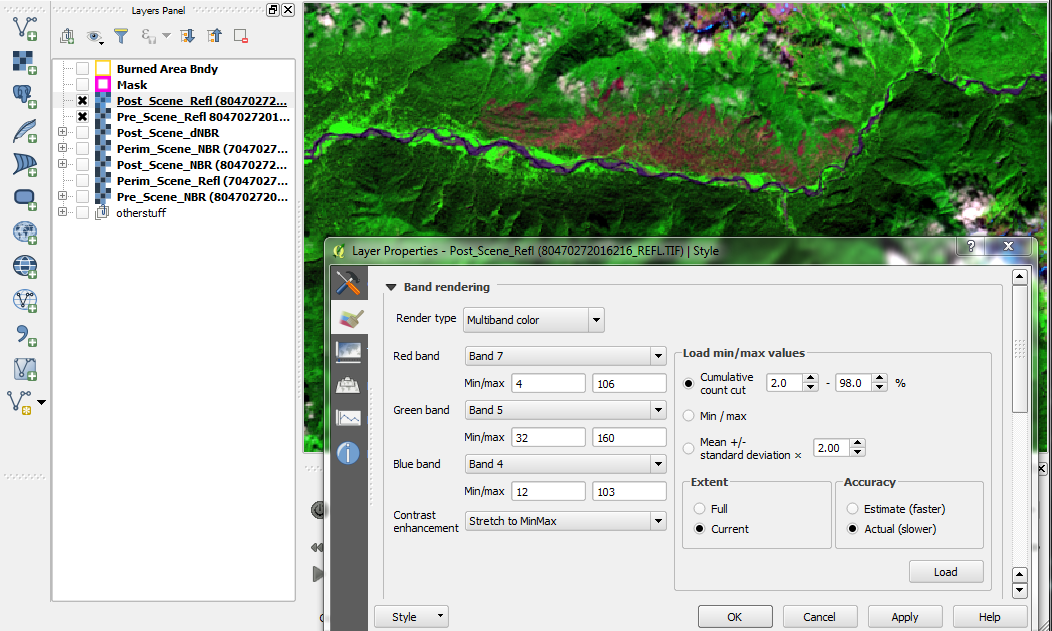
Alternatively, create a custom stretch by using the Layer Properties/Style interface to adjust the Min/Max values for the Red/Green and Blue bands (Figure 3). A good starting point is to enter 0 and 127 as the min/max for each band, and “Stretch to MinMax” as the contrast enhancement then click Apply (Figure 4). Experiment with different stretches to find what is easiest to interpret, and then apply the same Min and Max values to both the pre and post images (Figures 5-6)



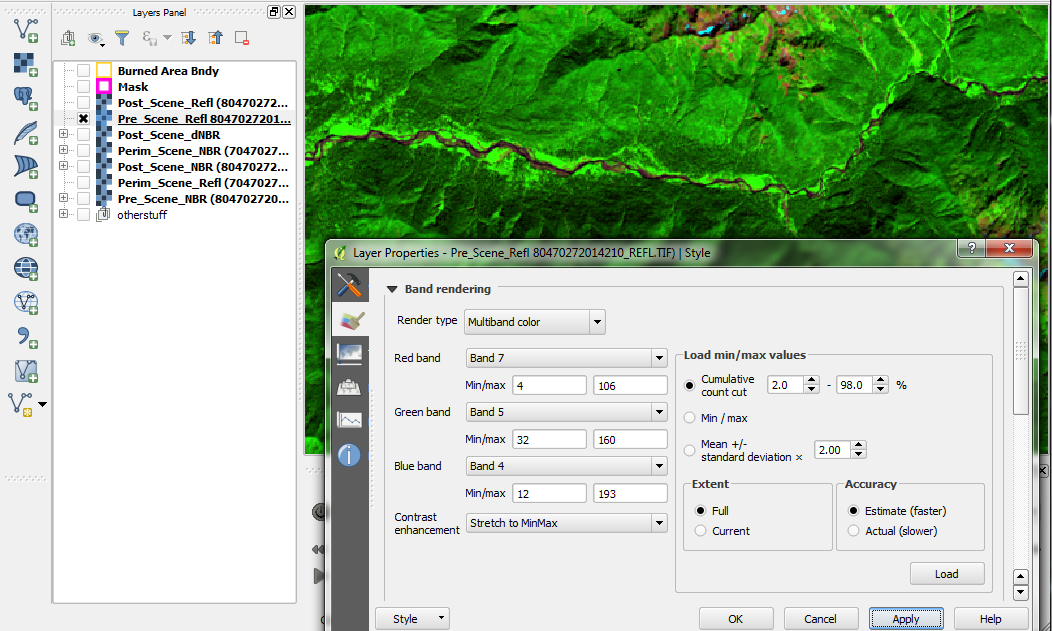
**Figure 3:** Example of the properties for a post-fire reflectance with bands 7, 5, 4 (RGB) with no enhancement.



**Figure 4:** In this example the image has been adjusted: Enter Min = 0, Max = 127; Stretch to MinMax: brighter w/low contrast.



**Figure 5:** For this image adjustment set the: Cumulative 2 – 98 %, Current Extent, Actual, Load, Stretch to MinMax, (note the values). If you used Raster Tools, open Properties/Style to note the MinMax values and apply them to the pre-fire image.



**Figure 67:** This pre-fire image has the RGB Min & Max values derived from the post-fire 2-98 % cumulative counts, and manually entered. Note similar appearance to post-fire image.

If you manually load Landsat 5&7 and Sentinel-2 reflectance images you will need to assign the correct band sequence, 6, 4, and 3; for the red, green, and blue display (properties/style). Band 7 is renumbered to “6” because the real band 6 is thermal data and not processed nor included as a spectral band in the final Top of atmosphere “reflectance” image. For Landsat 8&9, the correct RGB sequence is 7, 5, and 4.

Many image processing software packages will default to a two standard deviation stretch which can make it difficult to visually compare images. A useful enhancement is a piecewise linear stretch: input 0 – 150, stretched to 0 – 255.

The default stretch for the dNBR (-300 to +1000 MinMax black to white) and the NBRs (-1000 to +1000 MinMax) allows consistent interpretations.

**Confirm Image Registration**: After adjusting the image display, confirm the co-registration precision of the pre- and post-fire imagery. Display the Landsat scenes and zoom in to the vicinity of the fire (~1:24000 to see individual pixels). Determine whether the images are precisely aligned (within one pixel, i.e. 30-m, or 20-m if using Sentinel-2 \_20m resolution) by flickering the imagery while looking at small single pixel feature such a small water body. Usually there is no problem but sometimes an image shift beyond 1 pixel is apparent. Correct this by adjusting the image origin coordinates. **See Appendix #2** for instructions to adjust image origin coordinates.

**Delineate Perimeter**: Click on View/Toolbars and click on “Advanced Digitizing” and “Digitizing” toolbars. Toggle-on Editing for the “burned area boundary” vector file and click on the Icon for “Add Feature.” Digitize the burned area extent that is visible in the dNBR and/or post-fire reflectance images. Zoom into 1:24,000 scale to digitize fires. To finish digitizing fire, right click and click “OK” on the dialog box that appears. Fields will be populated on the next step. Save Layer Edits and Toggle-off editing when finished. While delineating the perimeter, toggle between the post-fire image(s), the NBR/dNBR, and the pre-fire image. This is especially important for areas of very low severity near the boundary of the burn. The final fire perimeter should provide an accurate representation of what burned when displayed at a scale where the full extent of the perimeter is visible. The perimeter is used to subset the full scene Landsat images.

A “mask” shapefile template is provided to mask-out clouds, shadows, snow, and water bodies in both the pre- and post-fire images as those features will falsely enhance or reduce the dNBR signal in the final thematic burn severity assessment. The process to create the mask is the same as creating the burn area boundary, except in areas with lots of water bodies. Manual digitizing will be tedious, so use an existing waterbody data layer or image classification techniques to classify water (beyond the scope of this user guide), then convert the classified image to a 0-1 raster image, convert that to a vector file and then merge it into the mask shapefile.

Tips for delineating the burned area boundary

* Use a ground-collected perimeter if available and merge it into the Burned Area Bndy shapefile and edit as necessary.
* Use an immediate post-fire scene when possible to delineate the burned area
* The NBR does not always accurately represent the burned area in wetlands (especially herbaceous wetlands with frequent flooding). Burned areas can be affected by wet/high moisture, flooding, saturated soil, etc. If the post-fire image is flooded, use the next available dry scene. It is not always easy to find good a post-fire image for assessing a wetland fire, and it is not an easy task to generate a burned area boundary using NBR imagery in the wetlands. If possible, select a dry post-fire scene as a supplementary image to help discern the burned area after the water has receded.

1. **FMT3 STEP: Subset-** Once the burned area perimeter is complete; click **Subset** to clip the various reflectance images, NBRs and dNBR to the extent of the perimeter plus three km. Additionally, a random sample of dNBR pixels are evaluated to estimate the dNBR offset and estimate the low, moderate, and high burn severity thresholds. The image subsets and vector files will be loaded into QGIS and the estimated dNBR values are loaded into the appropriate parameter boxes (dNBR offset and severity thresholds). The user can change the estimated values if necessary (see below).
2. **Open Event Folder:** This “step” just opens the fire event folder for convenience.
3. **FMT3 Step: RdNBR-** The Relative dNBR (RdNBR) is another useful burn severity index. Whereas the dNBR is a measure of the absolute difference between the pre- and post-fire NBR, theRdNBR tries to account the relative difference. For example, in terms of the RdNBR, a 50% loss of vegetation that originally covered 100% of the ground (50% remaining cover) would be the same as 50% loss of vegetation that originally covered 50% of the land surface (25% remaining cover). In terms of the dNBR the 50% loss of 100% cover is more “severe” than 50% loss of 50% cover (see Miller and Thode 2007).

Calculation of the RdNBR first requires determination of the “dNBR offset” (i.e., the average dNBR value of unburned vegetation). The **“Subset”** step (above) estimates this value from all dNBR pixels outside the perimeter. However, the estimated value may not be accurate if land cover not representative of the burned vegetation surrounds the fire; you should then manually determine the offset value. If standard deviation is greater than about 50, possible that the estimated value is incorrect.

Click: Layer/Create Layer/New Shapefile Layer, then select “Polygon” shape type, select the correct projection (e.g. EPSG: 5070 - NAD83 /Conus Albers or UTM zone) and save with a name such as “dnbr\_offset”. Edit the style of the new shapefile to a simple line with no fill. In QGIS, display the full scene dNBR, and zoom to the area of the fire. Toggle-on editing for the dnbr\_offset shapefile. Then, using the pre- and post-fire imagery as a guide, create one or more polygons to identify burned areas.

Be cognizant of slope, aspect, vegetation type, and cloud cover in both images. If the fire burned different vegetation types, then the unburned samples should reflect the types and proportions of the burned vegetation. When complete, save the edits and toggle off editing. If possible, try to delineate a single polygon to represent the range of unburned vegetation, but this may not be practical for very large fires. Otherwise, extra steps are needed to create a “multipart” shapefile out of the multiple polygons. This is necessary to get one average dNBR value from the multiple polygons. Note: two offset shapefiles have been provided, one single part (offset5) and one multipart (offset5\_multipart) to see the difference in the attribute table. When you finish outlining a polygon, you must “right” click and enter an ID #. **IMPORTANT: if you delineate multiple polygons, give then all the same ID#, such as 1,** otherwise you cannot convert them to a multipart shapefile. To convert a single part shapefile with multiple polygons into a multipart shapefile, click on Vector/Geometry Tools/Singleparts to Multipart, and select the input shapefile, unique field ID (all IDs = 1), and the output shapefile name. Click OK.

Now Click Raster/Zonal Statistics. (You will need to turn on the already installed Zonal Statistics plugin: Click Plugin/Manage and Install Plugins/Installed click on the Zonal Statistics checkbox.) Select the dNBR raster layer and the dnbr\_offset polygon layer, select the mean and standard deviation checkboxes, click OK. Then open the attributes for the offset shapefile to review the offset (mean) value and its standard deviation. Offset values should be less than 50 and are better when closer to zero (if the columns are blank, the projections of the dNBR raster layer and polygon shapefile do not match, recreate the polygon shapefile with a projection to match the raster layer). Lower offset values signal a better phenological match between the scenes. Likewise, Standard Deviations should be less than 50 and are better closer to zero. A low Standard Deviation signals a good estimate of the average offset dNBR value and suggests the burned/not burned threshold is closer to the offset value than a higher standard deviation.

Using the provided multipart shapefile, the offset for the (example) Paradise fire has a mean of 17 and a standard deviation of 27 (whole numbers are close enough).

If the dNBR offset values are ≥ 100 or ≤ -100: see if the area selected is indeed homogeneous and representative of the burned vegetation. See that the scenes are from the same time of year (+ or minus 30 days). Perhaps find a better-matched image pair.

To run the RdNBR step, select High or Low for Perimeter Confidence, select the Analysis Type (dNBR, NBR, etc.), enter or accept the dNBR Offset and Standard Deviation values, and enter any comment needed to explain the perimeter delineation (“hard to see”, “edits to park-provided perimeter”, etc.).

Click the “RdNBR” button to create the RdNBR, then add the RdNBR subset image to the viewing panel and open Properties/ Style to set the display gray scale -300 to +1000 (for viewing consistency with the dNBR and subsequent assessments of other fires).

1. **FMT3 STEP: Threshold-** This step creates a thematic burn severity map (Unburned to Low, Low, Moderate, and High severity).

The FMT3 **Subset** step estimated the Low, Moderate, and High thresholds based upon a statistical analysis of the pixels within the delineated fire perimeter. Click the **Threshold** button to accept the estimated values and create a burn severity image (\*.dnbr6.tif). Review the thematic result to see if it preserves the patterns seen in the grayscale dNBR. Initially, visually estimating the thresholds is a good way to evaluate the default thresholds or collect field data to compare with the dNBR values and over time, develop a set of “Default Thresholds” for your area of interest (see FIREMON and composite burn index (CBI) documentation: <https://www.frames.gov/documents/projects/firemon/FIREMON_LandscapeAssessment.pdf>).

**Visual Estimate of the Burn Severity thresholds**

The goal of estimating the burn severity thresholds is to create a thematic data layer that portrays and preserves the burn severity patterns within the burned area. The approach is similar for both the dNBR and NBR. The following discussion focusses on how to apply QGIS style-editor tools to manipulate and color-code the dNBR or NBR to estimate the burn severity thresholds. There may be ways that are more efficient in QGIS to accomplish same results.

* To create a burn severity map it is necessary determine low, moderate, and high dNBR thresholds. The best way is to establish pre-fire field burn severity plots (e.g., CBI) plots, assess the severity of each plot, and then correlate the field observations with the dNBR values. For wildfires pre-fire plots may not exist, but it should be a goal for Rx fires to properly evaluate dNBR severity and derive default thresholds for your locale.
* In the absence of field-observations, visually interpret the dNBR image and color code it to show the highest, lowest, and moderate severity areas within the perimeter. The higher (brighter) dNBR values represent moderate to high severity and lower (gray) dNBR values show little to no severity, very dark dNBR values show areas of increased greenness (or cloud shadows).
* Load the dNBR, RdNBR, and Reflectance subset images into the QGIS display: Click the add raster button and add all the raster subset images. The reflectance **Subset** images are loaded with a default style (band combinations = 7, 5, and 4 for L8 and L9; or 6, 4, and 3 for L5,L7, and S2). The dNBR and RdNBR are also loaded with a default (black to white) color ramp for single band signed 16-bit images.

You are going to interpret the dNBR and RdNBR images to pick severity thresholds. First, determine the low and high threshold dNBR values.

Click and drag the dNBR image to the top of the “table of contents” panel. Arrange the remaining layers, including post-fire reflectance, pre-fire reflectance, and RdNBR, and turn the reflectance images off so only the dNBR and RdNBR are “on”.

* **Color coding the dNBR image**:

Double click the dNBR entry and the “Properties” window will open. Select “Style”. This interface will let you color code the dNBR (and RdNBR) image to help estimate the burn severity thresholds.

By default, the dNBR will be “rendered” as a “***singleband gray***” image with a black to white stretch using the ***estimated*** minimum and maximum values.

Change the render type to ***Singleband pseudocolor***.

Set color interpolation to ***discrete.***

Click the radio button on for ***MIN/MAX***, click EXTENT to ***Full***, and ACCURACY to ***Actual***, then click ***LOAD***. This determines the actual Min and Max values for the dNBR image subset and displays them in the Min and Max windows (e.g. -667 and 950).

In the “Generate new color map”, select the “Greys” color ramp, click “**Invert**”. Select ***equal interval*** as the “Mode”. Note that “Classes” defaults to 5. Click the “Classify” button, then “Apply”. The dNBR image is now displayed with 5 gray levels, 2 covering the burned area. Each class interval covers about 400 dNBR values. Change the class number to 100 and click “Classify”and “Apply”. Now over 100 classes represent the full range of values, each class covering a range of 16 dNBR values, but the entire gray scale ramp is not visible

Only one interval of the gray scale ramp can be selected and color coded at a time; adjust the Min and Max values and number of classes so that the most important part of the dNBR histogram is depicted with a reasonably small number of classes. Use the Histogram tool the see the distribution of the dNBR values. Note the histogram starts to rise off the X-axis around -200 and the returns to the X-axis around +700.

Go back to the ”Style” interface and enter the ***Min*** value as -200 and the ***Max*** value as 700 in the Singleband pseudocolor render interface and set the number of classes to 23 then click Classify and Apply (at 23 classes, all the gray levels are visible in the color-ramp window). Each interval covers about 40 dNBR levels (the “Values” are displayed as decimals, but the actual dNBR image values are integers). Editing the values by intervals of 40 may be too coarse for precision (+ or – 10) but can be overcome later. Click “OK” to close the “Properties” interface.

Look at the dNBR image with this rendering. There is good contrast and the gray levels inside the burned area range from bright white to mid-level and darker grays and depict the patterns of burn severity within the fire. Unburned areas are much darker. First find the dNBR values that correspond with the burned/not-burned (low) and high thresholds.

Click “on” the post-fire reflectance image that sits below the dNBR image in the table of contents. If you are using the sample images (Paradise fire), red patches appear in the white areas of the dNBR. This is the post-fire reflectance image showing through the dNBR image where values greater than 700 are transparent. In the color ramp window, click and edit the 700 “Value” to 900, then “Apply”: the transparent areas fill in, any dNBR values over 900 remain transparent. Click off the dNBR image to see the full reflectance image (in QGIS version 2.14, you need to close the “Properties” window to do anything with the layer or display panels). Click on and pan/zoom into each image in turn to see how the dNBR patterns match the post- and pre-fire reflectance images. When finished, zoom to extent of the burned area boundary (about 1:50,000)

As dNBR thresholds are colored, compare the new thresholds against the post-fire reflectance image and an uncolored version of the dNBR image as well. Right-click the dNBR entry and select “Duplicate.” This creates a copy of the dNBR image in the table of contents that matches the “style properties” of the original (min and max of -200 and 900 and 23 classes, but class deletions and edits to interval values are not copied). Click on the Duplicate image, rename it to something like “dNBR\_copy”, and click off the other images so they do not show through the transparent areas of the dNBR.

Double click the original dNBR entry in the table of contents and open the properties/style editor. Resize the window to save space. Some of the “generate new color map” parameters revert to default values: “Invert” is unchecked, “Mode” is continuous instead of equal area, etc.

Start by trying to determine the dNBR value for the burned/unburned threshold. The dNBR offset value was calculated to be 17 with a standard deviation of 27 (see RdNBR step above) so the burned/unburned or “low” threshold is probably close to 17 plus about 2 standard deviations (17 + 27 + 27 = 71). This is just a starting estimate, a visual interpretation of the dNBR and post-fire imagery can be more accurate.

* **Visual estimate of the low threshold**: There are two approaches to color-coding the dNBR to find the low threshold. “Bottom-up” starts at the bottom of the dNBR gray scale and works up, coloring the unburned pixels first. “Top-down” is the opposite, coloring the burned pixels first, and working down to the low threshold.

Bottom-up: Starting from the darkest value (-200), double-click the “color” box and a “change color” window appears with several ways to define and save colors. Define and save a dark green (for unburned), a light blue (for low), yellow (for medium), and red (for high). Click the saved dark green color and click OK. The color will appear on the dNBR image only when you click “Apply” in the “Style” interface. Small areas of dark green appear to the north of the fire appear to be cloud shadows and/or pre-fire barren areas that are greener in the post-fire image.

The low threshold is estimated to be close to 70, we can select and (in turn) delete (click minus sign) or color code several gray scale intervals (those below 4) and then color code the 4-value level to dark green. The value 4 (Paradise fire example) represents the highest value now colored dark green. The colors assigned to the image for any level are values **at and below the ‘value’ shown in the color ramp.** Double-click the next higher level in the color ramp (45 Paradise fire), this time select and apply the yellow color. The vast majority falls outside the perimeter and the few that fall inside appear to be unburned. Change this level to dark green. Select and color code the next level (86) to yellow. Again, most pixels fall outside the perimeter but some fall inside. Use the Transparency tool in the style editor: Open the Properties/Transparency for the dNBR image and drag the slider from ‘None’ to ‘Full’ and click ‘Apply’ to see the post-fire reflectance image. You cannot zoom, pan, or arrange the image order while the properties window is open, so click ‘OK’ to close the properties window to make these adjustments if needed.

Zoom into clumps of yellow pixels inside the perimeter (~1:10,000). Then view the color-coded dNBR, pre-fire reflectance, and post-fire reflectance images in-turn to determine if these pixels look burned. In the reflectance images, obviously burned pixels look red, however low severity pixels may only look darker when compared to pre-fire conditions. Inspect isolated yellow pixels and those along the perimeter. Looking at the pre- and post-fire images, find pixels around the perimeter that look only slightly burned (i.e., slightly darker in the post image). Use the “Identify Features” tool to determine the dNBR value of individual slightly burned pixels.

*Top-Down:* In this case, start at the top of the dNBR scale and color code each level working down using steps that are like those described above. The dNBR offset value and standard deviation suggested that the low threshold is around 70. As lower and lower levels are color-coded, notice the ring of bright dNBR pixel values surrounding the color-coded burned pixels (ignore the clouds). Turn on the fire perimeter and cloud mask layers (no fill). Open the properties/style interface for the dNBR\_copy. Recall that the min and max values were originally set to -200 and 700 with 23 classes. Change the value “700” to “1000” and apply the dark green color. Then select and color code classes 659 to 168. Do several at a time before clicking “Apply“ and notice the color-coded burn pixels expand out toward the perimeter. At 168 (green) notice the brighter pixels along the edge of the fire zoom in to the western edge of the fire and toggle on/off the dNBR, post- and pre-fire images to confirm whether these brighter pixels burned. Color code class 127 (actually, 87 to 127) to yellow and zoom out to see the entire fire. The yellow pixels tend to fall along the edge of the fire and the unburned areas inside the perimeter and relatively few fall outside the fire. This suggests they burned. Color code this class green. Selecting the next level, 86, and color-coding it to yellow reveals thousands of pixels outside the burned area.

It is likely that the correct value is somewhere between 87 and 127. What is the correct value? There is no definitive way to tell without field observations. Even then, some subjectivity remains. **Experience will improve interpretive skill especially when combined with field observations.** The mid-value between 87 and 127 is 107. The MTBS project estimated a dNBR value of 100 as the low threshold for this fire. To maintain consistency between different MTBS analysts, all will map the same fire and compare the results. “Agreement” is proclaimed if all analysts are within 50 for their chosen thresholds. Any of the values: 87, 107, 127 would be considered acceptable.

* **Estimating the High severity threshold using the RdNBR**: For estimating the high threshold, the MTBS project uses the RdNBR image to help determine the high severity threshold in the dNBR image. Miller and Thode 2007, investigated many California fires and found specific RdNBR threshold values to be highly correlated with ground estimates of high severity. They recommended different RdNBR thresholds for extended assessments (640) verses initial assessments (750).

For fires that burn in a homogeneous land cover types, the objective is to use the patterns of high severity depicted in the RdNBR to estimate the high severity dNBR threshold. Visually, the high severity displayed in the dNBR should be like the high severity displayed in the RdNBR.

For fires that burn in heterogeneous land cover types, using RdNBR to establish the high severity dNBR threshold is more difficult. RdNBR will likely show high severity across all the land cover types (i.e., grass, shrub, and forest) within the burned boundary. MTBS tries to limit the “high severity” class to only the densest vegetation cover. For example, if the fire burned in dense conifer and neighboring shrubland and grass, the RdNBR may show high severity throughout the forest, shrub, and grass. When determining the dNBR high severity threshold, MTBS chooses the value that confines the high severity to the forest areas. Doing this assumes the dNBR values will show sufficient variation between the different vegetation types to allow this discrimination.

* The example Paradise fire data is performed as an extended assessment in homogeneous forest cover. To estimate the high severity threshold:

Set the RdNBR high threshold to 640: Display the RdNBR in singleband pseudocolor, enter the values -700 and +1100 as Min and Max, and classify 23 levels black to white. Using methods described above, use Red to color-code RdNBR values >= 640. Close the style editor. Move the RdNBR image under the dNBR image.

Display the dNBR in singleband pseudocolor and if necessary, reset the color ramp to Min and Max = -200, 700; 23 classes, discrete, black to white etc., change the 700 value to 1000. Then work down the color ramp color coding each level to red and compare each update to the RdNBR image (use the Transparency slider with the RdNBR under the dNBR). The dNBR values > 659 do not fully match the RdNBR patterns so select and color code the next level, 618. This looks better but more dNBR pixels need to be Red to better match the RdNBR patterns. The next level 577 (actually, 537 ─ 577) produces a very good match. Only a few pixels change when the images are flickered. The dNBR High threshold can be set to 540: i.e., round to the nearest 10 or 25 so as not to imply measurement precision that cannot really be discerned.

We have now estimated the low threshold as 110, and the high threshold as 540.

* For MTBS, the Moderate threshold can be calculated as the median of the high and low thresholds. Then, it is adjusted from there using high resolution imagery, dNBR, reflectance imagery, or any ground observations if available.
* If no high severity exists in within the fire perimeter (no RdNBR values exceed 640 for extended assessments or 750 for initial assessments), enter 9999 for the high severity value and use image interpretation techniques to estimate a Moderate severity value, choosing a value that preserves the major patterns of burn severity seen in the dNBR.
* The No Data Threshold is set at automatically set at –970 and represents dNBR values that are artifacts and not representative of actual burn severity. The increased Greenness Threshold is set automatically at -150. DNBR values less than -150 represent areas of increased vegetation. There is usually no reason to adjust this value unless the average unburned dNBR value (the offset) is well below zero i.e. < -30. Then you may want to drop this threshold to – 180.
* Enter any mapping comments deemed appropriate and click the “Threshold” button.
* Typical high burn severity dNBR values range from 550 to 700. If the high burn severity values are lower than 450 or above 750, then an alternate scene pair may be needed.

**Interpreting burn severity for an NBR image (single scene assessment)**

Single scene (SS) assessments are used when no pre-fire image can be found to match the post-fire image, commonly resulting from phenology, seasonal illumination geometry, or moisture conditions. Wetland areas are typically assessed with a SS. Even though a SS assessment is chosen because a well-matched pre-fire scene is not available, it is useful to order a clear scene prior to the fire occurrence to compare pre- and post-fire vegetation conditions.

**Create New Mapping-** Select “Initial (SS)” as the assessment strategy and select the image for the post-fire. Select another image as the “supplemental” image. The “supplemental” and “perimeter” images are optional for a single scene assessment. Note “Run Scene Prep” is greyed out, because a dNBR is not created for an SS.

**FMT3 Step Run Fire Prep**- This creates a mapping folder with the name of the Fire-ID in the FireMappingQgis/event\_prod/fire/year/ folder and fills it with shapefile templates for the fire perimeter, cloud/shadow mask, and a .qgs project file.

**FMT3 Step Delineate Perimeter**- The post-fire reflectance and NBR images are loaded along with the shapefile templates for the fire burn boundary and mask for clouds/shadows etc. If a Supplemental or perimeter image is chosen it should be added to the viewer. See the “Delineate Perimeter” in the dNBR discussion above for specific QGIS instructions.

Toggle Editing for the “burned area boundary” vector file and click the icon for “Add Feature.” Digitize the burned area extent that is visible in the NBR and/or post-fire reflectance images. Zoom into 1:24,000 scale for delineation. Save Layer Edits and Toggle-off editing when finished.

**FMT3 Step Subset**- This step extracts subsets from the full scene Landsat images based upon the extent of the perimeter plus 3000 meters. If a Supplemental/Perimeter image is chosen it should be subset as well. Note: the estimated burn thresholds are added to the threshold window.

**FMT3 Step Threshold**- Click the **Threshold** button and add the result (\*\_nbr6.tif) to the viewer. Is the result reasonable? Only the local land manager who prescribed the fire will know for sure. Since this is a single scene assessment, there is no way to assess of the amount of change in the vegetation. Whenever possible, a dNBR is preferred to a single scene NBR for severity assessment.

Look at the site in Google Earth. Using the time slider, adjust back and forth from before the fire and after the fire to look at severity. See if any trees or shrubs have burned severity.

Estimate the average NBR value for the unburned vegetation by delineating a polygon of unburned vegetation:

Layer/create Layer/New Shapefile layer: Polygon, Project CRS: EPSG 5070 (Conus Albers) click OK,

Save layer as UnburnedNBR.

Digitize a polygon to enclose an area of unburned vegetation. Add the ID #1 to finish the polygon. Save the and close the edit session.  
Click Raster/Zonalstats, choose the Post\_Scene NBR as the Raster layer, and Unburned NBR as the Zonal layer, click the Mean and Standard Deviation check boxes. Click OK

Open the attributes of the UnburnedNBR shapefile.

The Mean is 623 and the Standard deviation is 70.

Display and Color Code the unburned to low severity class:

Display the full scene gray scale NBR image and zoom to the extent of the burned area boundary. The default mapping is “singleband gray” with a min/max stretch. The burned area is completely black and no patterns are discernable. Visually enhance the burned area: Open properties/style to determine and “load” the actual Min () and Max values (877) from the full image: Under “Load min/max values”: Click Min/Max; Extent = Full; Accuracy = Actual; click Load.

Now the image shows the full range of NBR values and subtle gray scale patterns are visible in the burned area. This image will be a reference for comparing high, medium, and low burn severity patterns.

Display the post-fire NBR subset. Open “Properties/Style” and choose “Singleband pseudocolor” render type. Then choose “discrete” color interpretation. For “Generate new color map”: Select “Greys and Invert”, choose “Equal Interval” as the mode, and choose 23 classes. Change the “Max value” to, well above the estimated unburned NBR value, as we are now interested in the burned pixels. Click “Classify” and “Apply”.

Any active images displayed below the NBR will show thru the NBR where pixel values above max value are now transparent (The value listed next to the gray scale ramp represents the value at the top of the interval, so values above max have no assigned color). Click on the max value on the gray scale ramp, change that value to 877, and click “Apply”. The transparent areas fill with white.

It is useful to make a copy of this image and its gray-scale rendition to compare with the color–coded image to be created. Right-click on the NBR subset image, click “Duplicate” and rename as “NBR copy”.

Patterns within the burned area can be discerned. The darkest areas in the NBR are those with the greatest amount of ash and charred vegetation that probably correlate with the more severely burned areas (i.e., the most vegetation lost). With no field observations to objectively set severity threshold levels, the goal is to preserve the patterns of burn severity so relative levels of severity can be discerned.

Select the 469 gray scale interval, change the value to the estimated low threshold, double click on the Color box to open the color chooser. Select dark green and click “OK”. In-turn select the moderate and high levels and color each dark green as well, then click “Apply”. Use the transparency slider in the properties window to compare the color coded NBR to the reference gray scale image (or close the properties window to display/compare with other images).

Estimate the High Threshold:

Close the Properties window and use the “Identify Features” tool to query the values of different NBR values. The darkest value is -273 (in the central part of the fire). Open the “Properties” window again and note the value -256 on the color ramp. Select that level and double click the color box. Pick the red color and click “OK” then “Apply”. Two pixels become colored red… -273 and one in the northwest part with a value of -262. Apply red to the gray levels below -256 (-296 and -377).

Select and color the next highest gray level (-216) to yellow. Comparing the patterns of these pixels to the reference NBR image, the values between -216 and -261 are probably high severity, so change the color back to red. Select subsequent gray levels and color code them in turn as deemed necessary to define the severely burned pixels by comparing the color-coded image to the full scene reference NBR image. It may help to note that high severity usually occurs in contiguous patches rather than scattered isolated pixels. For example: color the -175 and -135 levels to red. Most patches are contiguous. Try changing the value from -135 to -155 and the numbers of single, scattered, isolated pixels will appear. The value of -135 appears to match the darker patterns in the reference gray scale NBR. Choose -135 as the High threshold.

Estimate the moderate threshold.

Unlike the dNBR process, MTBS does not have a formula to generate the moderate threshold for single scene assessments. Unless there are ground observations to guide selection of the moderate threshold, visually estimate a value that preserves patterns seen in the NBR. Picking a value mid-way between the High and Low thresholds is a reasonable starting point.

Flicker the color-coded NBR with the grayscale NBR and the Post-fire and supplemental reflectance images to assess the severity classification. Adjust the values of the class intervals to better match the patterns.

Enter the estimated low, moderate, and high threshold values into the appropriate boxes: low value on the left, moderate in the middle, and high value on the right. The “no data threshold” can stay at -970 (bad data values) and “increased greenness threshold” does not apply for a single scene assessment so leave the value set at none. Enter a mapping comment “Visual estimates of severity classes.” Be sure to remove the previously generated \_nbr6.tif image before clicking the “Threshold” button, otherwise the process will fail because the previous image cannot be overwritten while loaded into the QGIS viewer panel.

END of Single Scene assessment procedure

**FINAL STEPS (after Threshold):**

**FMT3 Step: Mapping Status**- Once a fire assessment is finished, select “Complete” from the drop-down list, and click “Update Mapping.” The “Mapping Status” changes from “in-progress” to “complete”. It can be changed back to “in-progress” should the analyst need to make revisions.

**FMT3 STEP: Generate Metadata-** Clicking this button will generate a text file containing all the parameters associated with the fire severity assessment and add it to the fire folder.

# Glossary of Terms

**“Discovered fires”-** These are unknown fires i.e. they have no corresponding record in the fire occurrence database or Event Tracker Database (ETD). They are “discovered” while working on other, known fires and meet the size MTBS fire mapping criteria (size, not agriculture land). Check to be sure it is not a fire scar from a previous year. If it is a discovered fire, then use the ETD to add a fire record to the database. Search earlier Landsat imagery and use the date of the earliest Landsat scene for the fire “start” date.

# References:

Miller, J.D. & Thode, A.E. 2007. Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). *Remote Sensing of Environment*, 109, 66-80.

# Appendix #1 Assessing Peak of Green using NDVI curves

Full documentation for how to use the NDVI Profile tool is available at <https://mtbs.gov/ndvi-graphs>.

The MTBS NDVI Profile Tool (<https://mtbs.gov/ndvi-graphs>) displays the NDVI curves in multiple ways:

Single to Multiple Land Cover categories; one to multiple continuous years (Figures A&B)

Single Land Cover Over multiple years superimposed, (Figure C)

NDVI curves for neighboring Path/Rows (note 3x3 grid in upper right, click a p/r and NDVI curve will display below initial curve).

The fire date is indicated by the vertical line. By default, the top 5 land cover classes (by area) are displayed but individual land cover curves maybe clicked on or off, As the mouse cursor is moved over the graph, dates and actual NDVI values are displayed.

Use this interface to determine peak of green and evaluate the quality of image phenology match. Regional conditions are similar if the NDVI curve values are within 0.05 of each other. However, greenness conditions in the locale of the fire may differ from the scene average. The analyst should look for visual clues in the browse images such as the amount of greenness in grasslands or farmlands near the fire location, or snow levels in the mountains

**QGIS NDVI Curves:**

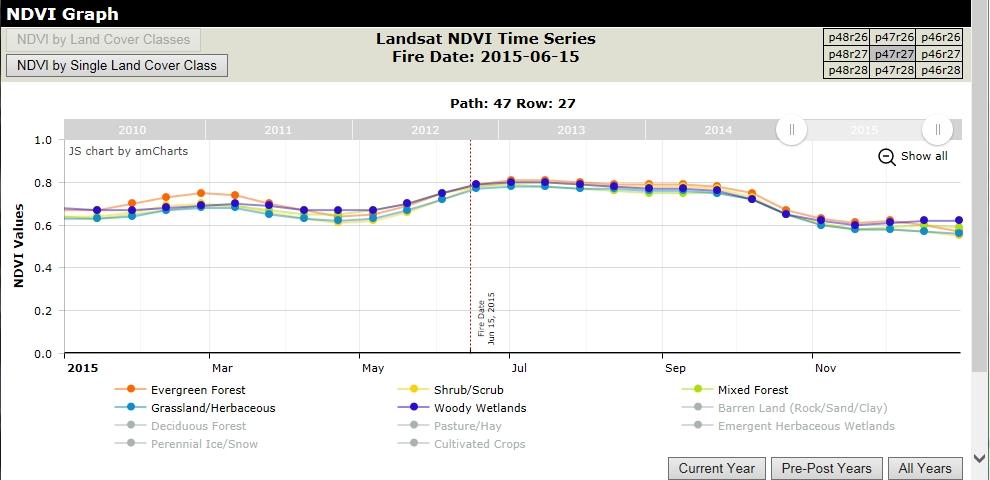
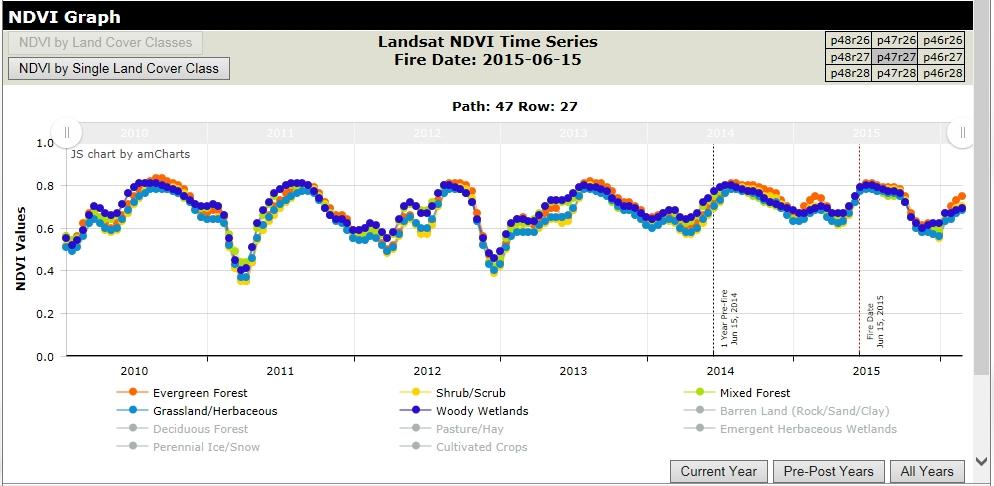
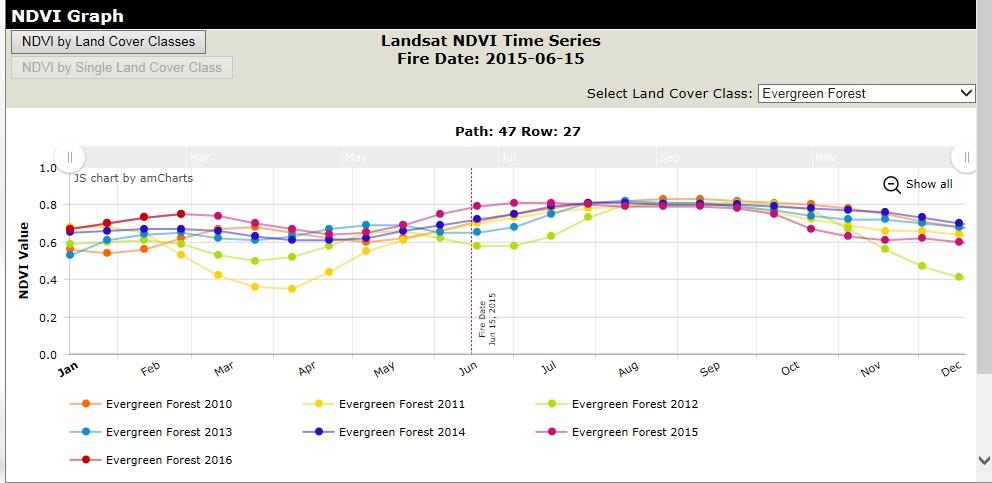


Figure A. Multiple land cover over one year.



**Figure B:** Multiple land cover over many years.



**Figure C**: One land cover over multiple years superimposed.

# Appendix #2: Adjusting Image origin coordinates:

First determine how far the image needs to move in the x and/or y direction to bring it into alignment. The convention adopted by MTBS is to adjust coordinates of the pre-fire image in 30-m increments to maintain pixel alignment between the pre- and post-fire images. However, if the post-fire image is obviously the one in error when compared to several other images, then adjust it instead.

Select the image to adjust and make a “duplicate” (Right click, “duplicate”.) Then, to avoid confusion, “rename” the duplicate. Duplicates can be saved permanently. Select the duplicate image and open the Properties/Metadata interface. At the bottom of the window there is another “Properties” window. Scroll down to find “Layer Extent.” The units are in meters and refers to the **outside corners** of the **lower left** and **upper right** pixels. Record these values in-case you need to revert to the original values. The next step (in QGIS Version 2.16) expects coordinate values for the **upper left** and **lower right** outside pixel corners, so you’ll need to be careful to get these values correct.

Click on “Raster/Conversion/Translate”. The “Translate” interface opens where you select the image to translate and enter the output file name. As you and enter the input and output file names, they appear in the dialog box at the bottom of the screen. Click on the pencil icon to edit and add the following command between the input and output file names:

-a\_ullr ulx uly lrx lry

Where ulx uly lrx and lry refer to the new coordinates for the Upper Left and Lower Right pixel corners of the output image.

Following is an example of the entire command listed in the dialog box:

>>>>>>

gdal\_translate -of GTiff D:/FireMappingQgis/event\_prods/fire/2015/wa4770212379720150615/mtbs\_11/test\_rdnbr.tif

-a\_ullr -2080875 3056895 -2061975 3044295

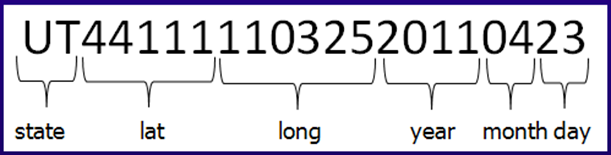
D:/FireMappingQgis/event\_prods/fire/2015/wa4770212379720150615/mtbs\_11/test\_rdnbr\_y60\_x-30.tif

>>>>>>

The output file name in this example shows the y coordinate added 60 meters and the x coordinate was reduced by 30 meters (-30). Compare this image see if the adjustment improved image alignment. If so, delete or rename the original and **rename** the adjusted image with the name of the original file (so subsequent processes use the adjusted image).

**Once you accept the adjusted origin coordinates, don’t forget to adjust the NBR origin and correctly update the NBR image name. Then re-run Scene Prep to re-create the dNBR with the adjusted image.**

**Appendix # 3: Event-ID Naming Convention:**



Note Lat and Long are decimal degrees and longitudes that are less than 100.000 West are preceded with a zero (e.g. -84.634 becomes: 084634).