Demonstrating the Use of Landsat Satellite Data for Burn Mapping using the Planned Burns GIS Toolbox

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1 Introduction

The following document outlines a feature added to the DELWP Planned Burns GIS Toolbox that allows retrieval and processing of Landsat Data via the Open Data Cube, which is managed on the National Computing Infrastructure (NCI) by Geoscience Australia (as Digital Earth Australia) and freely accessible by CSIRO.

The tool is designed to demonstrate that, in the absence of aerial imagery, it is possible to map burn severity using image segmentation and attribution. The specific use of Landsat data and the Data Cube are one example of how to approach this. However, other sensor systems (Sentinel and other high resolution satellite data) could just as easily be utilised, given the existence of a suitable image archive.

The example described below provides an overview of the steps required to use the tool. It does not demonstrate creation of a severity map product suitable for incorporating into DELWP systems or processes. More complete testing of the tool will occur in collaboration with DELWP staff, who are properly trained in developing severity maps suitable for the corporate Fire History spatial dataset.

2 Initial data preparation

The purpose of this step is to easily and accurately navigate to the region of interest (ROI), within which the burn has occurred and for which you require satellite imagery. This step is optional and it is possible to download imagery for the ArcMap window currently being displayed.

The easiest way to define the ROI is to use a polygon representing the boundaries of the planned burn. In this example I will use the Fire History shapefile and extract a previous fire severity mapping done manually.

2.1 Method

1. Load the Fire History shapefile
2. Navigate to the burn polygon(s) of interest
3. Select them using the Select Features tool

4. Extract those features by using Create Layer From Selected Features tool. This is located in the right-click menu of your layer, Selection submenu
5. Export the data (we will use it later on in the workflow). This can be done by using the *Export Data*... tool located in the right-click menu of your layer, *Data* submenu.

6. Focus the view of your document to the new layer by using the *Zoom to Layer* tool.

### 3 Retrieve Landsat Images

This step will automatically retrieve the region of interest from the Data Cube dataset hosted in the NCI infrastructures. This image archive includes data from Landsat 5, Landsat 7 and Landsat 8 satellites. Communication and data transfer are performed using the THREDDS server through HTTP requests. Those requests are built automatically in this way:

- The first portion of HTTP request is derived from listing and exploring the server data structure. This is completely independent from user input.
- A second portion directly derived from user input after completing the appropriate conversions (coordinate system conversion, date formatting, etc.)

Once a HTTP request is built, two types of data are retrieved:

- Pixel quality dataset (PQ), used to test the image for missing data and its quality
- Analysis ready dataset (NBART)

If the dataset retrieved meet the criteria, the image is then converted from netCDF to GeoTIFF.

#### 3.1 Method

1. Focus the ArcMap window on the ROI.
2. Run the *0 – Retrieve Satellite Images* tool from the *Planned Burns* Toolbox. Set the input parameters as following:
3.2 Result

When you press OK two raster images will be downloaded from the NCI. These images correspond to the first available image before the selected burn date and the first available image after the selected date.

The tool will select the images closest to your burn date, given they are cloud-free and don’t have missing data. Those last tests are performed using the PQ (pixel quality) dataset associated with each Landsat analysis-ready image.

Note that ArcMap will not initially display the image in true colour (Red, Green, Blue) format. To correctly display the image in true colour, change channel Layer Properties colour mapping to have Red -> Band_3, Green -> Band_2, Blue -> Band_1 as follows:

![Layer Properties](image)

Similarly if you wish to display the image in false colour (NIR, Red, Green), change channel Layer Properties colour mapping to Red -> Band_4, Green -> Band_3, Blue -> Band_2. You may also noticed that some areas are white, indicting missing data. Those are under- or over-saturated pixels that are automatically removed by the Data Cube pre-processing.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Preferred satellite imagery (please note this effects the time coverage available)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent</td>
<td>Same as Display (alternatively select the layer representing the ROI)</td>
</tr>
<tr>
<td>Date</td>
<td>Date of the planned burn</td>
</tr>
<tr>
<td>Saving Location</td>
<td>Preferred location to save the satellite image</td>
</tr>
</tbody>
</table>
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Example of pre-burn image (bands not correctly mapped)

Bands correctly mapped to true colour
4 Pre-processing

This step will perform several operations on the image to meet requirements for segmentation and classification. This includes:

- Conversion to an 8 bit unsigned image
- Resampling the image to a specific spatial resolution range

4.1 Method

1. Run the **1- Pre-Processing** tool using the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raster File</td>
<td>Select the post burn image</td>
</tr>
<tr>
<td>Cell Size</td>
<td>25 (m, to maintain the original resolution)</td>
</tr>
<tr>
<td>Interpolation</td>
<td>NEAREST (you could also select CUBIC or BILINEAR)</td>
</tr>
<tr>
<td>Output_path</td>
<td>Location for the re-sampled image</td>
</tr>
</tbody>
</table>

4.2 Result

The new image will likely appear identical to the input, but will be 8 bit unsigned integers (per channel) instead of 16 bit.
Pre-processed image (visible colours, Landsat bands 3-2-1)

Pre-processed image (standard false colours, Landsat bands 4-3-2)
## 5 Segmentation

This step will process the image using the Super-Linear Iterative Clustering (SLIC) algorithm to generate polygons representing “pseudo-homogeneous” areas. This will use all bands available (6 bands in the case of Landsat Thematic Mapper).

Because all bands are included, the resulting segmentation may not appear consistent with the image as it is displayed. However, this is likely to be the best estimate of continuous homogeneous land cover based on all wavelength bands recorded by the sensor.

In this step we will use the polygons that we extracted during step 1 to define the ROI, to ensure that only the “burn plan” area is segmented.

### 5.1 Method

1. Run the **2-Segmentation** tool from the Planned Burns Toolbox using the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raster File</strong></td>
<td>Select the resampled post-burn raster generated in the previous step</td>
</tr>
<tr>
<td><strong>Fire boundary</strong></td>
<td>Select the polygon defining the burn plan (optional)</td>
</tr>
<tr>
<td><strong>Region size</strong></td>
<td>This is the nominal (starting size) for the segmented polygons. The size of polygons changes as a result of the iterative process employed by SLIC</td>
</tr>
<tr>
<td><strong>Other parameters</strong></td>
<td>As per the figure below</td>
</tr>
</tbody>
</table>

![2-Segmentation Diagram](image)

### 5.2 Results

The output of this tool is a shapefile of polygons defining homogenous areas. Those polygons are affected by the parameters used, and in particular:
- Their initial size is equal to **Region size in pixels**, however the algorithm will iteratively adjust the size of each of them to better delineate those homogeneous areas.

- The complexity of their boundaries is affected by the **Smoothness** and **Blur Kernel Size**. The second parameter will define the strength of the initial image smoothing: a stronger smoothing will reduce the amount of details, causing more regular polygons. The first parameters instead influences directly the SLIC algorithm, that will be forced to limit the complexity of boundaries.

- The polygon size distribution is influenced by the **Minimum Size Percentage** parameter. A lower value will preserved very small polygons.

Due to the complexity of the algorithm used, multiple iterations of this step may be required to find your optimal result.

Sometimes you may wish to process a buffered area beyond the ROI (e.g. burning has occurred beyond the initial burn plan). This can be achieved by merging the ROI polygons (if required), and run the standard ArcMap Buffer tool to generate a larger polygon. You can then pass this new polygon as Fire Boundary to the Segmentation tool.

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**Polygons created using the Segmentation tool, overlayed on a false colour Landsat image**
6 Classification

This step will use the pre-processed image to cluster similar polygons from the segmentation. This can be used to assist in efficient burn severity classification, but will likely require some manual interpretation and adjustment. This initial classification step is sensitive to any local changes, including illumination, different vegetation and vegetation health, cloud and humidity. For this reason use of a greater number of classes than ultimately required can be useful, since merging like classes into a single burn severity is more efficient than trying to separate classes that include multiple levels of burn severity.

The classification is performed using clustering engines. Those will use pre-computed statistics for each of those polygons to group (cluster) similar features. Those pre-computed statistics can be selected using the user interface. Different combination of statistics will work better in different dataset, so iterating this step is strongly encouraged to obtain the best result.

6.1 Method

1. Run the 3 - Classification tool from the Planned Burns toolbox using the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raster file</td>
<td>Select the pre-processed post-burn satellite image</td>
</tr>
<tr>
<td>Geometry file</td>
<td>Select the shapefile from generated using the segmentation step</td>
</tr>
<tr>
<td>Expected number of classes</td>
<td>As preferred (more is better so they can be merged later)</td>
</tr>
<tr>
<td>Stats</td>
<td>Select the band (spectral) metrics you want to use to separate polygon classes</td>
</tr>
<tr>
<td>Skip Data Collection</td>
<td>Select False on the first classification run. You can select True on subsequent runs if you are using the same image and polygons</td>
</tr>
</tbody>
</table>
2. Change the symbology properties to display polygon classes in different colours. This step needs to be done the first time and any time you change the number of classes.

6.2 Results

This step will likely be an iterative process. In fact this type of classification will separate polygons that appear different for various reasons (including but not limited to fire severity). For certain images default parameters may already be the optimal ones, but for others you may need to increase the number of classes, change the statistics used or even try different clustering algorithms.

The efficiency of this iterative process will be aided by the *Skip Data Collection* option. This needs to be off the first time you classify the polygons from a new segmentation, but after that you can reuse the results of the previous run to perform a new classification (by ticking the Skip Data Collection option).

The effectiveness of the segmentation will also affect the classification. Only one class is attributed to each polygon, so if the polygon spans two different land cover types the result of the classification will likely be a “mixture” class.

The classification can be changed manually for individual polygons by changing the *AUTOCLASS* field in the attribute table. The most efficient way to do this is by selecting ALL polygons that you want to change, then in *editing mode*, use *Field Calculator* to assign the class you want.
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Classified polygons overlayed on a false colour Landsat image

Classified polygons overlayed on manually mapped severity (light purple is higher severity in both)
7 Populate Attribute Table

This step will perform two operations:
1. it will populate the segmented polygons attribute table with the appropriate information like SEASON and START_DATE;
2. it will help the user link the automatically generated class (AUTO_CLASS) to a fire severity (FIRE_SEV_3) class.

7.1 Method

1. It is useful to manually change colours of your classes to something that intuitively matches the fire severity (this will help avoid mistakes in the next step). Use the same colour for different automatically generated classes that you believe are the same fire severity.

2. Run the **Populate Attribute Table** tool from the Planned Burns toolbox, using the following parameters:

<table>
<thead>
<tr>
<th>Geometry file</th>
<th>Select the Segmented and classified polygon shape file</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert Autoclass to Severity class</td>
<td>True</td>
</tr>
<tr>
<td>Relational Table</td>
<td>This table is used to map each autoclass to a severity class by clicking on the Severity Class cell and change to the appropriate value</td>
</tr>
</tbody>
</table>
Demonstrating the Use of Landsat Satellite Data for Burn Mapping using the Planned Burns GIS Toolbox

![Image of Planned Burns GIS Toolbox interface](image)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firefly (optional)</td>
<td></td>
</tr>
<tr>
<td>Method (optional)</td>
<td></td>
</tr>
<tr>
<td>Method Code (optional)</td>
<td></td>
</tr>
<tr>
<td>Accuracy (optional)</td>
<td></td>
</tr>
<tr>
<td>OSF ID (optional)</td>
<td></td>
</tr>
<tr>
<td>GPA ID (optional)</td>
<td></td>
</tr>
</tbody>
</table>

Check box for Convert AutoClass to Severity Class (optional)

Relational table between AUTO_CLASS values and FIRE_SPY3 (optional)

<table>
<thead>
<tr>
<th>AUTO_CLASS</th>
<th>Severity Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UNBURN</td>
</tr>
<tr>
<td>4</td>
<td>UNBURN</td>
</tr>
<tr>
<td>5</td>
<td>UNBURN</td>
</tr>
<tr>
<td>6</td>
<td>BURN_3</td>
</tr>
<tr>
<td>7</td>
<td>UNBURN</td>
</tr>
<tr>
<td>8</td>
<td>UNBURN</td>
</tr>
<tr>
<td>9</td>
<td>BURN_3</td>
</tr>
</tbody>
</table>
8 Merge Polygons

This step will simplify your map by merging adjacent polygons of the same burn severity class. The native ArcMap operation that this uses is called *Dissolve*, and can be performed on the basis of any attribute table field. In our case this will be either the AUTO_CLASS or the FIRE_SEV_3 field.

8.1 Method

1. Run the **5 - Merge Polygons** tool from the Planned Burns toolbox using the following parameters:

<table>
<thead>
<tr>
<th>Geometry file</th>
<th>Select the Segmented and classified polygon shape file</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>FIRE_SEV_3 (or AUTO_CLASS depending on which field you want to base your polygon merge on)</td>
</tr>
</tbody>
</table>
The output of the merged polygon step is a classified map that can act as a basis for further manual editing and validation, e.g. to generate a final burn severity map. For best results overlay the merged polygons over high resolution aerial imagery. In cases where no high resolution imagery is available, satellite based segmentation and classification may act as an interim estimate of burn performance against objectives.