BAL Documentation

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Geoscience Australia

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CONTENTS

CHAPTER

ONE

OVERVIEW

This toolbox is used to compute the Bushfire Attack Level (BAL) for an area of interest within Australia based on the input vegetation and elevation datasets.

The computation algorithm is adapted spatially to Method 1 in the Australian Standard AS 3959 (2009)–*Construction of buildings in bushfire-prone areas*.

The output contains eight raster files that represent the BAL for each of eight cardinal directions and an extra raster file that represents the maximum BAL of the eight directions for each grid cell.

CHAPTER

TWO

DISCLAIMER

2.1 Disclaimer

Geoscience Australia has tried to make the information in this product as accurate as possible. However, it does not guarantee that the information produced by this product is totally accurate or complete. Therefore, users should use the BAL values derived from the BAL toolbox as an indicative guide only, and should not solely rely on this information when making a decision.

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CHAPTER

THREE

INTRODUCTION

3.1 Introduction

Fire is a natural feature of the Australian landscape and remains an ever-present threat. Bushfire threat analysis aims to inform the fire authorities and the community of the bushfire hazard in an effort to manage the risk posed to life, property and the environment.

Bushfire Attack Level (BAL) is a measure of the severity of a building's potential exposure to bushfire. It is defined in the Australian Standard AS 3959 (2009)–*Construction of buildings in bushfire-prone areas*, to serve as a basis for establishing the requirements for construction, to improve the protection of buildings from bushfire attack. The Standard describes how to compute the bushfire attack level for any location and directly links this to recommendations on the design of existing or planned buildings.

The BAL toolbox implements the rules described by Method 1 in AS 3959 (2009) by integrating them into a computational code that can be run in the ESRI ArcGIS 10.2 environment.

3.1.1 Package structures

The toolbox name is **BAL.tbx**. This toolbox is associated with a python script, **bal.py**, to derive BAL. The script **bal.py** links to a python script **calculate_bal.py** and a module **Utilities**, which includes supporting dictionaries defined in two python scripts:

- value_lookup.py;
- bal_database.py.

There are three more folders:

- **docs**: holding the documentation files.
- **tests**: holding the unit tests, scenario tests and their test data.
- **examples**: holding the example input and output data.

3.1.2 Use limitations

The BAL tool developed in Geoscience Australia (GA) has been developed and tested in ArcGIS 10.2. However, GA does not guarantee that the information derived is totally accurate or complete. Therefore, you should not solely rely on this information. Key limitations/approximations include the following:

- The BAL is produced based on the simplified method (Method 1) in AS 3959 (2009). When the land downslope is more than 20 degrees, more detailed method (Method 2) should be adopted. Method 2 has not been incorporated into the toolbox developed. Instead, a constant value of 200 is provided as BAL for such circumstances.

- Elevation data is a critical input of the tool. Digital Elevation Model (DEM) with finer resolution usually leads to more accurate BAL results. The example data uses a DEM with a resolution of 1 second of arc (approximate 30 m by 30 m grid cell at the equator), the best available national scale elevation dataset at the time of modelling. As with all spatial analyses, the results are sensitive to the input DEM's quality, resolution, coverage and currency and should therefore be used with this understanding.
- Vegetation data is another critical input into the tool. Method 1 in AS 3959 (2009) considers the vegetation up to 100 metres from the site of interest. Ideally the vegetation with finer resolution (preferred at metre level) is required to derive sensible BAL analyses. Where finer vegetation data is not available, the alternative coarse vegetation data may lead to inaccurate output BAL.
- The BAL toolbox requires availability of one extension within ArcGIS - **Spatial Analyst**. If the extension is available, its licence will be automatically checked out when needed and checked in when it is not needed any more. Without the licence of **Spatial Analyst**, the tool will fail to run.
- The BAL toolbox is intended to run in the ArcGIS toolbox environment and is not intended to run in a Python script environment.
- This software algorithm adapts to the Method 1 in AS 3959 (2009) by modelling it spatially. Readers are assumed to be familiar with AS 3959 (2009). For the detailed description of the Method 1, please refer to the Standard AS 3959 (2009).

3.2 Background

The algorithm used to calculate the BAL is based on Method 1 in the Australian Standard AS 3959 (2009)– *Construction of buildings in bushfire-prone areas*.

Method 1 is a simplified procedure that involves five steps to determine BAL, and is subject to limitations on the circumstances in which it can be used.

Limitation: This method doesn't apply to the circumstances where the effective slope under the classified vegetation is more than 20 degrees downslope.

3.2.1 Procedure to determine BAL

According to the Standard AS 3959 (2009), five steps are involved to calculate BAL.

Step 1: Select the relevant FDI based on the locations according to Table 2.1 in the Australian Standard AS 3959 (2009). For example, from Table 2.1, the FDI for Western Australia is 80.

Step 2: Reclassify the input vegetation dataset into seven vegetation types defined in Table 2.3 in the Standard AS 3959 (2009).

- 1: Forest,
- 2: Woodland,
- 3: Shrubland,
- 4: Scrub,
- 5: Mallee/Mulga,
- 6: Rainforest,
- 7: Grassland/Tussock moorland.

The numbers from 1 to 7 are assigned to these vegetation classes respectively for calculating BAL.

Step 3: Calculate the distance of the site from the classified vegetation. According to AS 3959 (2009), the vegetation is considered when its distance from the site of interest is within 100 metres.

Step 4: Determine the effective slopes (the gradient from each cell) and their aspects under the classified vegetation types. If a slope's aspect is in the same direction as the vegetation from the site, this slope is regarded as a downslope that will be further analysed. Otherwise the slope is regarded as an upslope.

When calculating BAL, upslopes and flat lands are treated as a single category. For downslopes, the Standard breaks them down into five classes:

- 0 < downslope <= 5 degrees
- 5 < downslope <= 10 degrees
- 10 < downslope <= 15 degrees
- 15 < downslope <= 20 degrees
- > 20 degrees (beyond consideration of Method 1)

Step 5: Determine the BAL from an appropriate table defined in AS 3959 (2009) based on the input FDI. For example, for Western Australia, the FDI is 80 and thus Table 2.4.3 is adopted for deriving the BAL.

3.2.2 Deriving and interpreting BAL

We consider eight cardinal directions: north, northeast, east, southeast, south, southwest, west, and northwest.

For each cardinal direction, we consider the neighbouring cells up to 100 metres from the site. We calculate the BAL for each neighbouring cell with regards to the site based on the neighbouring cell's vegetation type, upslope or downslope degrees, and its distance to the site.

The BAL falls into a list of (12.5, 19, 29, 40, 100), where 100 represents Fire Zone (FZ). There is one more circumstances beyond Method 1 in AS 3959 (2009).

- Where the downslope is greater than 20 degrees and there is vegetation, a constant value of 200 is given to the BAL.

The maximum BAL is selected among all neighbouring cells in a given cardinal direction to represent the BAL for that direction.

The final BAL for the site of interest is determined by selecting the maximum BAL from all eight cardinal directions.

CHAPTER

FOUR

HOW TO USE THE TOOLBOX

4.1 Installation

Installing BAL Toolbox is intended to be a simple process, requiring only basic understanding of ArcGIS toolbox operations. It has been installed and tested on ArcGIS 10.2.

4.1.1 Unzipping the toolbox

The software package is delivered as a compressed zip file. Unzip the toolbox into a location on your computer, for example C:\bal. Then you will have stored all the files at folder C:\bal.

4.1.2 Dependencies

This toolbox is developed and tested within ArcGIS 10.2 that integrates with Python 2.7 and Numpy 1.6.2. It is not recommended to install an independent version of Python for use in ArcGIS. Using a different version of Python may lead to compatibility issues.

However, if necessary, there are several ways to obtain the required libraries – using Python's recommended tool pip, installing a distribution such as Python(x,y) package (for Windows environments), or installing the libraries from source or binary installers (pre-compiled binary Windows installer versions for all the libraries (both 32-bit and 64-bit) can be obtained here).

For detailed instructions on installation of these dependencies, please see the documentation for each individual library.

- Python - v2.7 preferred
- Numpy - v1.6.2 preferred
- Arcpy in ArcGIS 10.2

4.1.3 Setting the environment

To enable BAL toolbox to run flawlessly, you may need to change some environment settings. The important variable to set is the `PYTHONPATH` variable. This should be set to the path where you have extracted the contents of the zip file. A complete discussion on environment variables in Python is given in the Python documentation.

Windows

The Python documentation contains some simple instructions for setting environment variables on Windows systems here. See this link for setting the variables on different Windows systems.

4.1.4 Testing the installation

The code includes a suite of unit tests that ensure elements of the code base work as expected. The code should be tested before running the toolbox.

The test suite can be run from the main directory. On Windows, run the `run_test_all.cmd` script from the main BAL directory.

4.2 Setting up the toolbox

4.2.1 Adding the toolbox into ArcGIS 10.2

Follow the steps below to add the toolbox into ArcGIS 10.2:

- Open the ArcToolBox window. See Figure 4.1.

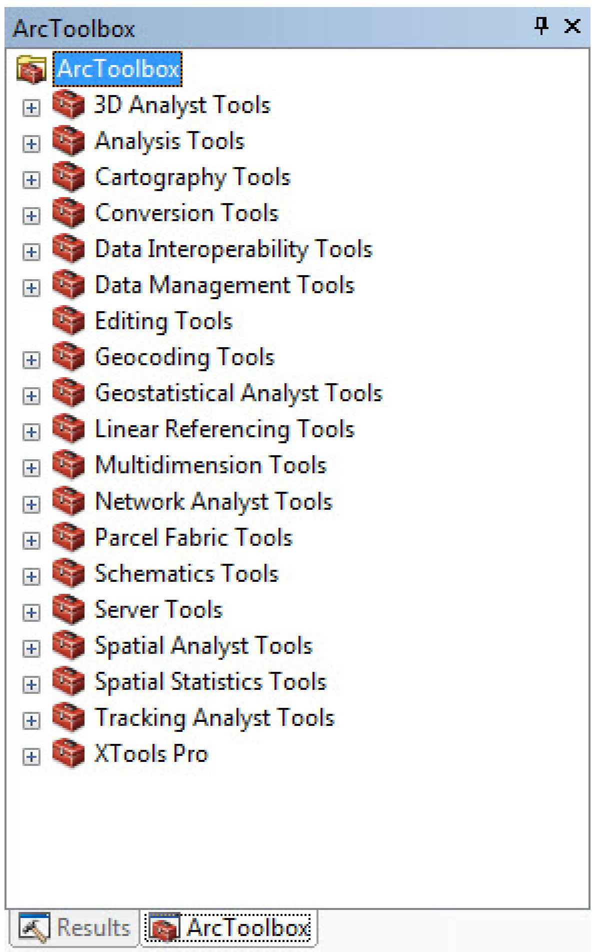

Figure 4.1: The ArcToolbox window.

- Right click **ArcToolbox** at the top of the window, see Figure 4.2.
- Select **Add Toolbox...**, a dialog box is open. See Figure 4.3.
- In the dialog box, navigate to the location of the package, for example C:\bal, you will find the **BAL.tbx**. See Figure 4.3.

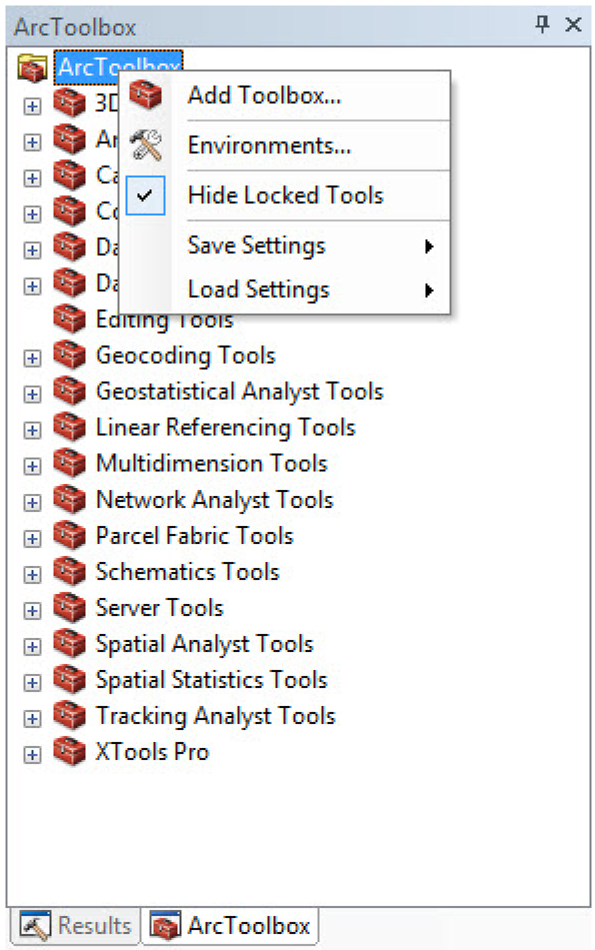

Figure 4.2: Right click **ArcToolbox** in the ArcToolbox window.

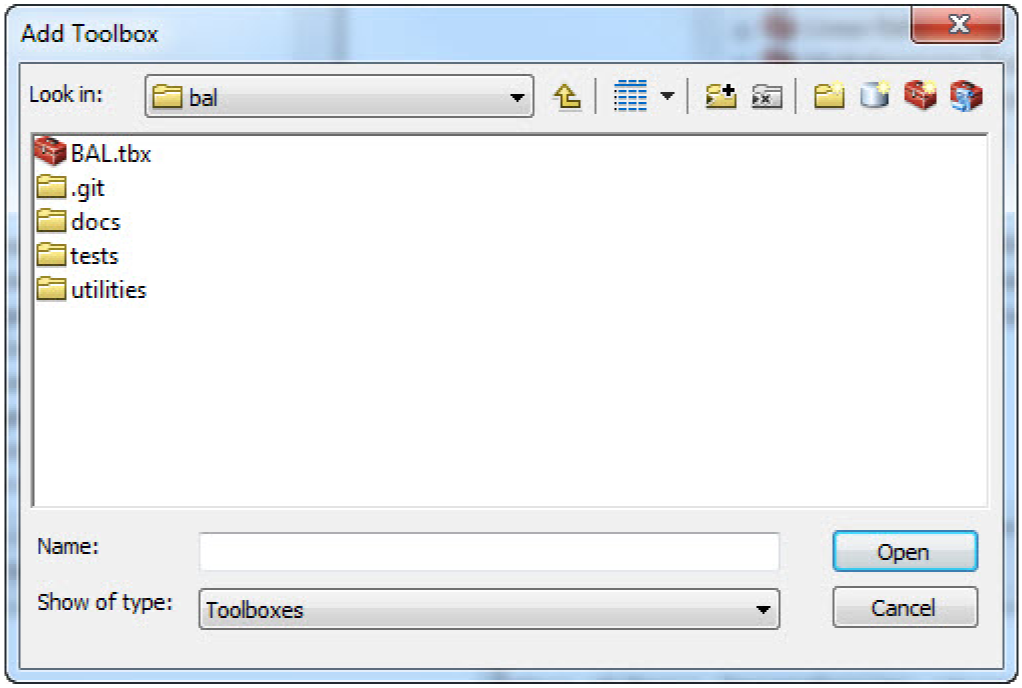

Figure 4.3: The **Add Toolbox** dialog window.

- Select **BAL.tbx** and click **Open**, a new toolbox called **BAL** is added to the ArcToolbox. See Figure 4.4.

4.3 Running the tool

To calculate the BAL, we use the **BAL calculation** tool within the **BAL** toolbox installed in ArcGIS 10.2.

Select the **BAL calculation** tool within the **BAL** toolbox, see Figure 4.5.

Then the **BAL calculation** window is open, see Figure 4.6.

4.3.1 Parameters within the tool

Input DEM raster:

Open the input DEM file from a specific location. The DEM is required to be in a projected coordinate system with linear unit metre. For example GDA94 / MGA zone 50 is a projected spatial reference system and is suitable for use in the western part of Western Australia. More information about GDA94 / MGA zone 50 can be found here.

Input vegetation raster:

Open the input vegetation dataset from the location same as the input DEM. The vegetation dataset can be in either a geographical or a projected coordinate system. It will be reprojected to the same projection and same resolution as DEM by the BAL tool.

Vegetation reclassification:

Reclassify the input vegetation classes into those defined in the Australian Standard AS 3959 (2009). There are seven classes defined in the Standard. In this tool, we give each class a unique number, i.e.:

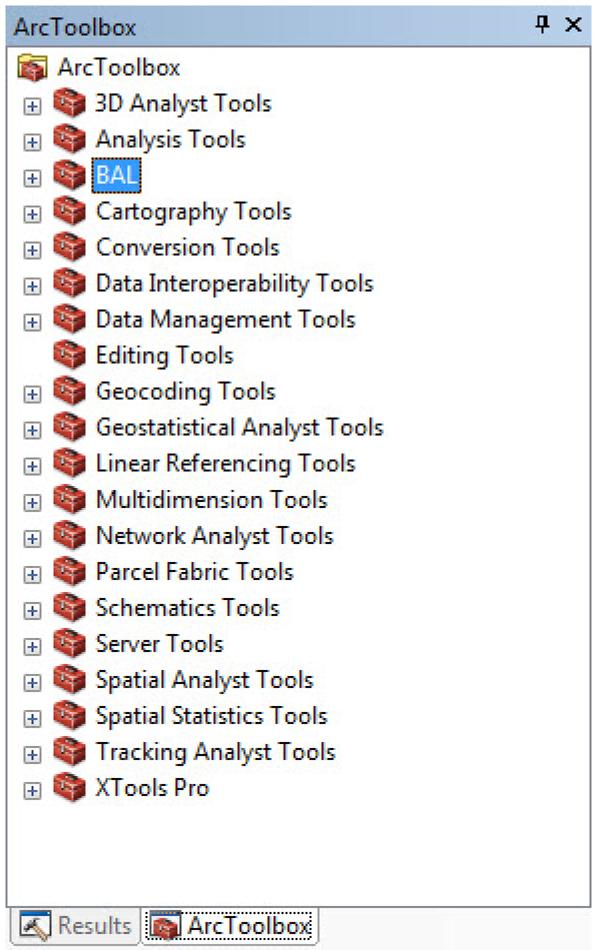

Figure 4.4: The **Bal** toolbox is added.

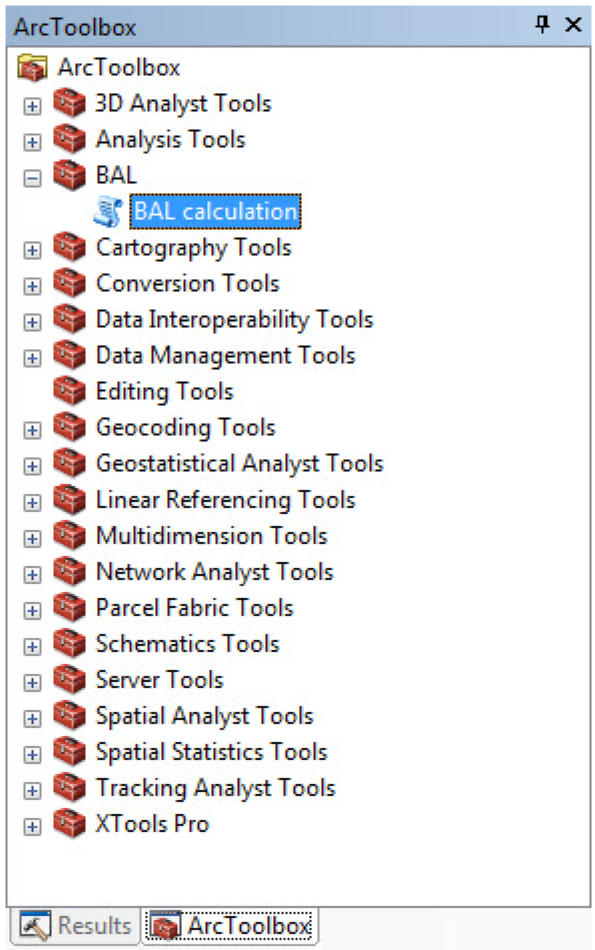

Figure 4.5: Select the tool **BAL calculation**.

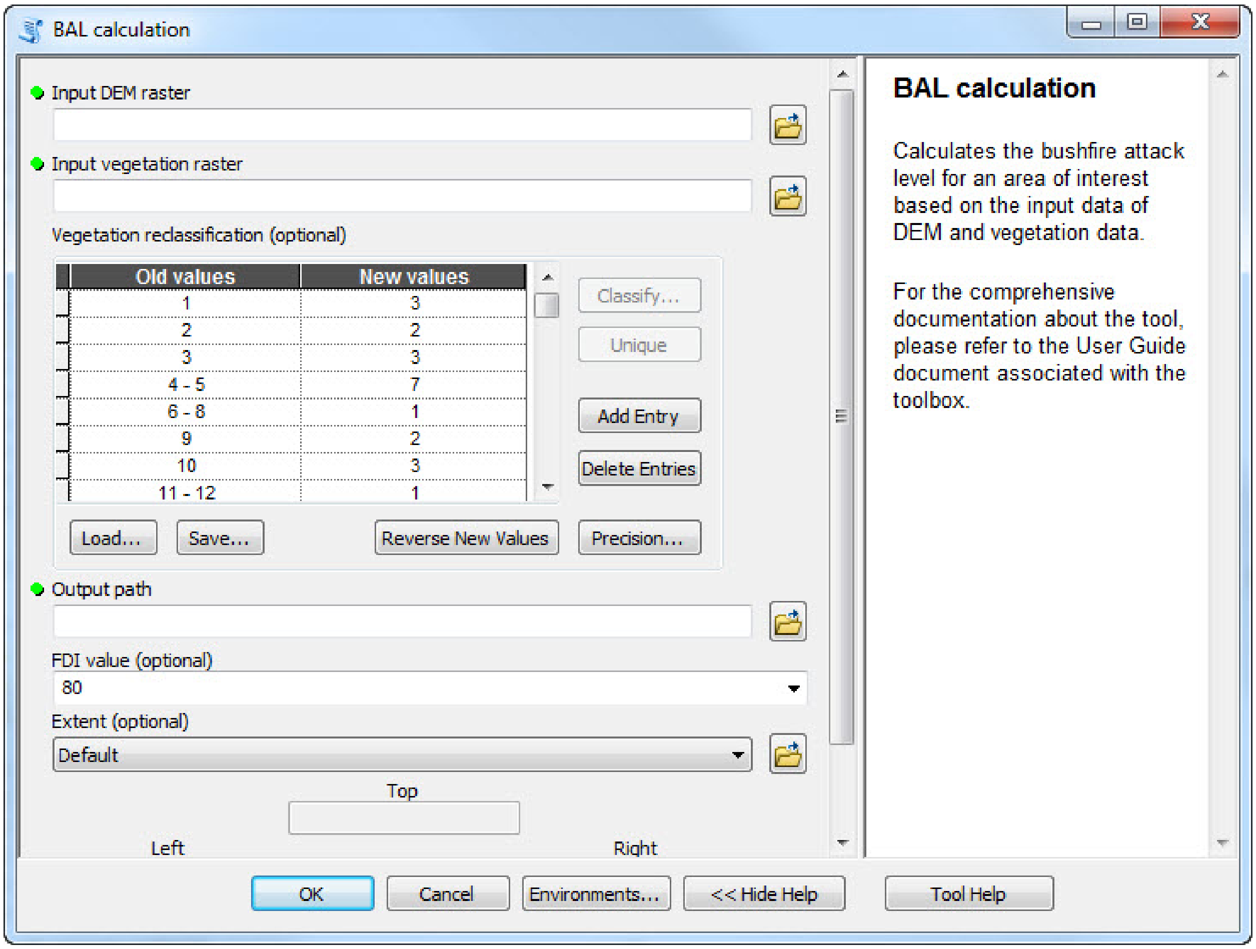

Figure 4.6: The **BAL calculation** window.

- 1: Forest,
- 2: Woodland,
- 3: Shrubland,
- 4: Scrub,
- 5: Mallee/Mulga,
- 6: Rainforest,
- 7: Grassland/Tussock moorland.

A sample reclassification map is entered for the example data. The reclassification map needs to be changed by the users according to their own input vegetation data.

Output path:

Define the output location.

FDI value:

The input Fire Danger Index (FDI) value has four choices (100, 80, 50, 40) based on the locations, which are specified in the Australian Standard AS 3959 (2009).

- 100: Australian Capital Territory (ACT), part of New South Wales (NSW) (Greater Hunter, Greater Sydney, Illawarra/Shoalhaven, Far South Coast and Southern Ranges fire weather districts), and Victoria general (excluding alpine areas).
- 80: NSW general (excluding alpine areas, and the areas with FDI 100), South Australia (SA), and Western Australia (WA).
- 50: NSW alpine areas, Tasmania, and Victoria alpine areas.
- 40: Northern Territory (NT), and Queensland (Qld).

Select the FDI value from a suite of values (100, 80, 50, 40). It is optional. The default value is 80 that is applicable in Western Australia.

Extent:

The extent is used to select the area of interest for which BAL will be calculated. The output data extent will be where you have consistent coverage of DEM and vegetation data within the area of interest.

Note:

- There is a limitation in raster file name length and file path length in ArcGIS. For a raster name in ESRI Grid format, the maximum number of characters is 13 and for full path name, the maximum number of character is 128. For more information, click here. In addition, as tested, each folder name's length should be restricted to at most eight characters.
- The script requires that the input DEM and vegetation dataset are in the same location. The tool will fail to run when the input DEM and vegetation datasets are not in the same folder.

4.3.2 Output

A suite of rasters are produced and stored in the output folder. They represent the BAL for the area computed in each of eight cardinal directions (E, S, W, N, NE, NW, SE and SW) and the maximum BAL of all directions. Figure 4.7 is an example output.

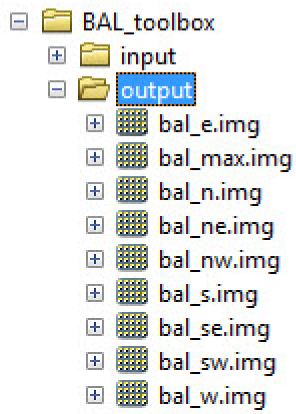

Figure 4.7: An example BAL output window.

4.4 An Example

4.4.1 Input

Input DEM:

jerram_dem: Esri Grid format, MGA 50, 25 m resolution. See Figure 4.8. The input DEM is located under the **examples\input** folder.

Input vegetation:

jerram_veg: Esri Grid format, GDA 1994 Australia Albers, 100 m resolution. See Figure 4.9. The input vegetation dataset is located under the **examples\input** folder.

Input vegetation reclassification map:

There are many classes in the original vegetation. To derive the target vegetation classes described in the Standard (1: Forest, 2: Woodland, 3: Shrubland, 4: Scrub, 5: Mallee/Mulga, 6: Rainforest, 7: Grassland/Tussock moorland.), the remap string is defined as: "1 6;2 1;3 1;4 1;5 13 2;14 5;15 18 3;19 22 7;23 4;24 25 NODATA;26 4;27 28 NODATA;29 4;30 1;31 2;32 5;99 NODATA".

Output path:

The example output path is C:\github\bal\examples\output.

FDI value:

Default value 80 is selected.

Extent:

Default is selected.

After all input parameters are defined, the fields in the BAL calculation window are all populated. See Figure 4.10.

4.4.2 Process

After clicking the **OK** button in the above window, the calculation starts running with a progress reporting in a pop-up window. When it finishes successfully, the pop-up window looks like Figure 4.11.

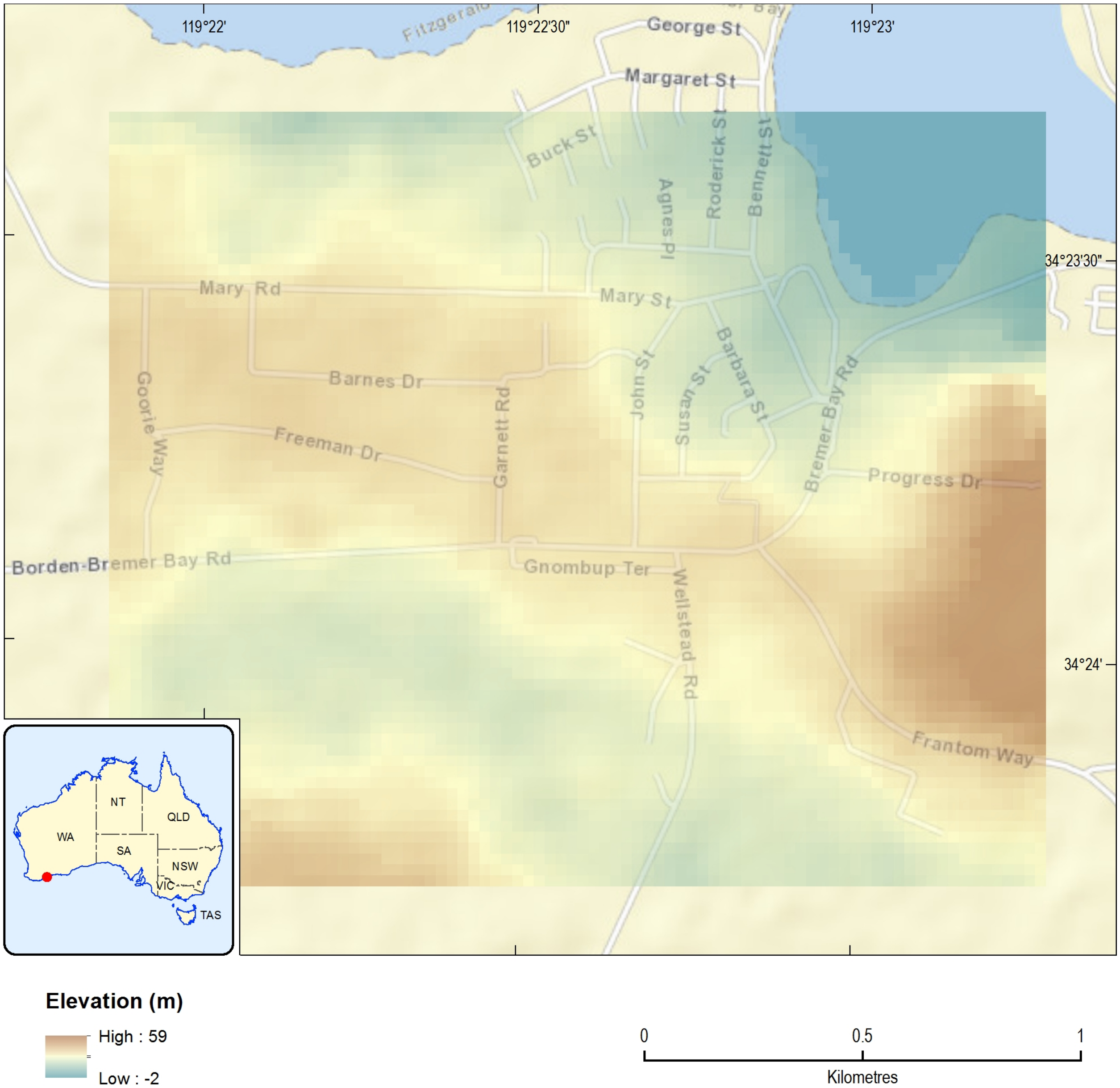

Figure 4.8: Example DEM data at Jerramungup, WA.

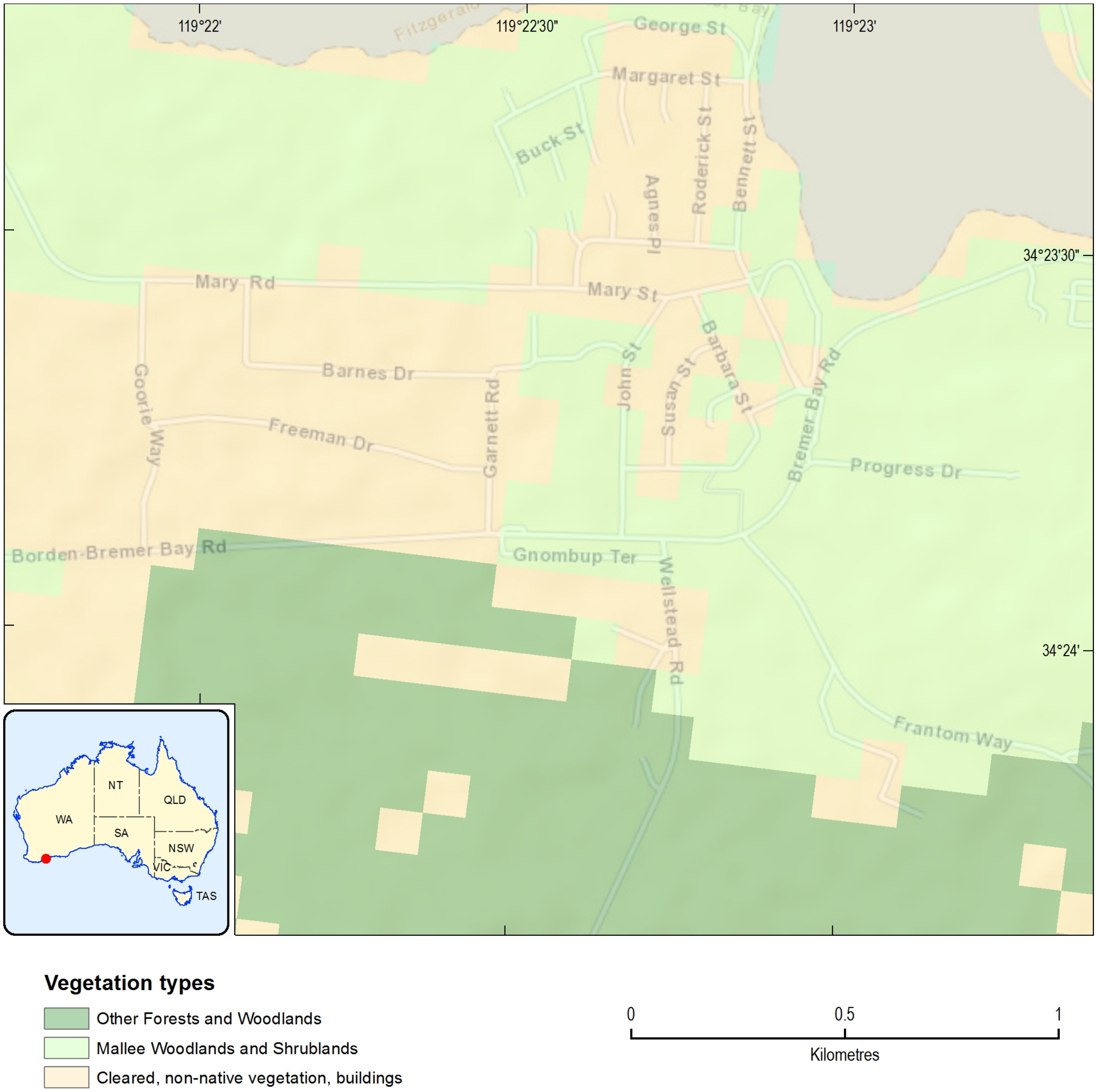

Figure 4.9: Example vegetation data at Jerramungup, WA.

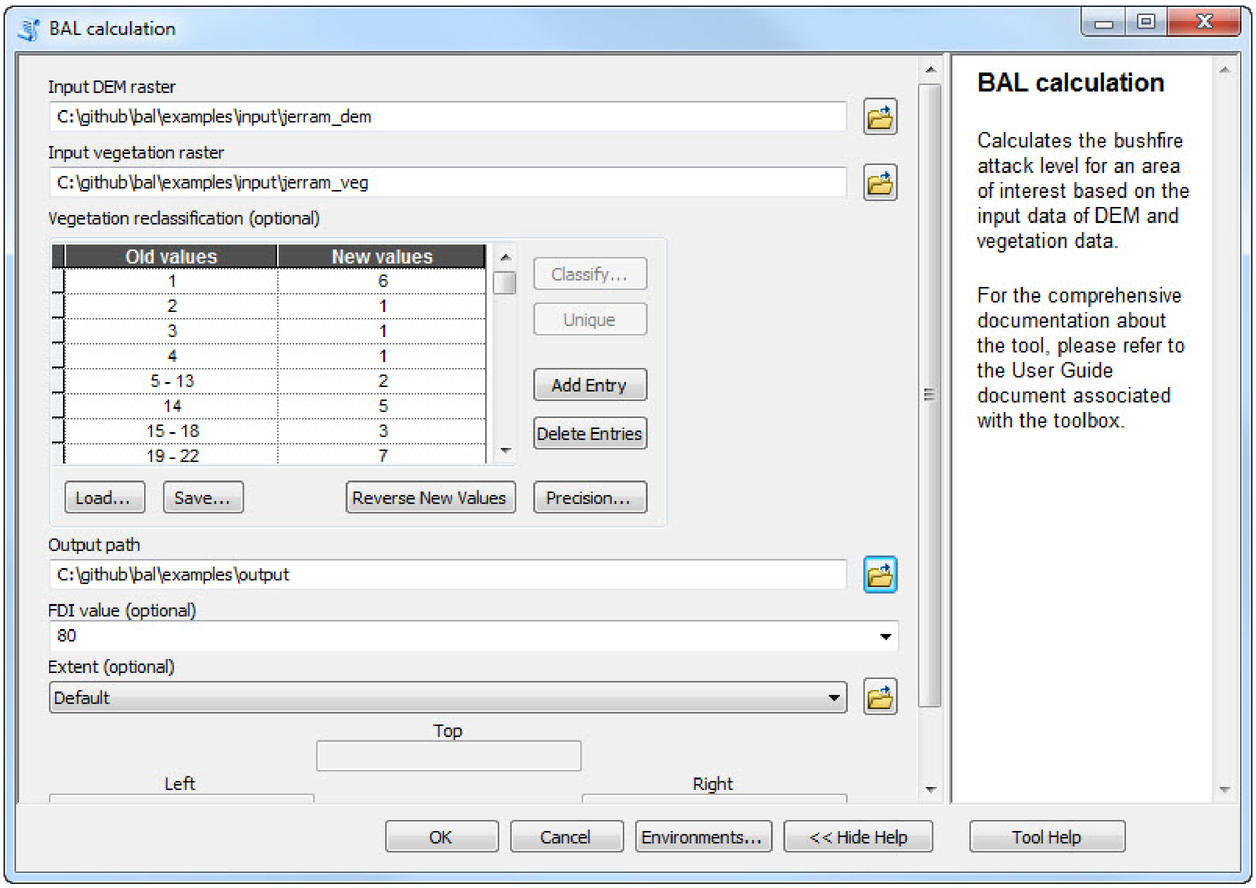

Figure 4.10: Example input parameters within BAL calculation window.

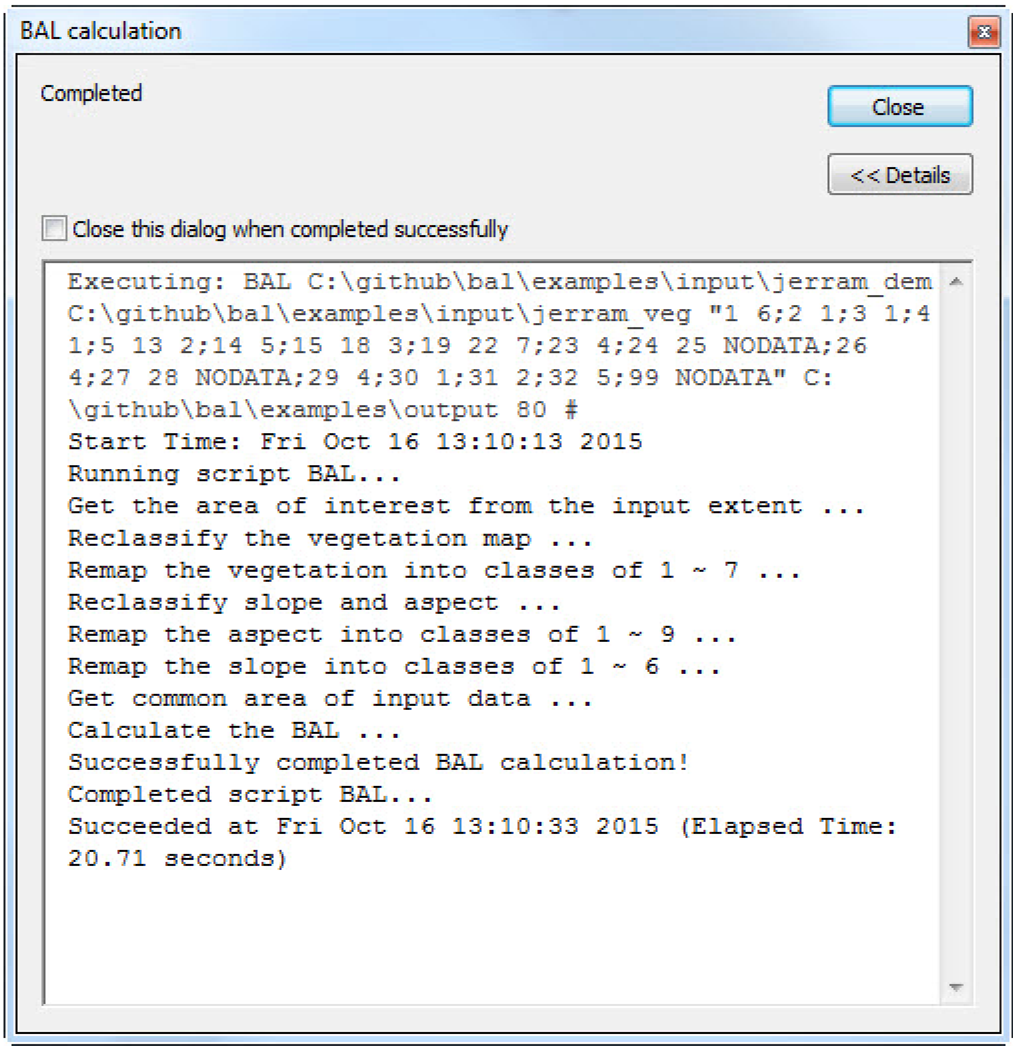

Figure 4.11: Example pop-up window when the calculation finishes.

4.4.3 Output

Nine rasters are produced under C:\github\bal\examples\output. Figure 4.12 displays the maximum BAL raster file named as bal_max.img for this example.

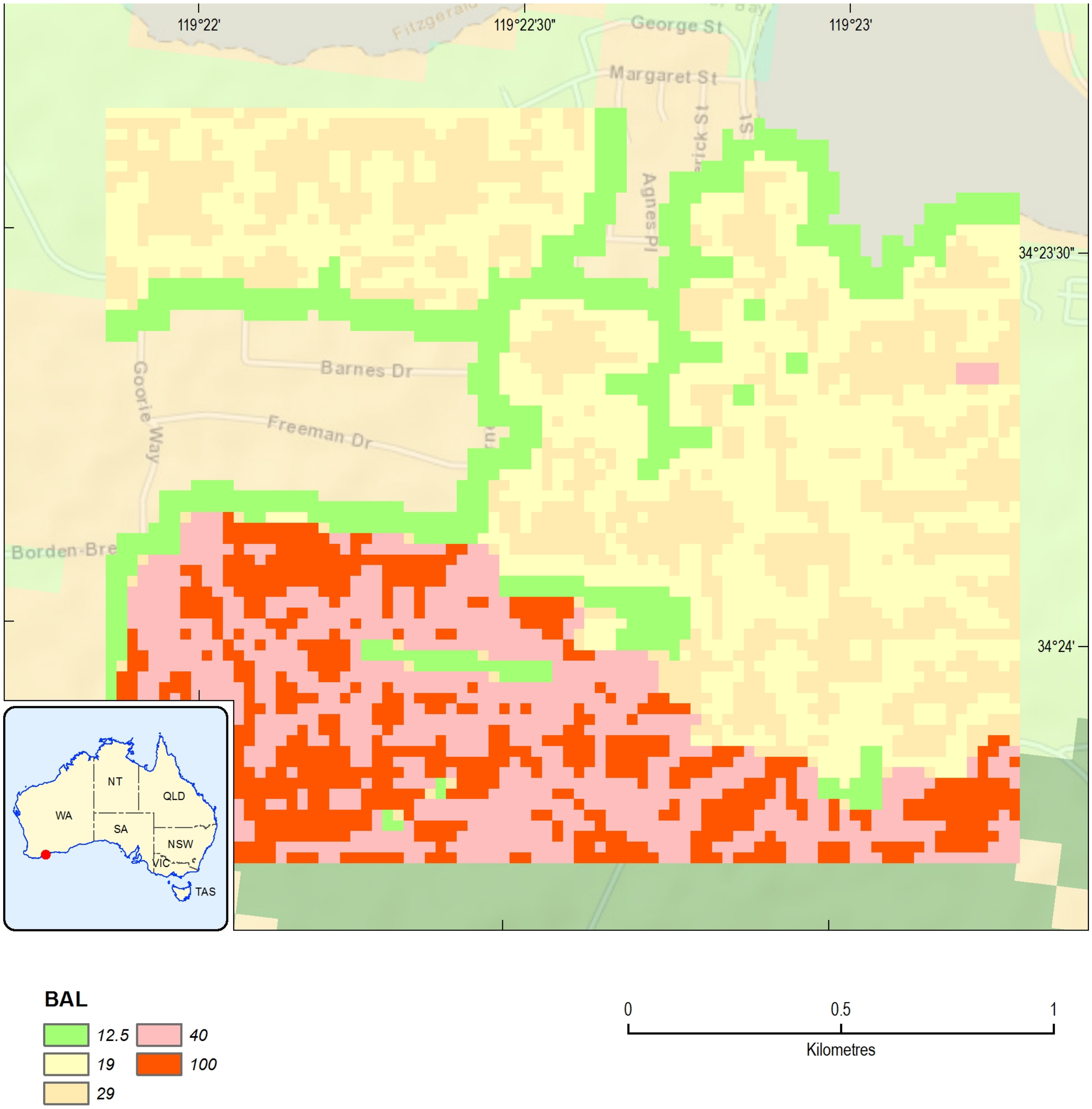

Figure 4.12: Example output BAL at Jerramungup, WA.

CHAPTER

FIVE

CODE DOCUMENTATION

This part is extracted from the source code in-line documentation and included in this document for the completeness of the software package. It does not directly instruct users how to use the toolbox to calculate the BAL. Instead, it might be useful for software engineers or developers to review the source code and maintain or upgrade it in the future.

5.1 Bushfire Attack Level

5.1.1 bal.py

`bal` - Calculate the bushfire attack level (BAL)

This module is used to produce the bushfire attack level (BAL) for an area of interest within Australia based on input vegetation and elevation datasets as per Method 1 in the Australian Standard AS 3959 (2009) – Construction of buildings in bushfire-prone areas.

moduleauthor Tina Yang <tina.yang@ga.gov.au>

`bal.`**`bal_calc`**`(`*vegetation*, *dem*, *fdi*, *output_folder*, *remap*, *mask*`)`

Calcuate BAL based on vegetation map and DEM.

Parameters

- **vegetation** – *file* the original vegetation
- **dem** – *file* the input DEM
- **fdi** – *int* the input FDI value
- **output_folder** – *str* the output folder
- **remap** – *srt* the vegetation reclassification
- **mask** – *file* the mask for the effective area of interest (AOI)

`bal.`**`find_aoi`**`(`*extent*, *dem*, *veg*`)`

Find the effective area of interest based on input vegetation map, DEM and extent.

Parameters

- **extent** – *str* the input extent
- **dem** – *file* the input DEM
- **veg** – *file* the input vegetation

Returns *file* the mask for effective AOI

`bal.find_common_area(veg_class, slope, aspect)`
Find the common area of vegetation, slope and aspect to calculate BAL.

Parameters

- **veg_class** – *file* the reclassified vegetation
- **slope** – *file* the slope derived from DEM
- **aspect** – *file* the aspect derived from DEM

Returns *file* the vegetation in common area

Returns *file* the slope in common area

Returns *file* the aspect in common area

`bal.get_extent_mask(extent, mask)`
Derive the mask for the customised input extent.

Parameters

- **extent** – *str* the input extent
- **mask** – *file* the output mask

`bal.get_footprint(raster, footprint)`
Find the footprint of a raster

Parameters

- **raster** – *file* the input raster
- **footprint** – *file* the output footprint

`bal.get_slope_aspect(input_dem, output_folder, mask)`
Calculate the slope and aspect from the input DEM

Parameters

- **input_dem** – *file* the input DEM
- **output_folder** – *str* the output folder
- **mask** – *file* the mask for the effective AOI

Returns *file* the reclassified slope

Returns *file* the reclassified aspect

`bal.reclass_veg(veg, dem, output_folder, remap, mask)`
Reclassify the original vegetation into the categories classified as Table 2.3 in AS 3959 (2009).

Parameters

- **veg** – *file* the input vegetation
- **dem** – *file* the input dem used as reference projection
- **output_folder** – *str* the output folder
- **remap** – *srt* the vegetation reclassification
- **mask** – *file* the mask for the effective AOI

Returns *file* the reclassified vegetation

`bal.run()`
Run the BAL calculations.

5.2 Calculate_bal

5.2.1 calculate_bal.py

`calculate_bal` - essential part of calculating the bushfire attack level (BAL)

This module includes algorithms that are used to calculate BAL as per Method 1 in the Australian Standard AS 3959 (2009) – Construction of buildings in bushfire-prone areas.

moduleauthor Tina Yang <tina.yang@ga.gov.au>

`calculate_bal.`**`bal_cal`**(*veg_class*, *slope*, *aspect*, *fdi*)
Calculate the BAL based on the classified vegetation and the combined slope and vegetation according to an appropriate table in AS 3959 (2009) to determine the bushfire attack level (BAL).

Parameters

- **veg_class** – *file* the input classified vegetation
- **slope** – *file* the input slope
- **aspect** – *file* the input aspect
- **fdi** – *int* the input FDI value

`calculate_bal.`**`bal_esti`**(*veg*, *dist*, *slope*, *fdi*)
Calculate the BAL based on the vegetation class, slope degree and horizontal distance from the point of interest (POI).

Parameters

- **veg** – *float* the vegetation type
- **dist** – *float* the horizontal distance from POI
- **slope** – *float* the slope value
- **fdi** – *int* the input FDI value

Returns *float* the output BAL value for this neighbour point regards to the POI

`calculate_bal.`**`convo`**(*a_dir*, *veg_data*, *slope_data*, *aspect_data*, *pixel_width*, *fdi*)
Find the maximum BAL for the point of interest in one direction by assessing all neighbours' BAL values in that direction (up to 100 metres).

Parameters

- **a_dir** – *string* the specific direction
- **veg_data** – `numpy.ndarray` the classified vegetation values
- **slope_data** – `numpy.ndarray` the slope values
- **aspect_data** – `numpy.ndarray` the aspect values
- **pixel_width** – *float* the pixel width of the classified vegetation
- **fdi** – *int* the input FDI value

Returns `numpy.ndarray` the output BAL values

`calculate_bal.`**`find_dist_class`**(*dist*, *dist_limit*)
Decide the BAL class based on the input distance and the distance upper-limit for each BAL class.

Parameters

- **dist** – *float* the horizontal distance from POI
- **dist_limit** – *list* the upper-limit for each BAL class

Returns *int* the distance class defined in bal_database.py

`calculate_bal.`**`get_slope_in_aspect`**(*slope_data*, *aspect_data*, *rows*, *cols*, *aspect_value*)

Get the slope data in a specific aspect.

Parameters

- **slope_data** – `numpy.ndarray` the slope values
- **aspect_data** – `numpy.ndarray` the aspect values
- **rows** – *int* the row number of the slope_data
- **cols** – *int* the column number of the slope_data
- **aspect_value** – *int* the aspect value

Returns `numpy.ndarray` the slope data in an aspect

5.3 utilities

These are tools or functions used to support the main computation.

5.3.1 __init__.py

5.3.2 value_lookup.py

`value_lookup` - helpful dictionaries for calculating the bushfire attack level (BAL)

These dictionaries are helpful to adapt the algorithm spatially to Method 1 in AS 3959 (2009).

moduleauthor Tina Yang <tina.yang@ga.gov.au>

5.3.3 bal_database.py

`bal_database` - relevant dictionaries for calculating the bushfire attack level (BAL)

These dictionaries are translated from tables from 2.4.2 to 2.4.5 in AS 3959 (2009) to determine the BAL for an area of interest within Australia.

moduleauthor Tina Yang <tina.yang@ga.gov.au>

REFERENCES

AS 3959, 2009. Construction of buildings in bushfire-prone areas, Australian Standard

PYTHON MODULE INDEX

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