FIRETOOLS CLOUD - USER GUIDE

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INTRODUCTION

FireTools Cloud is web-based GIS processing environment designed to replicate and replace the functionality of the FireTools II ArcGIS processing plugin to assist in fire management planning. Users are able to upload a datapack containing the GIS files used to run a standard FireTools II analysis, configure the layers and fields that define the analysis, and submit the analysis for processing. After processing is complete, users are able to view vegetation, fire management zone, and strategic fire advantage zone status maps based on fire history, and download a results pack containing GIS files with analysis results.

FireTools Cloud support ESRI Geodatabase, ESRI Shapefile and OGC Geopackage data formats for input, and produces ESRI Shapefile, OGC Geopackage and GeoTIFF raster files as output.

FireTools has been tested in recent Google Chrome, Opera, Safari, FireFox and Edge browsers. It is not compatible with Microsoft Internet Explorer.

USERS AND ADMINISTRATION

Currently FireTools Cloud is hosted on the NSW Bushfire Risk Management Research Hub website at the following URL:

- **http://ft.bushfirehub.org**

Upon visiting this URL in your web browser, you will see a site menu and login box as in Figure 1. You will have been provided with the password (which should be changed) which can be used along with your email address to sign in.

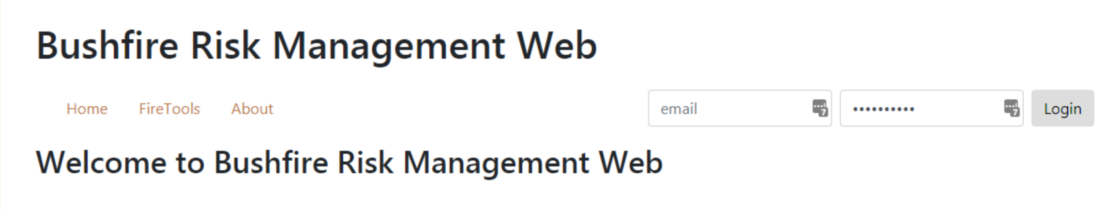


Figure 1 - Main FireTools Cloud interface before sign in.

After logging in, you will see the FireTools main screen as Figure 2. The menu on the left lists the various steps of conducting a FireTools analysis. If you are a user with administrator privileges, an *Admin* button will be visible in the site menu at the top of the screen. Ordinary users will see an *Account* link to the top-right, that can be used to change their password, and a *Logout* link

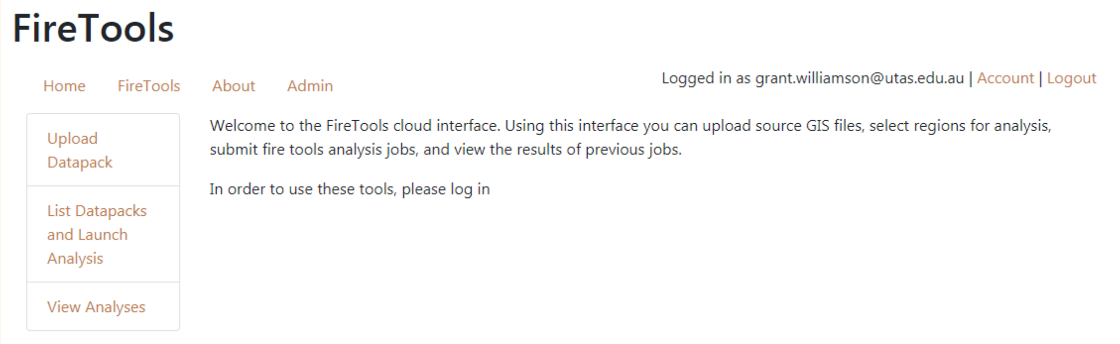


Figure 2 - Main FireHub / FireTools interface after sign in.

ADMINISTRATION FUNCTIONS

Users with administrator-level access are able to create and edit accounts of other users on the system. The administration interface can be accessed by clicking the *Admin* link in the menu at the top of the FireTools screen. Upon clicking this link, the administration menu will be shown, as in Figure 3. Currently there are three options in this menu, *Add User*, used for creating a new user account, *List/Edit Users*, used for editing existing users' emails, names and passwords, and *List Logs*, for viewing all analysis output and processing logs from all users.

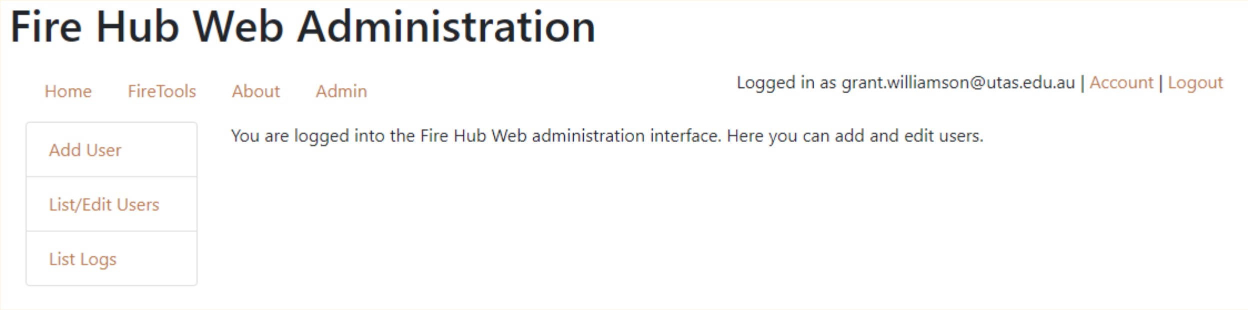


Figure 3 - Administration screen and menu, when logged in as an administrator user.

ADD USER

Clicking on *Add User* in the left-hand administration menu will bring up the form shown in Figure 4. To create a new user, enter their name, their email address (which will be used for their account login), and a password of your choice. The passwords in the two boxes must match in order to submit the user creation form. In addition, if you wish the user you are adding to have administrator access, you may tick the *Admin user* box. Click the *Add User* button to create the account.

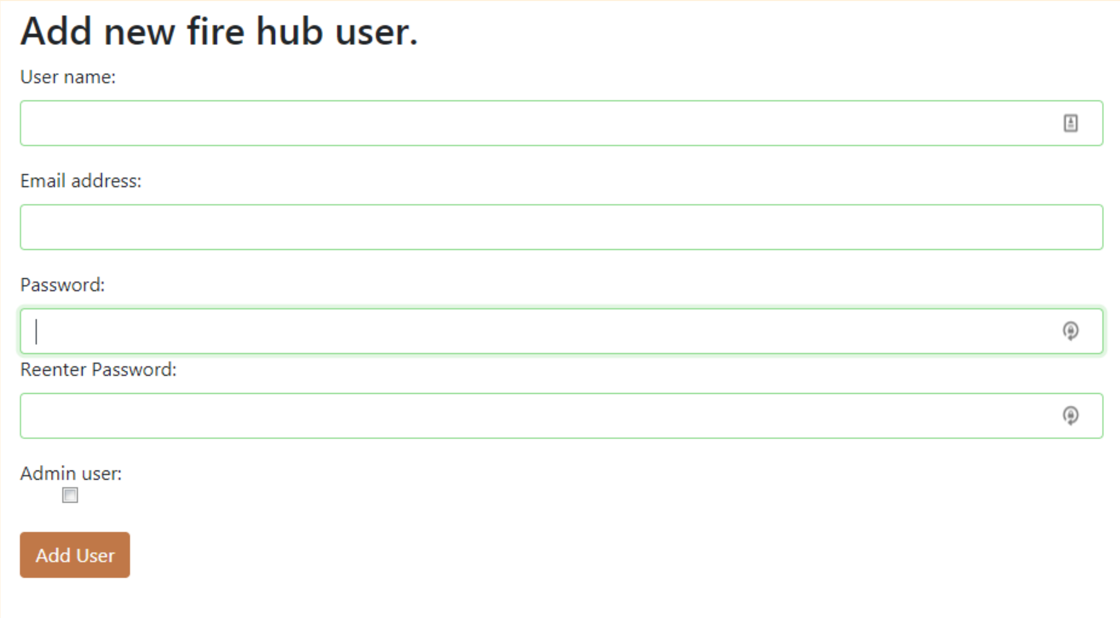


Figure 4 - Administration interface to add a new user.

LIST/EDIT USERS

To view a list of users and edit them, click the *List/Edit Users* link in the left-hand administration menu. This will display a list of users as in Figure 5. You can view basic account information for each user, and can click on the *Edit User* button next to each user name to edit their account information.

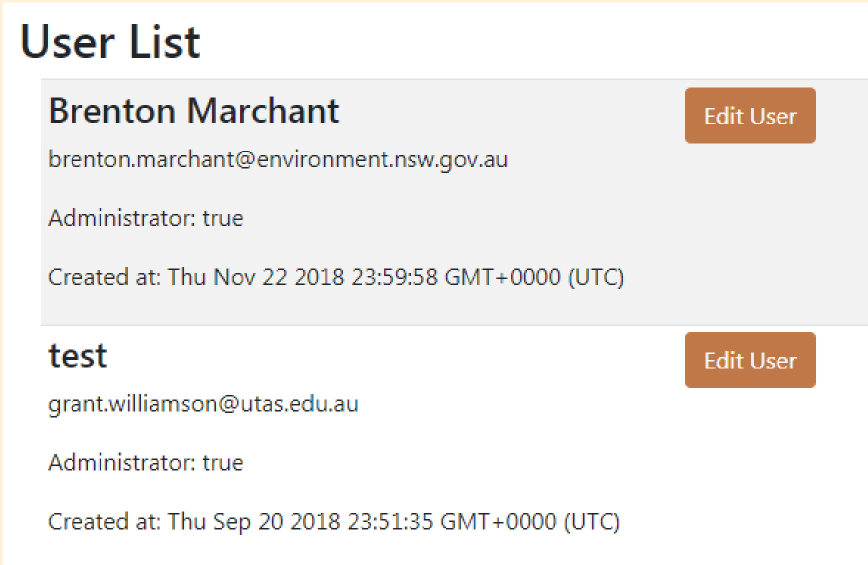


Figure 5 - Administration interface to list users.

The user account editing form is shown in Figure 6. It looks similar to the form for adding a user, and allows you to change the user name, email address, password and administrator account status. Note that changing the email address here will change the email the user needs to use to log in to their account. The password for the user will stay the same if you leave the password entry boxes here blank.

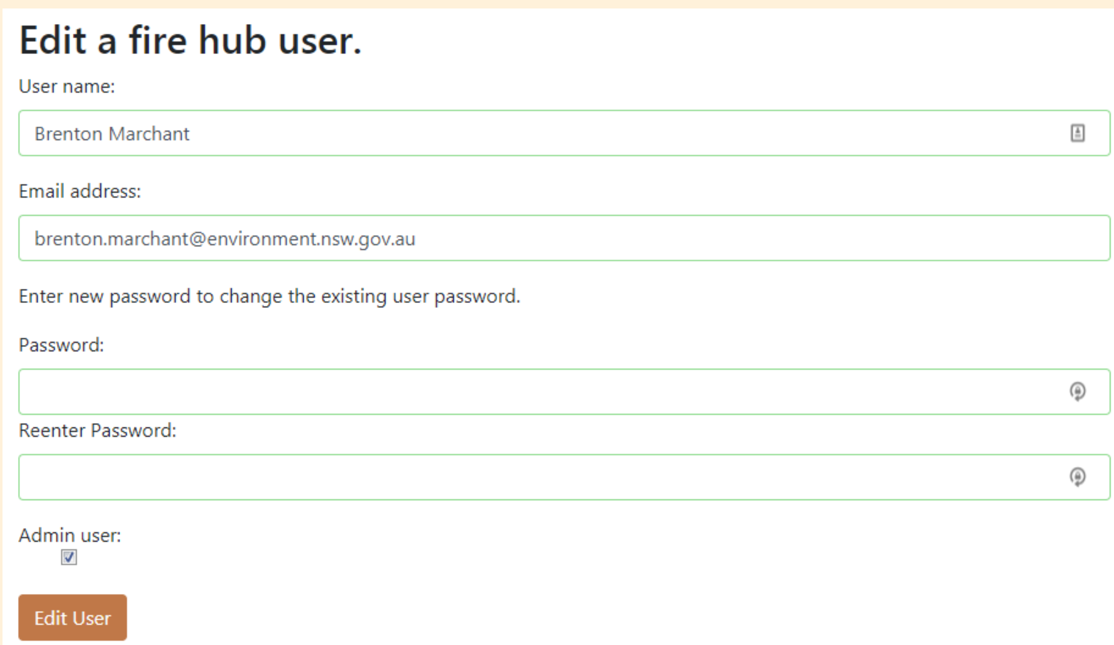


Figure 6 - Administration interface to edit an existing user account.

CHANGING YOUR OWN PASSWORD

Non-administrator users who wish to change their password can click the *Account* link in the top-right corner of the screen. This will bring up the account editing form shown in Figure 7. Users may change their name and email address, noting that if they change their email address, they will need to use the new email address to log in to FireTools in the future. If the password fields are left blank, the existing password for the user will be retained. If you wish to set a new password, enter the same password in both fields and click *Save Changes*. Currently FireTools does not have a password recovery system if you forget your password, so be sure to remember it. This feature will be implemented in a later update.

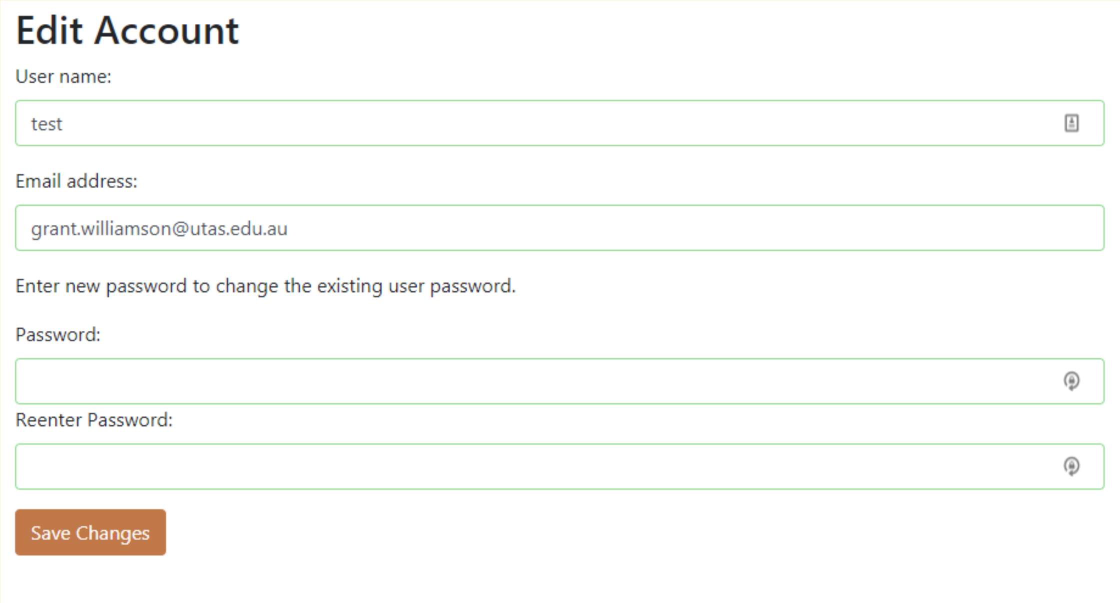
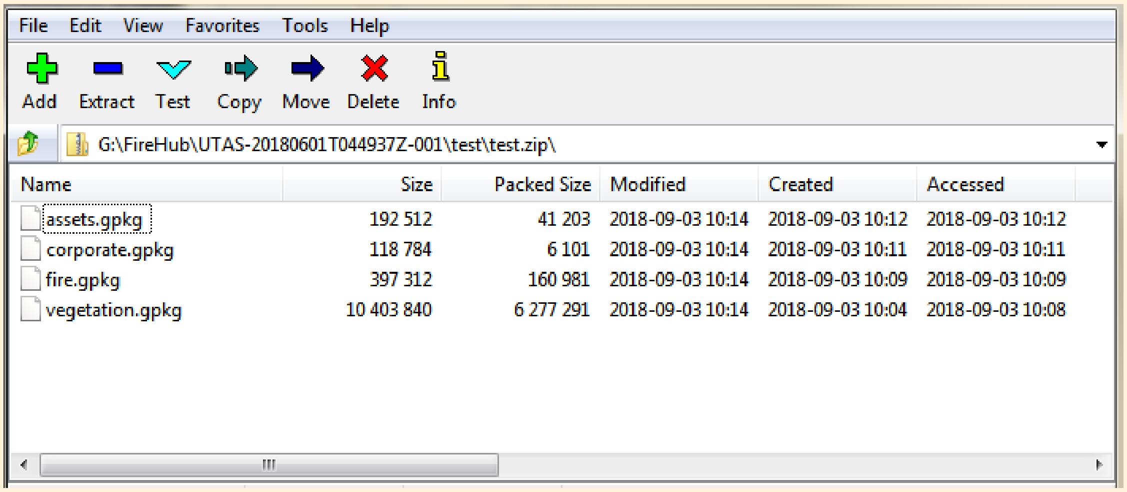


Figure 7 - User account editing, where users can edit their own email address and password.

CREATING AND UPLOADING DATAPACKS

The main data structure on which FireTools Cloud currently acts are **Datapacks**. These are ZIP files containing the GIS layers required for an analysis. Users may upload data packs and mark them as public, so other users also have acess to them as the basis of analyses, or private, in which case only the user who uploaded them can launch analyses using their data. FireTools Cloud supports three formats of vector GIS input files; ESRI Shapefiles, ESRI Geodatabases, and the open source GeoPackage format. The data pack ZIP file can include files within folders if required. Figure 8 shows an example of the contents of a ZIP file with four GeoPackage files, while Figure 9 shows a datapack with ESRI Geodatabases inside subfolders.



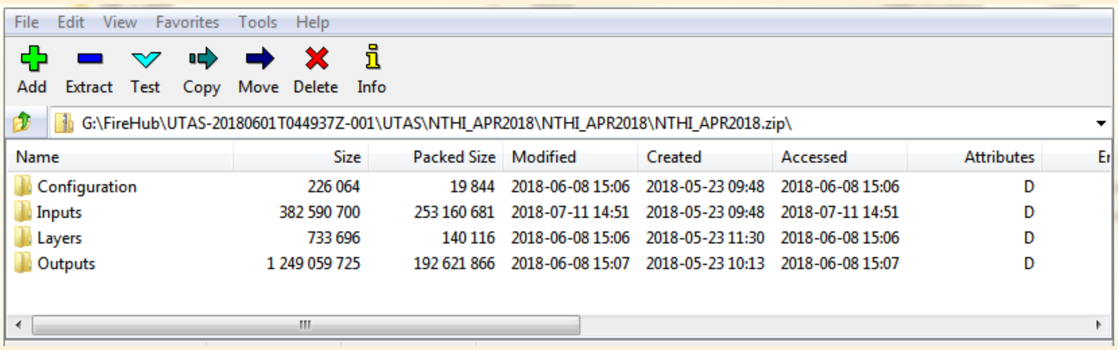
File Edit View Favorites Tools Help

Add Extract Test Copy Move Delete Info

G:\FireHub\UTAS-20180601T044937Z-001\test\test.zip\

Name	Size	Packed Size	Modified	Created	Accessed
assets.gpkg	192 512	41 203	2018-09-03 10:14	2018-09-03 10:12	2018-09-03 10:12
corporate.gpkg	118 784	6 101	2018-09-03 10:14	2018-09-03 10:11	2018-09-03 10:11
fire.gpkg	397 312	160 981	2018-09-03 10:14	2018-09-03 10:09	2018-09-03 10:09
vegetation.gpkg	10 403 840	6 277 291	2018-09-03 10:14	2018-09-03 10:04	2018-09-03 10:08

Figure 8 - Example of a ZIP file containing GIS geopackage data layers that constitutes a Datapack.



File Edit View Favorites Tools Help

Add Extract Test Copy Move Delete Info

G:\FireHub\UTAS-20180601T044937Z-001\UTAS\NTHI_APR2018\NTHI_APR2018\NTHI_APR2018.zip\

Name	Size	Packed Size	Modified	Created	Accessed	Attributes	En
Configuration	226 064	19 844	2018-06-08 15:06	2018-05-23 09:48	2018-06-08 15:06	D	
Inputs	382 590 700	253 160 681	2018-07-11 14:51	2018-05-23 09:48	2018-07-11 14:51	D	
Layers	733 696	140 116	2018-06-08 15:06	2018-05-23 11:30	2018-06-08 15:06	D	
Outputs	1 249 059 725	192 621 866	2018-06-08 15:07	2018-05-23 10:13	2018-06-08 15:07	D	

Figure 9 - Example of a ZIP file with GIS layers in subfolders, suitable for geodatabases.

Currently, FireTools Cloud closely follows the data structure of FireTools II, in that the data layers required are divided into Assets, Corporate, Fire and Vegetation data stores. You do not need to give your GIS databases these names, and if you like you could place all layers in a single database, as the analysis definition screen will allow you to define which database represents which of the four categories. However, you should be aware of the data layers each database is expected to contain:

- **Corporate** - The **Corporate** database is the database containing a layer with a polygon or multiple polygons that could be used to set the spatial bounds of of the analysis, for example, NSW Parks Branch polygons.
- **Assets** - The **Assets** database is the database containing a layer that defines fire management areas (FMZ, SFAZ), which is a polygon layer with a field containing a code for the fire management zone type.
- **Fire** - The **Fire** database is the database containing a polygon layer representing fire history (with a field containing fire season/year), as well as two non-spatial lookup tables. One lookup table joins to the fire management zone field code in the **Assets** database and allows association of each FMZ code with a maximum fire interval. The other lookup table contains vegetation fire data, and has a code for each vegetation type, which links to the polygons in the **Vegetation** database, as well as

fields for the maximum and minimum fire interval for each vegtation type, and fields indicating fire advantage and fire prone status.

- **Vegetation** - The **Vegetation** database contains vegetation layers, with polygons defining distinct vegetation communities. Each vegetation polygon should have a field containing a vegetation code that is reflected in the **Fire** database's vegetation look-up table. The **Vegetation** database is able to contain multiple vegetation polygon layers, and multiple such areas can be selected at once for analysis.

Figure 10 shows an example of a database hierarchy in a datapack, with a code for fire management zone type linking to the fire management zone lookup table, and a code for vegetation type linking to the vegetation lookup table.

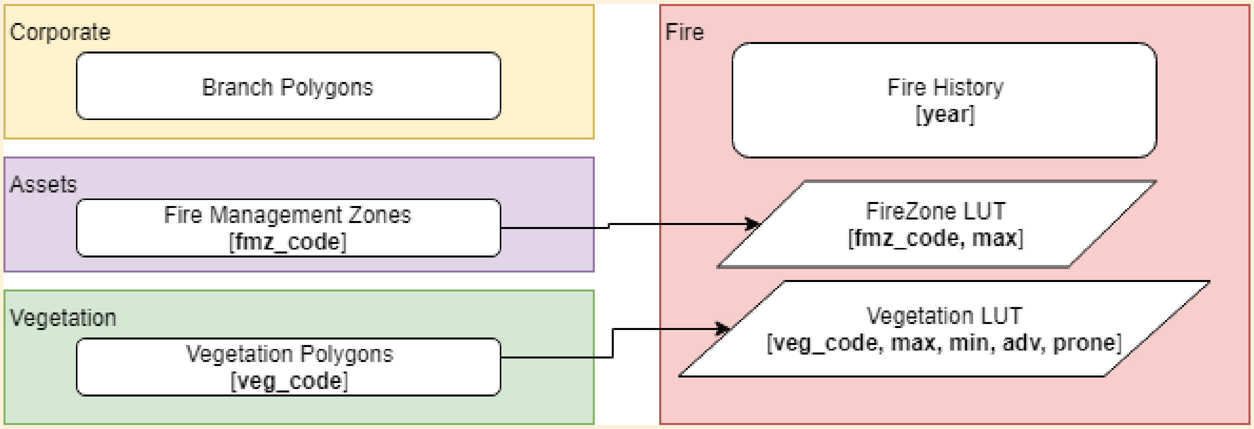


Figure 10 - Example of required inputs for Firetools Cloud, within the standard database hierarchy.

Once you have created a ZIP file with GIS layers for the above input data, click on the *Upload Datapack* link in the left-hand menu of the main FireTools page. The Datapack upload screen (Figure 11) allows you to provide the datapack with a name and description of its contents and purpose if you wish. You can also define a year of currency, which is primarily for record keeping. This date represents the year the data is current to. Finally, you can select whether this datapack is a **private** datapack. If you check this box, the datapack will only be visible to you, and other users will not be able to use it as the basis of analysis scenarios. By default this is not checked, and datapacks uploaded are available to all users.

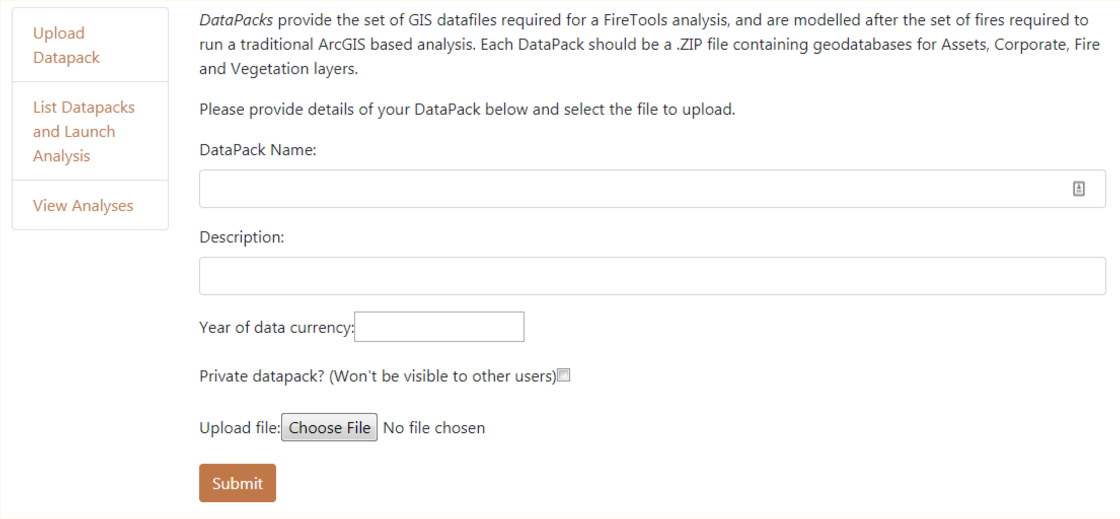


Figure 11 - Datapack upload screen.

After you have filled in the datapack upload form, click submit and the datapack will be uploaded and processed. This can take up to several minutes, depending on the size of the datapack in bytes, and the size of the geographic area it represents. The FireTools Cloud is validating the datapack, and obtaining spatial metadata from each of the GIS layers. After the datapack has finished processing, it will appear in the list of datapacks accessible by clicking the *List Datapacks And Launch Analysis* link in the left-hand menu of the main FireTools interface. The list of datapacks (Figure 12) shows all datapacks available to you, including the datapack recently uploaded once it has finished processing. Each datapack has a name and descritpion, a date of upload, a data size, a year of currency and a field indicating if it is a public or private datapack.

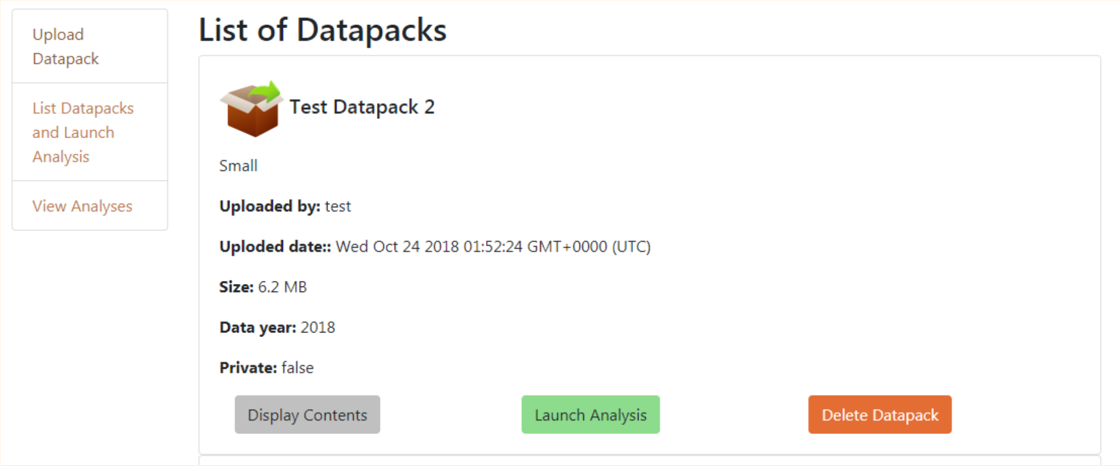


Figure 12 - Screen with list of available datapacks.

You can view additonal information about the datapack by clicking the grey *Display Contents* button below a datapack's record. This will expand a pop-out list, as in Figure 13, showing the spatial layers identified within each database contained in the zip file that was uploaded. You should check the datapack contents to ensure all your GIS input layers were detected. In Figure 13, we can see this datapack has fire management zone data within the **Assets** database, Parks branch boundary data within the **Corporate** database, a fire history polygon layer, and FMZ and vegetation look up tables (LUT) within the **Fire** database, and a single vegetation layer within the **Vegetation** database. This represents the minimum viable dataset required to run FireTools at present.

Note that old datapacks that are no longer required can also be deleted on this screen by clicking the orange *Delete Datapack* button. You will be prompted for confirmation.

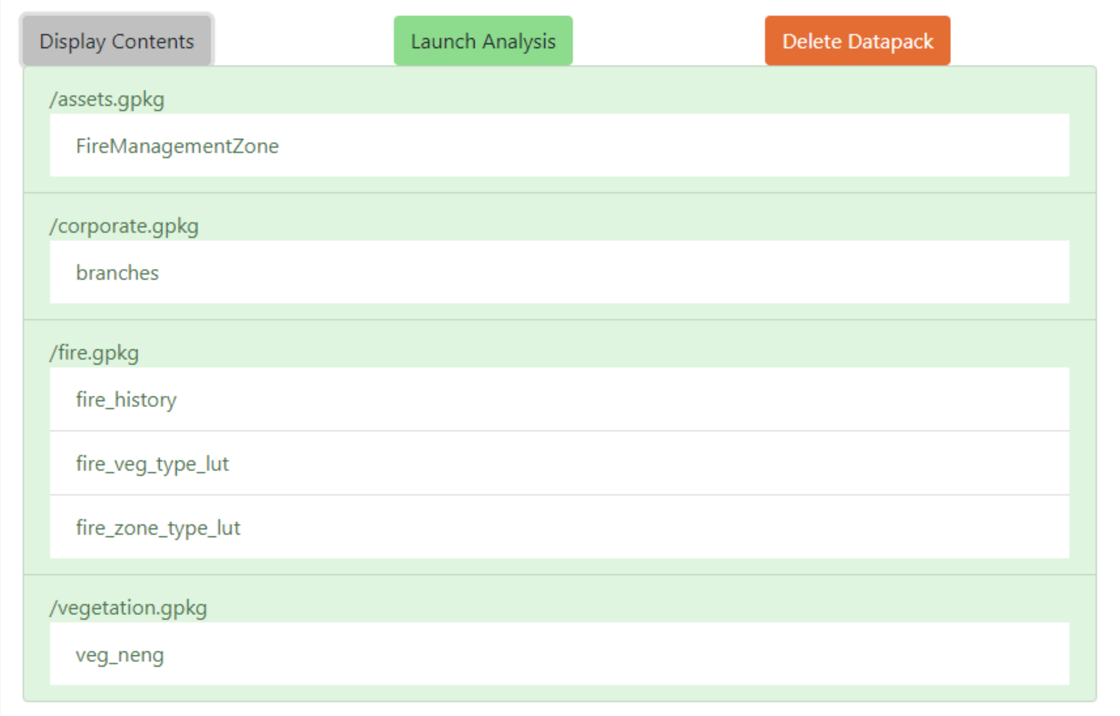


Figure 13 - Viewing the contents of a datapack.

DEFINING AND LAUNCHING AN ANALYSIS

ANALYSIS NAME AND DESCRIPTION

Analysis scenarios extend from single datapacks. To launch an analysis, find the datapack you wish to use as the basis of the analysis and click the green *Launch Analysis* button. You will be taken to the *Define Analysis* interface. This form requires you to indicate which GIS layers and fields in the datapack you uploaded represent which datasources required for the FireTools analysis, and also to define the spatial resolution and projection of the analysis raster output.

The first step is to provide the analysis with a name and description, as in Figure 14.

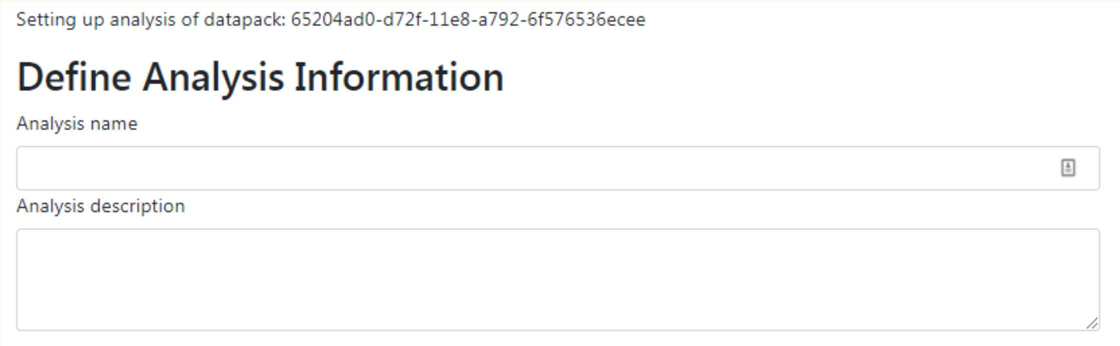


Figure 14 - Defining an analysis - entering a name and description.

CORPORATE GEODATABASE

Figure 15 shows the **Corporate Geodatabase** form. In the first drop-down menu, select the file in the datapack that contains the **Corporate** layer, that is, the branch of other boundaries that define the analysis region. Next, select the spatial layer within that database representing the boundaries. In the third drop-down menu you can, optionally, select the field containing the name of the boundary polygon you wish to limit the analysis to. For example - your polygon layer may contain all the branches in the state, with their name stored in a field named "BRANCH_NAME". If you select *BRANCH_NAME* in the third drop-down list, a list of branches to select from will appear in the fourth drop down, allowing you to restrict the analysis to a single branch. Note that this step is not necessary if you have supplied a spatial polygon layer that already contains the boundary of the complete analysis area. In this case, select the default option **NONE** from the third drop-down list.

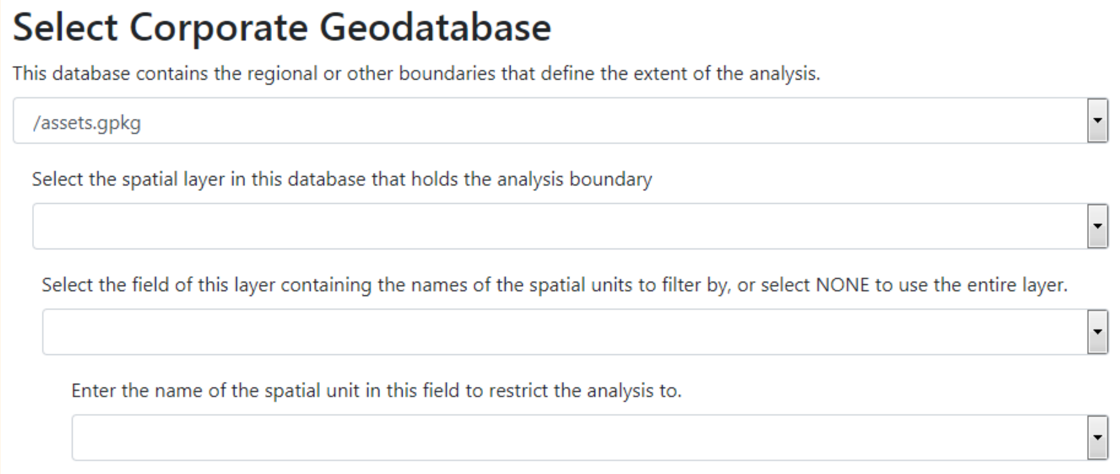


Figure 15 - Selecting corporate geodatabase and layer contains the analysis boundary (eg. Parks region).

ASSET GEODATABASE

The next set of drop-down menus, shown in Figure 16, allows selection of the spatial layers of the **Asset Geodatabase**, which represent fire management areas. In the first drop-down menu, select the file in the datapack containing the **Asset** layers, in the second drop-down, select the spatial layer within this database containing the fire management zones or blocks, and finally in the third drop-down list, select the field containing the fire management zone code. The standard name for this code field is **SubTypeCD**.

Figure 16 - Selecting the asset geodatabase and the layer containing the fire management zones.

FIRE HISTORY GEODATABASE

The largest sub-form is shown in Figure 17, which defines the fire history layers and lookup tables, contained in the **Fire Geodatabase**. The list below indicates the data required in each input field.

1. Database selection - select the file in the datapack containing the **Fire** layers.
2. Fire history polygons - select the spatial layer within the database containing fire history polygons.
3. Field containing fire season date - this may be called **FireYear** or similar, and must have the format YYYYXX, where, for example, "196869" would represent the 1968-1969 fire season.
4. FMZ code lookup table - select the lookup table (LUT) within the **Fire** database that associates each FMZ type code with a maximum fire interval. This should be a non-spatial table with a field for the FMZ code and a field for the maximum fire interval.
5. FMZ code field - select the field within the FMZ lookup table that will join to the field selected in the **Asset Geodatabase** fire management zone polygon layer, representing the type of fire management zone or block.
6. FMZ maximum fire interval - select the field within the FMZ lookup table containing an integer value representing the maximum fire interval for that fire management zone or block type.
7. SFAZ Code - Enter the numeric code representing the special case of Strategic Fire Advantage Zones in the FMZ lookup table. This has been set to the standard value of 6103, which is commonly used to represent SFAZ areas.
8. Set recently treated category threshold. By default, this is set to 6 years, however, if you have a very long or very short SFAZ fire return interval, modify this value to reflect the number of years which a SFAZ could be locally expected to remain “treated”. For example, in the west this may be longer than 6 years, on the north coast it may be shorter.
9. Vegetation lookup table - select the lookup table (LUT) within the **Fire** database that associates each vegetation community with a range of fire regime metrics.
10. Vegetation code field - select the field within the vegetation lookup table containing the vegetation code that will be joined to the vegetation polygon dataset. This is commonly the field "VEG" or similar.
11. Maximum fire interval - select the field in the vegetation LUT containing an integer value representing the maximum fire interval for each vegetation type eg. "MAX".

12. Minimum fire interval - select the field in the vegetation LUT containing an integer value representing the minimum fire interval for each vegetation type eg. "MIN".
13. Fire advantage - select the field in the vegetation LUT containing a value representing if each vegetation type has "fire advantage" status.
14. Fire prone - select the field in the vegetation LUT containing a value representing if each vegetation type has "fire prone" status.

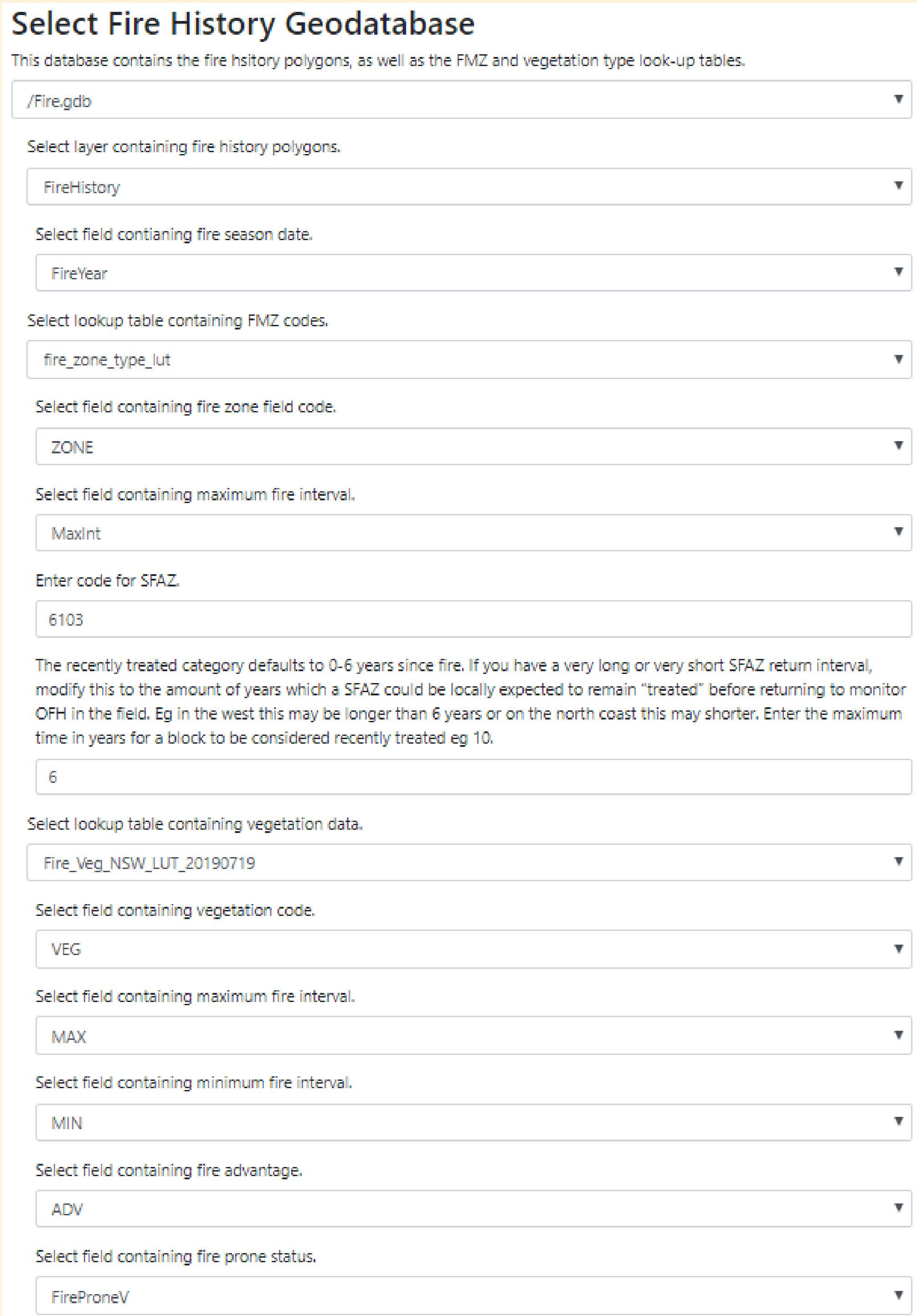


Figure 17 - Selecting the fire geodatabase, including fire history, and FMZ and vegetation lookup tables.

VEGETATION GEODATABASE

The next form, shown in Figure 18, allows you to select the spatial layers of the **Vegetation Geodatabase**. First, select the geodatabase containing the vegetation layers. A list of spatial layers within that geodatabase will appear in the box below. Click on the layer you wish to use as the vegetation layer in this box. You may select multiple vegetatation layers, in the situation where your region of interest has its vegetation map split over multiple layers. You can do this by holding down the **CTRL** key while clicking on multiple layers to highlight them. These vegetation polygon layers should contain a field named **Veg** with a unique vegetation code number for each vegetation community, which aligns with the code used in the vegetation LUT in the **Fire** geodatabase. It is currently hard-coded that this field should be called "**Veg**", the option to select a different fieldname may be added in a future release of FireTools Cloud.

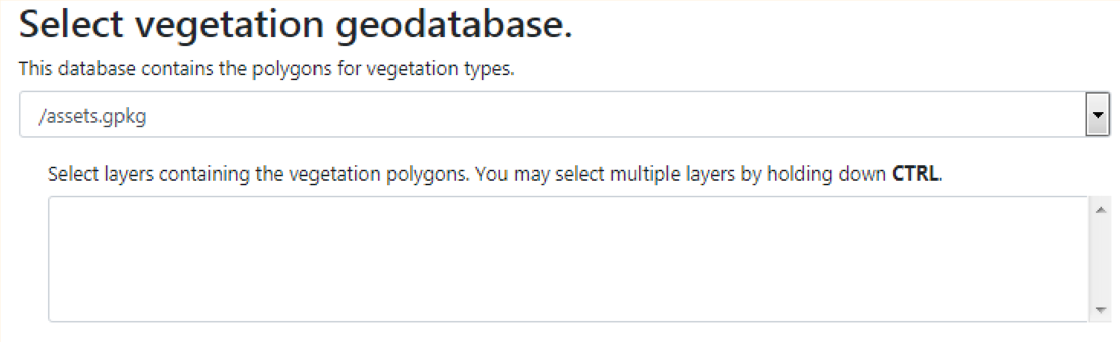


Figure 18 - Selecting the vegetation geodatabase - and multiple vegetation layers to merge.

DEFINE PROJECT SPATIAL ENVIRONMENT

The final step is to define the spatial settings for the analysis, shown in Figure 19. Enter the projection string for the output in **proj4** format (which can be searched for on http://spatialreference.org). By default, a projection string representing a Lambert conformal cubic projection for New South Wales is set, which provides good equal-area coverage across the state. Maintaining this projection is recommended, to ensure alignment with a standard grid, and to ensure output files have the correct projection. The resolution of the output, in metres, can be entered next. 25m resolution is the default, and is the highest resolution at which FireTools Cloud has been tested. Lower resolution (eg. 50, 100, 250m) can be entered for faster processing over broad areas or for trial runs. The output raster resolution, along with the size of the spatial domain over which the analysis is being conducted, are the primary factors determining the time analysis takes to complete. For testing purposes, if a fine-scale (25m) analysis fails with an error, it may be worth retrying the analysis at a broader scale (50m or 100m).

Next, enter the *baseline* year of the analysis - this represents the *current* year relative to the fire history data. For example, if you enter a value of 2018, fires that burnt in the 2016-2017 fire season will be considered to have burnt one year ago. Entering future years in this box will serve to project calculations into the future, on the assumption no further fires take place. By default, the current year is set. You may also, optionally, enter a baseline year to restrict the history to. If you enter a year in this box, fire history analysis will be restricted to fires occurring in or after this year. You can use this to ignore fires prior to part gazettal date, for example. Finally, you can define a bounding box by entering x- and y-coordinates in the extent limit box as an array (xmin, xmax, ymin, ymax), in the projection system defined above. This feature is currently experimental.

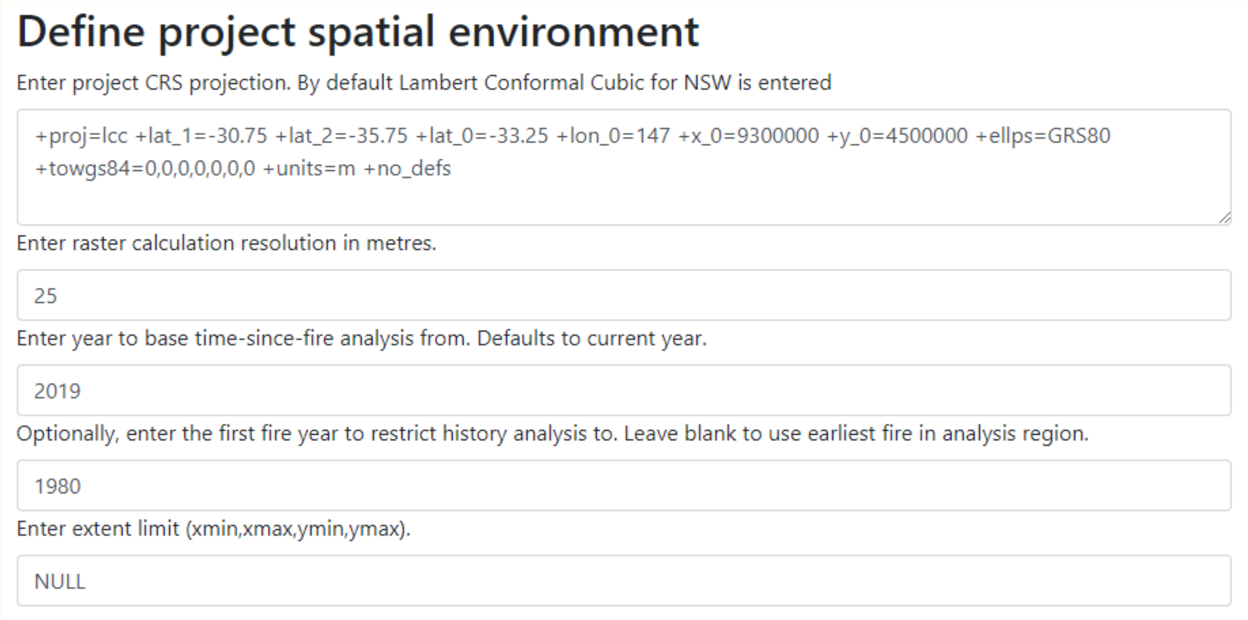


Figure 19 - Defining spatial projection, resolution, and analysis base year.

A new experimental feature has been introduced in this release of FireTools Cloud, but it is still under development. A map is now shown at the bottom of the page (Figure 20). This map will show the rectagonal bounds of the fire history, fire management zone and analysis boundary layers as you select them in different colours, to confirm the analysis area. It currently does not show vegetation layers, and in future actual polygons will be shown, and you will also be offered the ability to define a rectangular extent to restrict the analysis to using this map.

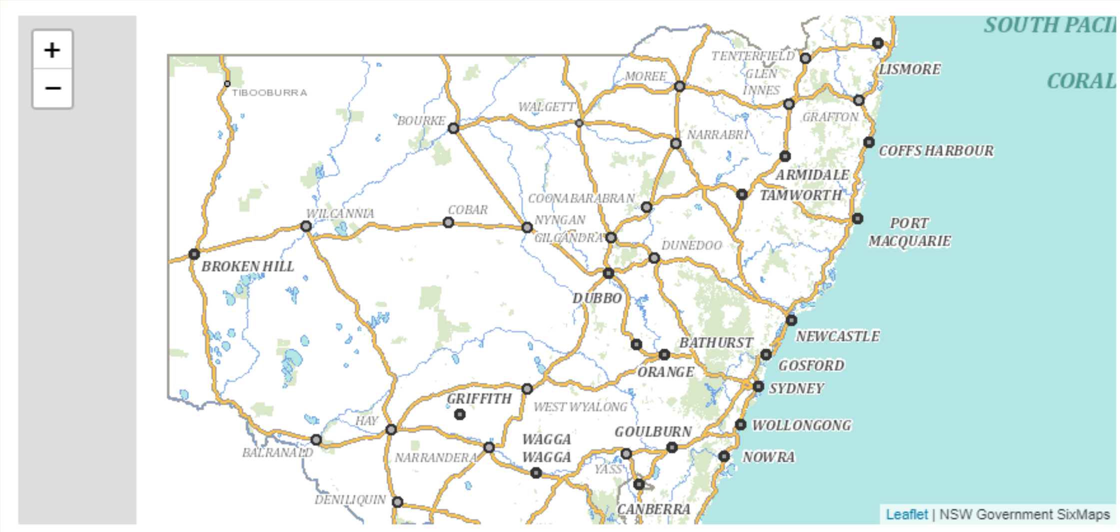


Figure 20 - The map at the bottom is experimental - it should display the bounding boxes of major layers.

LAUNCHING ANALYSIS

After you have filled in all fields on the *Define analysis* form, click the orange *Start Analysis* button to launch analysis. You will be returned to the *List of Analyses* page, which is also accessible by clicking the

View Analyses link in the left-hand menu on the main FireTools Cloud interface. The *List of Analyses* page lists all analyses that are currently running for this user, as well as analyses that have stopped due to an error, and analyses that have completed (Figure 21).

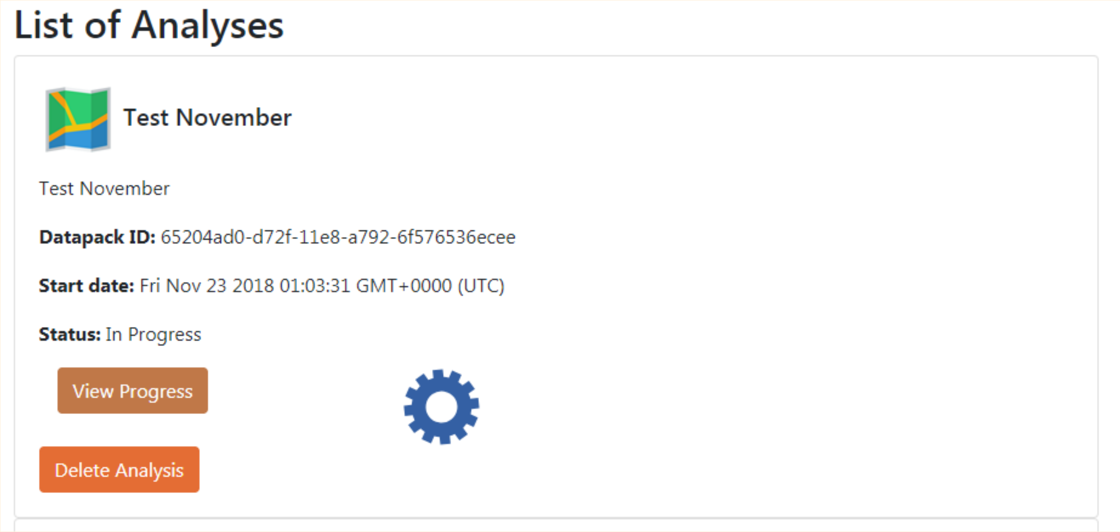


Figure 21 - List of currently running and completed analyses, which can be viewed or deleted.

VIEWING AND DOWNLOADING ANALYSIS

ANALYSIS LIST

On the *List of Analyses* page, currently running analyses have a rotating gear to indicate they are currently processing. Analyses that have encountered a problem have a red *Error* button that can be clicked on to view the error log, and a button to attempt to relaunch analyses that ended with an error. The relaunch button is primarily useful if the analysis ended with a server fault – if there were problems with the input data, the analysis should be redefined from the beginning and launched again.

Completed analyses have a green *Display Analysis* button that can be used to view and download results. In the case of currently running analyses, you may click the brown *View Progress* button to view the current state of the analysis and the log output. Analyses that are currently in the process of running will display a progressive log of their status, as in Figure 22.

Upon launching an analysis, FireTools Cloud will launch a processing server on a cloud computing service (DigitalOcean), transfer the selected datapack and a configuration file as defined by the *Define Analysis* form to the server, and launch a GIS processing environment to perform the calculations. The log displayed in the *Analysis Output* page details the current state of the analysis, both in terms of the creation and transfer of data to the cloud server, and the actual GIS processing once it is launched. The GIS processing is performed by the R software, along with some ancillary tools including Python and GDAL. The processing environment costs approximately 11c per hour to run for small datasets, and 22c per hour to run for large datasets. Processing time will vary depending on the spatial extent of the input data, and the selected output raster resolution. Processing time, in testing, varies from 20 minutes for small subsets of a region, to 36 hours for an entire region of the state (eg. Northern Inland).

If there are any processing errors, they will be listed in this log. The log will frequently display non-fatal warnings, which are usually of little consequence and are just the result of data conversions taking place during the GIS processing. Fatal errors will cause the analysis to stop processing, and the analysis will be marked with an *Error* status in the *List Analyses* screen. In the case of these analyses, the log of the error will still be available, and it would be useful if you could email it to me (grant.williamson@utas.edu.au) so I can help understand what went wrong. The most common errors are caused by attempting to process too large a region of the state at too high a resolution, resulting in the processing environment exceeding its memory constraints, or incorrect definition of fields and lookup tables.

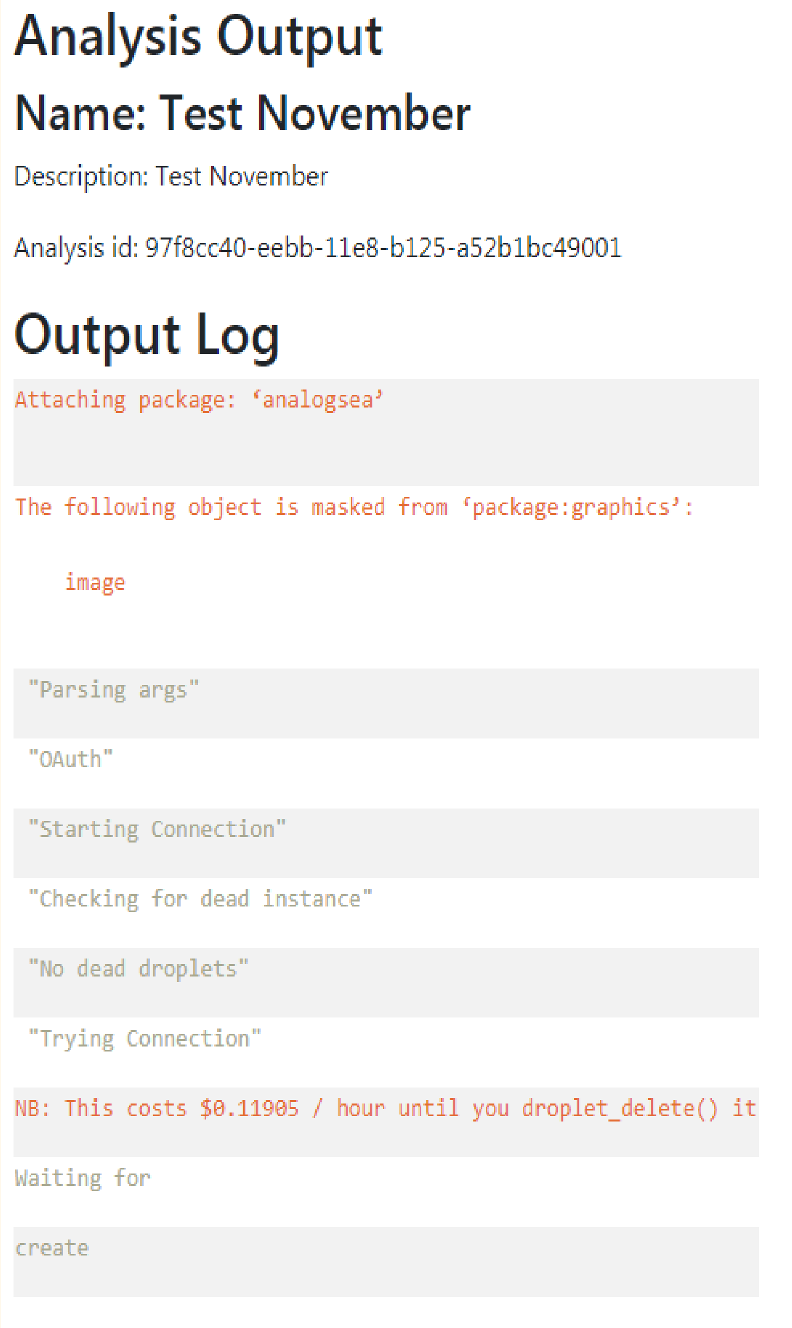


Figure 22 - Viewing an analysis in progress displays a log of the computation state.

After submitting an analysis for processing, you will receive an email confirming the analysis has started. Once the analysis has completed, you will receive a second email notifying you it has finished. Completed analyses will be displayed with a green *Display Analysis* button in the *List Analyses* screen (Figure 23). Clicking on this button will enable you to view the analysis results as maps, and to download a results pack containing the output GIS layers.

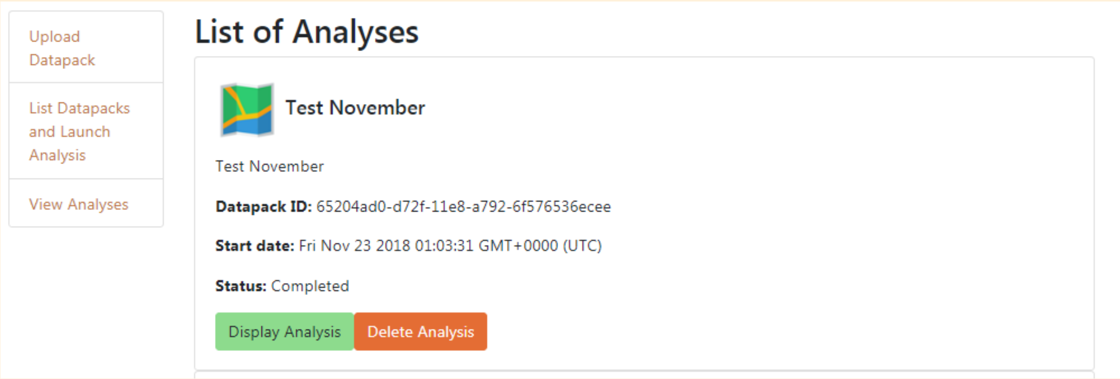


Figure 23 - Complete analyses have a green View Analysis button for viewing and downloading results.

ANALYSIS OUTPUT

The *Analysis Output* interface looks similar to the interface presented while an analysis is running, with the complete progress log displayed on the first screen. However, this interface now has a series of tabs, allowing you to view various maps and download results (Figure 24). The first tab contains the output log.

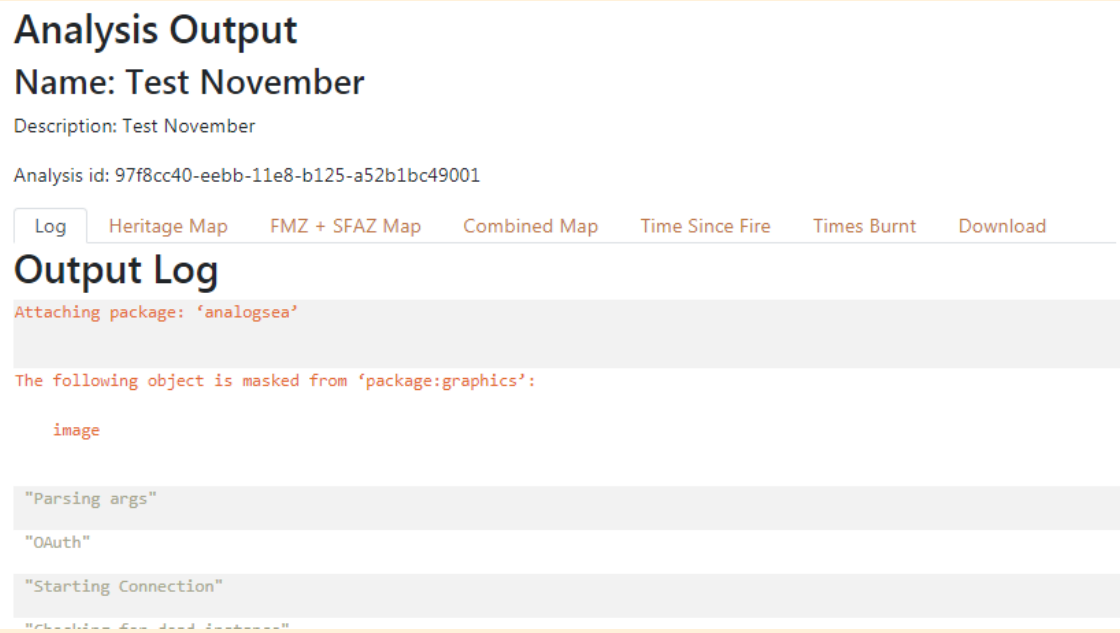


Figure 24 - Complete analysis screen shows the completed processing log, and tabs to view results.

The second tab contains a map of the output results as it relates to heritage status, based on vegetation type and the maximum and minimum fire thresholds for each vegetation type (Figure 25).

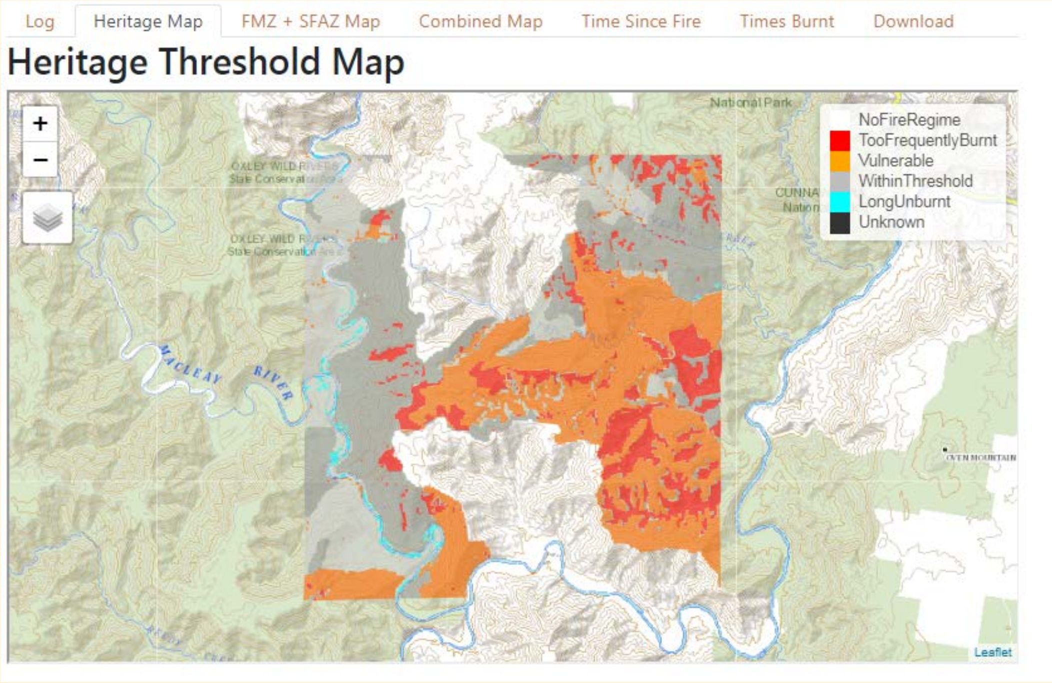


Figure 25 - Heritage analysis map, showing status of vegetation outside FMZ.

The third tab contains a map of the FMZ and SFAZ threshold status, ignoring vegetation type and based on the fire intervals for the fire management zones (Figure 26).

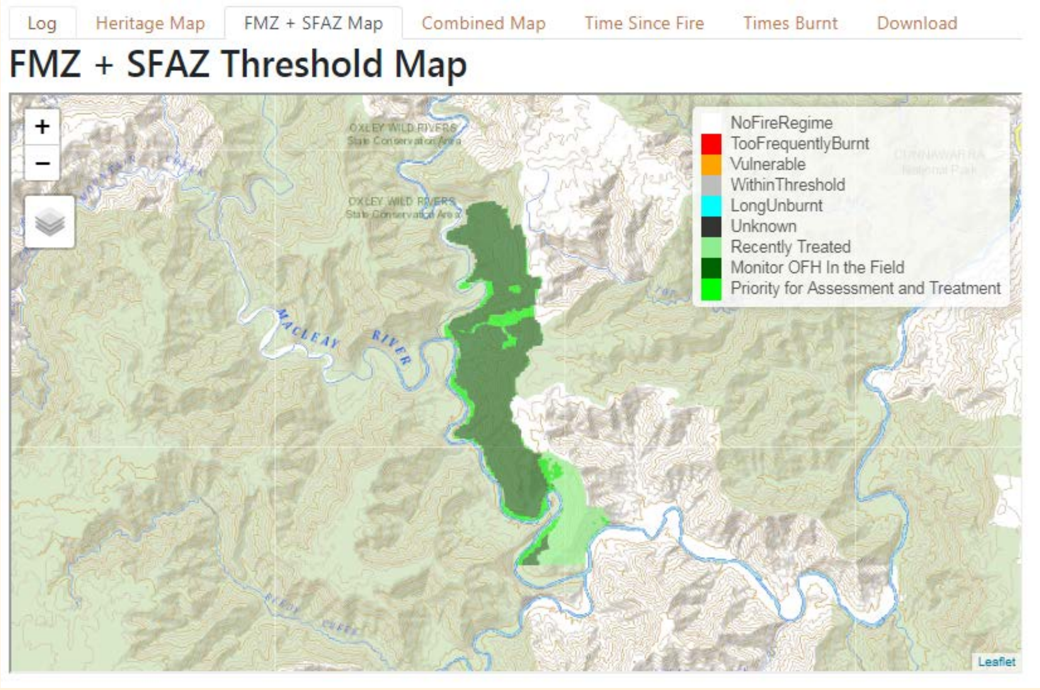


Figure 26 - FMZ analysis map, showing status of FMZ and SFAZ areas.

The fourth tab combines the previous two outputs into a single map, displaying heritage vegetation threshold status for areas outside FMZ and SFAZ polygons, and FMZ or SFAZ status within those fire management zones or blocks (Figure 27).

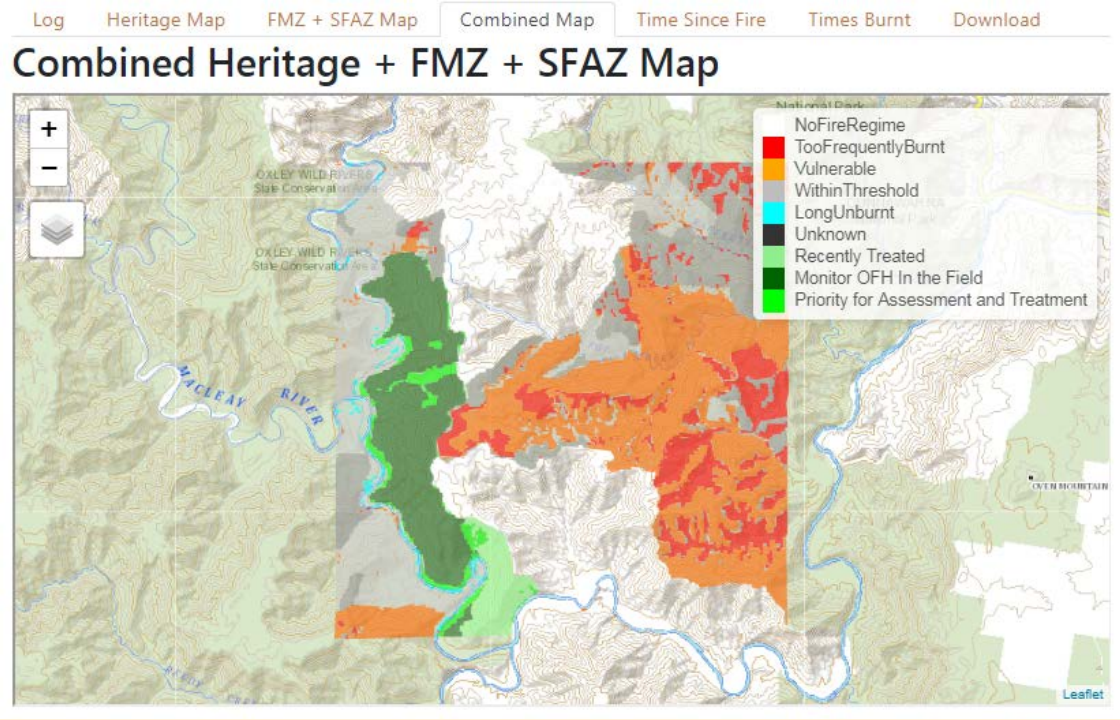


Figure 27 - Combined analysis map, showing FMZ and SFAZ status overlaid on heritage status.

The fifth tab shows a map of the time since last fire, relative to the analysis baseline year (Figure 28).

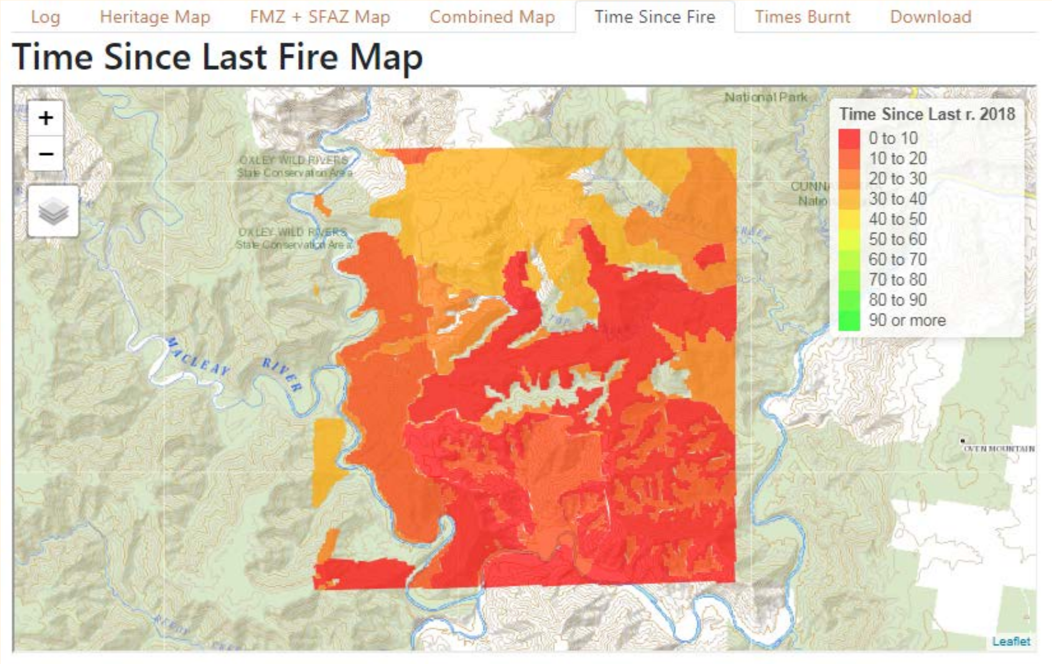


Figure 28 - Map of time since fire across the analysis region.

The sixth tab shows a map of the number of times each polygon within the analysis are has been burnt within the recorded fire history (Figure 29).

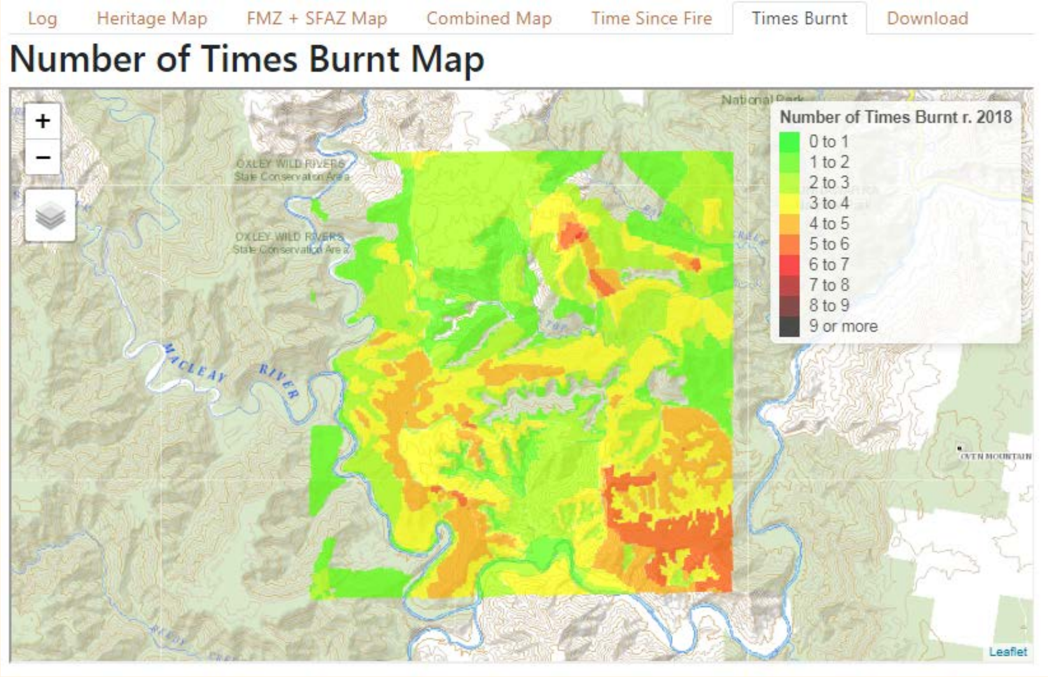


Figure 29 - Map of the number of times burnt across the analysis region.

The final tab, marked *Download,* allows you to download the analysis results for viewing and analysis in your own GIS software (Figure 30). Click the green *Download* button to download a ZIP file containing these results. In supporting GIS software (eg. QGIS), you can also directly view the maps as web tile service layers by entering the URLs provided below the download link into the software. ArcGIS currently does not support these layer types, but we hope to implement direct ArcGIS access in a future version of FireTools Cloud.

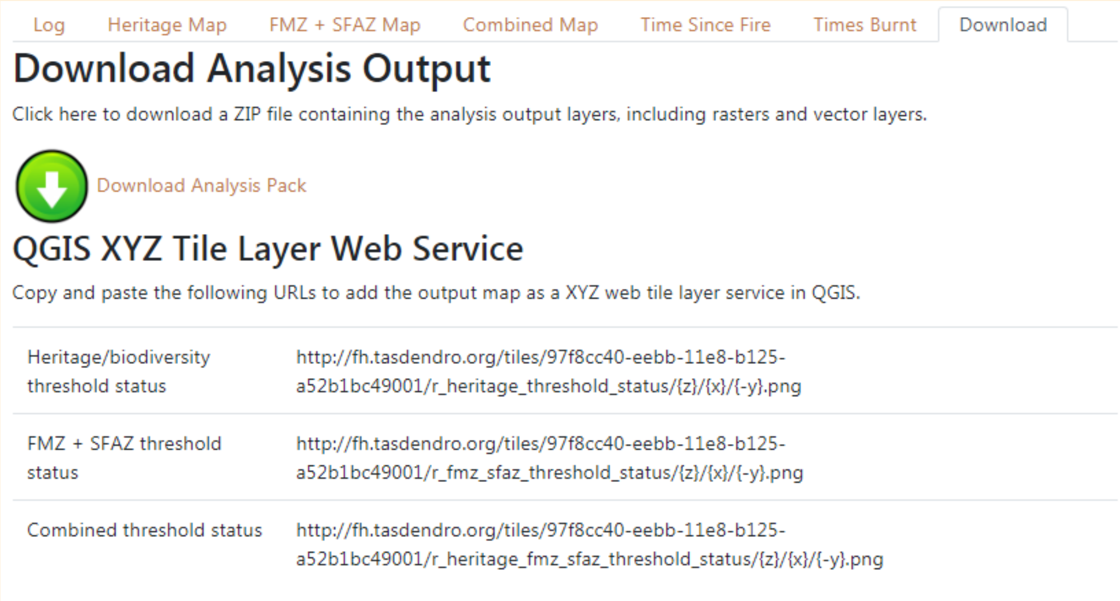


Figure 30 - Results can be downloaded as a ZIP file, or viewed as web tile maps in supporting GIS software.

The zip file contains a complete set of analysis output layers in a variety of formats, including ESRI Shapefile (extention .shp), GeoPackage (extension .gpkg) and raster GeoTIFF (extension .tif). FireTools Cloud currently does not support ESRI GeoDatabase output, but up to date versions of ArcGIS should be able to open Shapefiles, GeoPackages and GeoTIFF files. The raster output files have embedded symbology and attribute tables. The downloaded zip package also contains a log file (log.txt) containing a copy of the analysis output log, and a manifest file (MANIFEST.TXT) which contains a description of all the output layers (Figure 31)

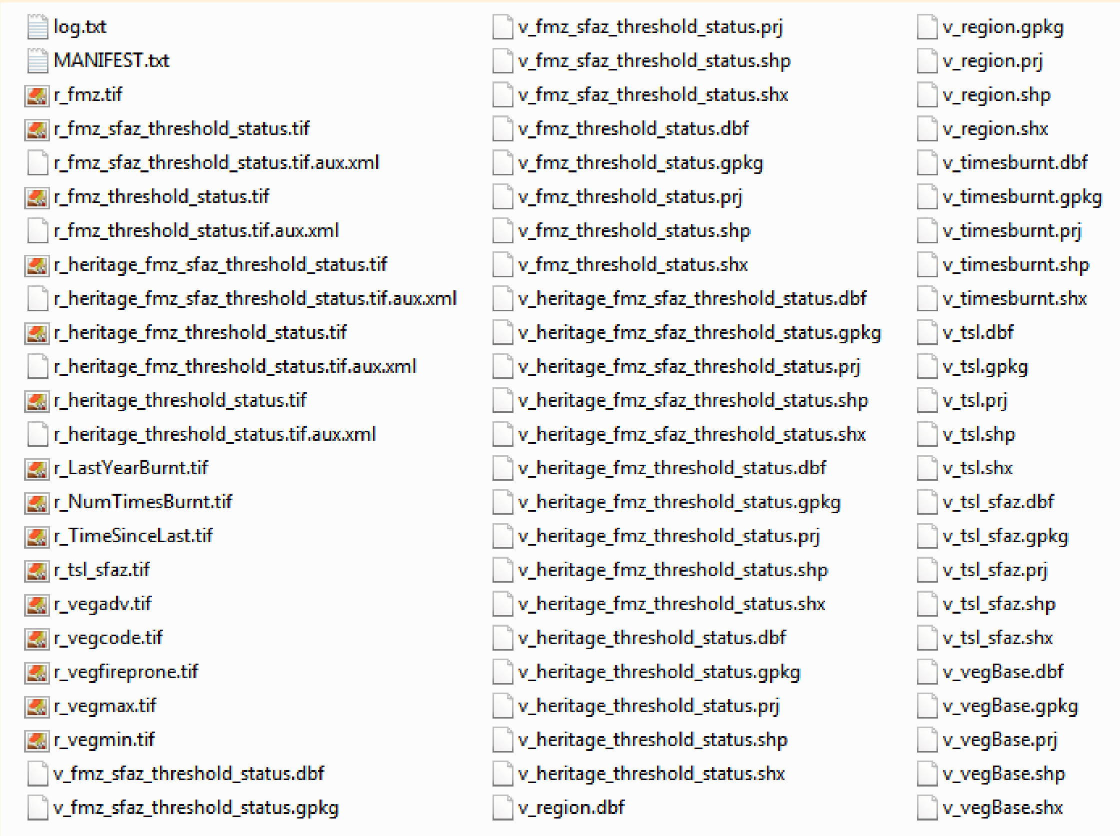


Figure 31 - Contents of an analysis download pack, containing shapefile, GeoTiff and GeoPackage versions of the output.

SOURCE CODE

Source code for the backend GIS processing component is held in a repository on GitHub:

https://github.com/ozjimbob/FireTools2R

The processing algorithm can be executed on a local machine; it requires R and GDAL to be installed, as well as a number of R packages, and it requires an analysis definition file to run.

PROCESSING ALGORITHM

1. Launch cloud server instance
2. Transfer datapack to cloud server
3. Clone latest version of processing code from GitHub onto cloud server and launch processing
4. Load analysis configuration file, processing environment configuration file, packages and internal functions.
5. Create and prepare output directory.
6. Type-check analysis form fields to ensure they are numeric as required
7. Prepare fire history and vegetation rasters.
    1. Load analysis extent polygon layer, filter to region of interest (ROI), transform to project projection, repair polygons and write to **v_region.gpkg**.
    2. Define a rectangular bounding box based on the ROI, and generate a template raster within that bounding box, aligned to the state grid, at the requested resolution. Crop this template raster to the defined subextent if requested.

   3. Generate a masking raster within the template raster by rasterizing the ROI, setting all cells outside the ROI to NA and all cells within to 1. Write to **roi_mask.tif**.
   4. Read fire history layer, transform projection, repair polygons, and clip to the ROI.
   5. Filter fire history to only years after the time since first fire option, if required.
   6. Extract a list of unique years in which fires occurred throughout the dataset, write to **yearlist.csv**.
   7. For each year in year list, filter the fire history layer, and rasterize each year, writing a binary output raster containing a value of 1 when a fire was present and 0 when it was not.
   8. Stack all fire history rasters into a data cube.
   9. Process stack to calculate Last Year Burnt output, writing to **rLastYearBurnt.tif**.
   10. Subtract Last Year Burnt from the current year to generate the Time Since Last output, write to **rTimeSinceLast.tif**.
   11. Vectorize Time Since Last raster to polygons, simplify and repair geometry, and write to **v_tsl.gpkg**.
   12. Process fire history stack to generate Number of Times Burnt, writing to **rNumTimesBurnt.tif**.
   13. Vectorize Number of Times Burnt raster to polygons, simplify and repair geometry, and write to **v_timesburnt.gpkg**.
   14. Read vegetation polygon layers and merge into a single dataset.
   15. Transform vegetation layer to project projection, repair polygons.
   16. Read vegetation-fire lookup table, join to the vegetation polygons based on the Veg field.
   17. Fill in missing values in Min, Max, FireProne and Adv fields with zeroes.
   18. Save joined vegetation polygon layer to **v_vegBase.gpkg**.
   19. Rasterize vegetation ID code to **r_vegcode.tif.**
   20. Rasterize minimum fire interval to **r_vegmin.tif.**
   21. Rasterize maximum fire interval to **r_vegmax.tif.**
   22. Rasterize fire prone status to **r_vegfireprone.tif**.
   23. Rasterize fire advantage status to **r_vegadv.tif**.

8. Process vegetation status
   1. Calculate the time since first fire (TSFF) for the FireTools biodiversity status algorithm
   2. Apply biodiversity algorithm based on minimum interval, maximum interval, times burnt, time since last fire, and fire history stack. The algorithm is adapted from the original FireTools flowchart and assigns each cell in the output raster a status value.
   3. Biodiversity status output raster is masked to the ROI and is written to **r_vegout.tif.**
   4. Biodiversity status is vectorized to polygons, joined to status category labels, and written out to **v_vegout.gpkg**.
9. Process fire management zone status
   1. Load fire management zone layer, transform to project projection and repair polygons, and clip to ROI.
   2. Load fire management zone lookup table and join to polygon layer based on the zone field.
   3. Rasterize the maximum interval field of the joined data, save to **r_fmz.tif**.
   4. Apply fire management zone threshold processing algorithm, to identify areas within or outside interval, and assign a status code.
   5. Fire management zone status output raster is masked to the ROI and is written to **r_fmzout.tif.**
   6. Vectorize fire management zone status to polygons, join to status category labels, and write to **v_fmzout.gpkg.**

10. Merge biodiversity and fire management zone status
    1. Load biodiversity status and fire management zone status rasters.
    2. In areas outside fire management zones, assign the status value of the biodiversity threshold, otherwise retain the fire management zone status.
    3. Status is masked to the ROI and a combined status raster is written to **r_fmz_bio_out.tif**.
    4. Vectorize combined status to polygons, join to status category labels, and write to **v_fmz_bio_out.gpkg**.
11. Process Strategic Fire Advantage Zone status:
    1. Read fire management zone layer, extract SFAZ polygons based on the defined zone code value, write to **v_sfaz.gpkg**.
    2. Rasterize SFAZ, write to **r_fmz.gpkg**.
    3. Intersect SFAZ polygons with time since fire polygons.
    4. Assign status code and text based on time since fire, for standard 6-year minimum interval, and custom interval.
    5. Write SFAZ status polygons to **v_tsl_sfaz.gpkg** and custom interval status to **v_sfaz_candidate_blocks.gpkg**.
    6. Rasterize SFAZ status polygons to **r_tsl_sfaz.gpkg** and custom interval status to **v_sfaz_candidate_blocks.tif**.
12. Merge Strategic Fire Advantage Zone status and fire management zone status.
    1. Load fire management zone status raster.
    2. Assign SFAZ status to areas inside SFAZ polygons, retain existing status in all areas outside.
    3. Write combined status to **r_sfaz_fmz_out.tif**.
    4. Vectorize combined status to polygons, join to status category labels, and write to **v_sfaz_fmz_out.gpkg.**
13. Merge Strategic Fire Advantage Zone status and combined biodiversity and fire management zone status.
    1. Load combined biodiversity and fire management zone status raster.
    2. Assign SFAZ status to areas inside SFAZ polygons, retain existing status in all areas outside.
    3. Write combined status to **r_sfaz_fmz_bio_out.tif**.
    4. Vectorize combined status to polygons, join to status category labels, and write to **v_sfaz_fmz_bio_out.gpkg.**
14. Render online maps
    1. Output web map for biodiversity status to output directory
    2. Output web map for fire management zone status to output directory
    3. Output web map for strategic fire advantage zone status to output directory
    4. Output web map for combined status to output directory
    5. Output web map for Time Since Last Fire to output directory
    6. Output web map for Number of Times Burnt to output directory
15. Post-process and clean up
    1. Delete temporary files, individual fire year rasters
    2. Write manifest file
    3. Write ESRI-compatible projection file and raster table for biodiversity, FMZ, SFAZ and combined rasters
    4. Add table and colour ramp to vegetation code raster, write ESRI-compatible projection file and raster table
    5. Mask times burnt, time since last fire and last year burnt rasters to ROI and write to output

6. Render web map tiles for biodiversity, FMZ, SFAZ and combined status
7. Create shapefile versions of the vector polygon output files for the biodiversity, FMZ, SFAZ and combined status, the ROI, time since last fire, times burnt, the SFAZ candidate blocks, and the vegetation base map.

16. End process, return control to host server.
17. Compress output files on processing server, download processing output.

COMMON ERRORS

If an analysis fails to complete, check for the following problems:

Incorrect layer and field specification	Ensure you have selected all the appropriate layers in each form in the analysis definition screen. For example, make sure the fire history layer is actually selected under **Fire History**, and that the field containing the season is selected as the appropriate field. Common problems stem from the vegetation polygon layer and look-up table field names; we recommend the linking field is named **Veg** and contains only numeric data.
Incorrect field data type	Ensure all relevant fields in the input layers have the correct data **type**. In particular, ensure that fields intended to contain numbers (year, fire intervals, vegetation or fire management zone codes) contain only numbers, and are set to a numeric, preferably integer type, when generating these layers in your GIS software. Some checking is performed by FireTools, but in cases where the input data cannot be coerced to a number, an error may result.
Incorrect layer extents	If the layers do not have overlapping extents, and in particular if the fire, vegetation, and fire management zone layers are not within the analysis boundary extent, no processing will be able to take place and an error will result.
Too large processing extent or to high resolution	FireTools Cloud is capable of processing extensive areas of the state in a single run, but memory limitations in the processing environment means it is not possible to process, for example, the entire state at once. We recommend processing individual Parks regions. Output will be clipped to the analysis boundary, so multiple regions can be displayed next to each other when viewing the output in your GIS system.
Incomplete or invalid polygons	FireTools Cloud performs geometry checking on input layers and attempts to repair any polygons that are invalid (edges crossing each other, multiple vertices in a single location etc.). However it is not always successful, and it best to use your GIS software's functions to ensure input vegetation and fire history polygons layers contain valid geometry.

FUTURE PLANS

FireTools Cloud is still heavily under development. It has undergone extensive testing with standard Parks datasets, but we are keen to identify bugs when users upload their own datasets which may not comply exactly with the assumptions we have made. Future additions we are planning to implement in FireTools include:

- Optional use of park gazettal dates to provide bounds for the known fire history record.
- Ability to define a rectangular spatial extent for analysis using a map interface.

- Automatic processing of future projections, to identify areas that will become long unburnt in coming years.
- Integration with a central spatial data store, so official vegetation and fire history layers can automatically be incorporated in the analysis, and so results can be automatically stored on the same system.
- Calculation of area summary tables, to summarise the area of vegetation of fire management zone or block with each burn status within the analysis region.

Please send any comments, questions, bug reports and support requests to me (**grant.williamson@utas.edu.au**).

APPENDIX 1 – FIRE REGIME THRESHOLD STATUS DEFINITIONS

Category Name	Guidelines for interpreting fire regime threshold status
Too Frequently Burnt (Consecutive fire intervals shorter than recommended minimum interval)	These areas have experienced sustained (two or more) consecutive intervals between fires shorter than the recommended minimum interval for this vegetation type. Any Rainforest / Mangrove/ fire exclusion vegetation that has been burnt will be in this category. *Areas of vegetation that are repeatedly burnt at intervals shorter than recommended for the vegetation type may experience a decline in the abundance of plant species sensitive to frequent fire. If inter- fire intervals shorter than the recommended minimum continue, these sensitive species are at risk of local extinction. Attempts should be made to minimise fire occurrence in these areas.*
Vulnerable to Frequent Fire (Most recent fire interval shorter than recommended minimum interval)	These areas have already experienced one inter-fire interval less than the minimum interval recommended for this vegetation type and/or the current time-since-fire is less than the minimum recommended interval. All unburnt Rainforest/ Mangrove/ fire exclusion vegetation is in this category.
Within Threshold	The time-since-fire age of the vegetation is greater than the minimum recommended inter-fire interval and less than the maximum recommended inter-fire interval. If a fire occurs before the number of years specified as the minimum interval has been reached it will move into the 'Vulnerable to Frequent Fire' category. If three or more fires occur in close succession the area will move into the 'Too Frequently Burnt' category.
Long Unburnt (One or more fire intervals longer than longest recommended interval)	The post-fire age of the vegetation is greater that the recommended maximum inter-fire interval for this vegetation type. *If fire continues to be absent from the vegetation for a prolonged time, it is anticipated that plant species that require fire to stimulate flowering or seed production (and their seed banks) may begin to senescence. Long unburnt areas in some vegetation types are very rare and therefore significant. Long unburnt vegetation may also have other ecological values that make it important habitat for certain species in a given area. Careful consideration should be given before burning these areas, and wherever possible the decision should be based on a scientific assessment and/or recommendation prior to burning.*
Unknown	There has been no fire mapped for this area and the maximum recommended fire interval for the vegetation type is longer than the length of time for which fire records are available in the study area. It is not possible to determine if the vegetation is in the 'Within Threshold' or 'Long Unburnt' category.
No Regime Assigned	Areas which do not have recommended fire intervals assigned to them eg. cleared land, rock.

APPENDIX 2 – BIODIVERITY THRESHOLD ANALYSIS LOGIC

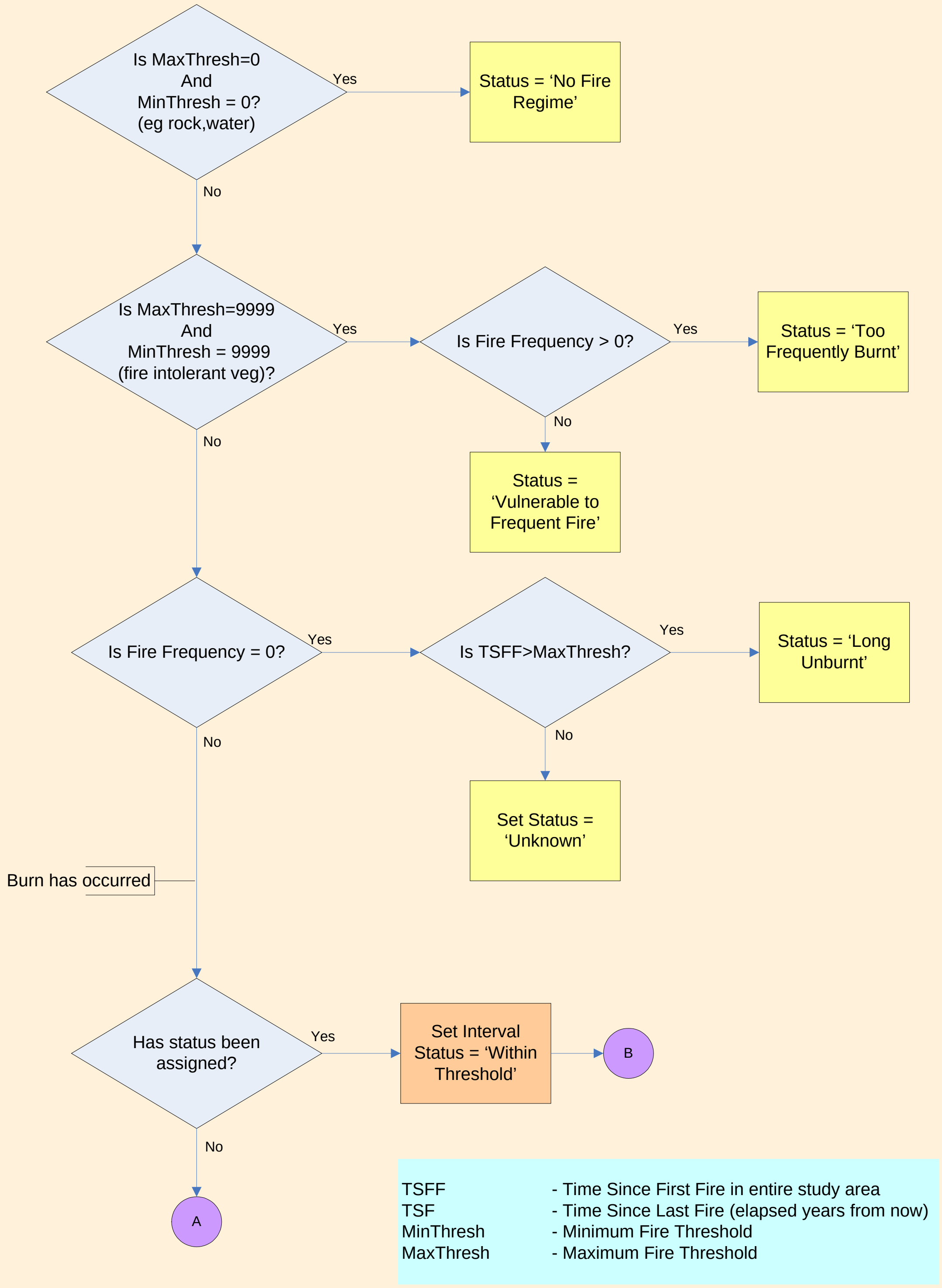


Figure 32: Biodiversity Threshold Logic - 1/3

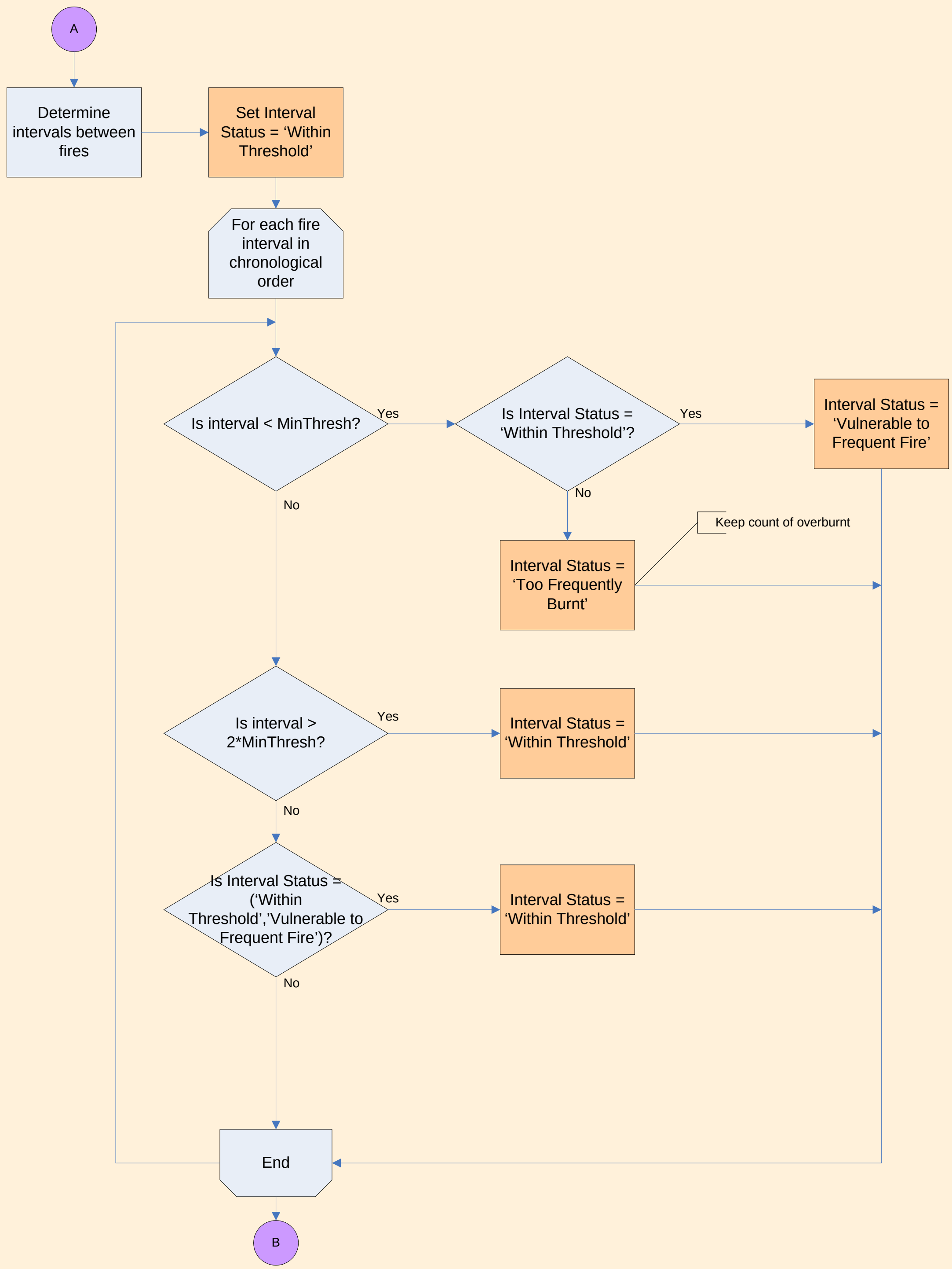


Figure 33: Biodiversity Threshold Logic 2/3

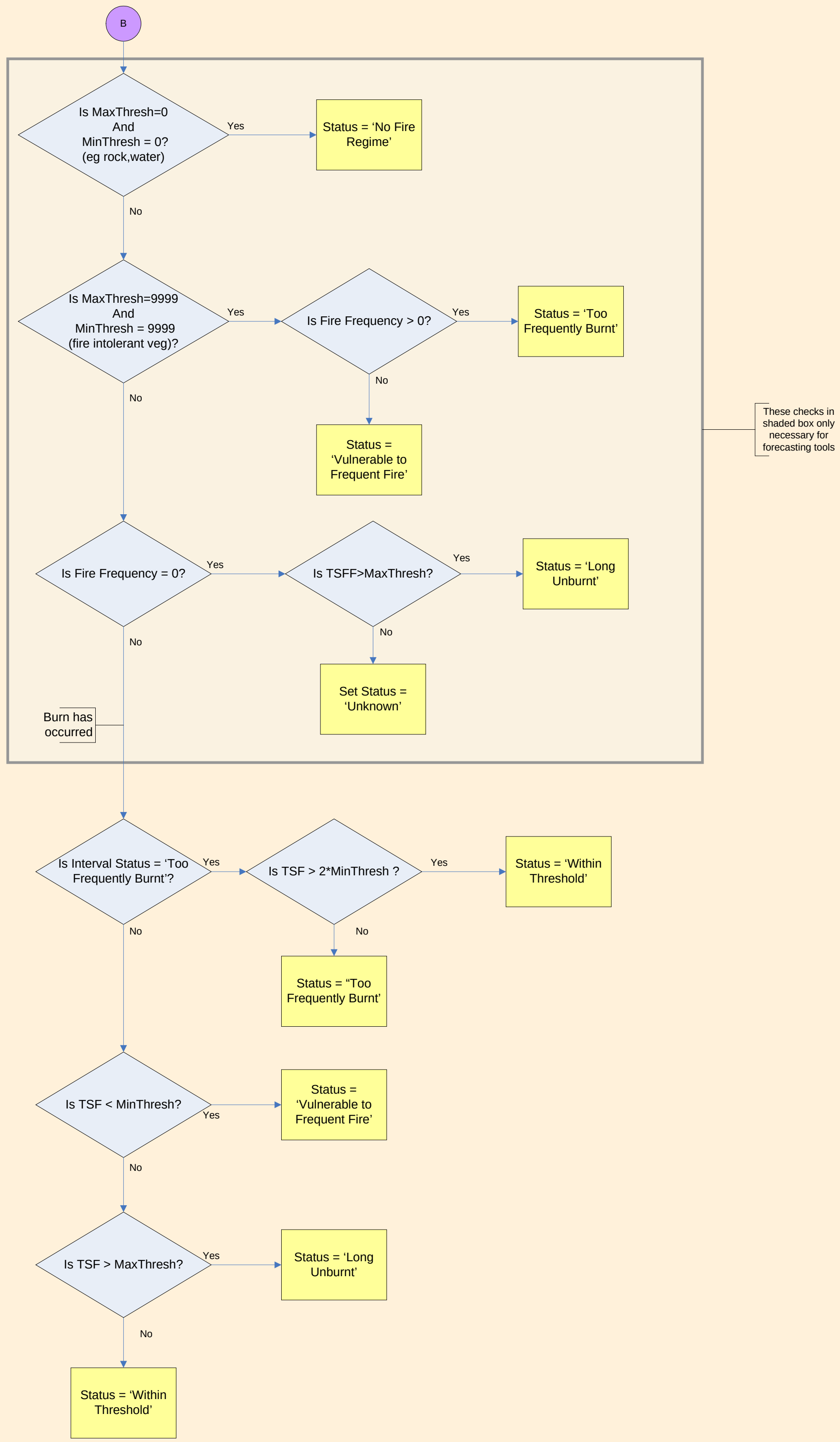


Figure 34: Biodiversity Threshold Logic 3/3