Fire as Landscape Complexity Metric Contributing to Native Vegetation Composition Account

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Background

Fire is an important driver of change in native vegetation condition. The key criteria measured are extent (area burnt), frequency, distribution, intensity (strength of the fire) and patchiness (number of distinct areas burnt at any one time) (State of the Environment Committee 2011). However, fire is often not incorporated into vegetation condition assessments. These methods provide a possible approach to incorporating fire as a landscape context metric, to complement a native vegetation condition account as described by the paper, *Best Practice for Constructing a Native Vegetation Condition Account* (Thackway *et al.* 2015).

Mosaic pattern measures demonstrate how continuous and complex the landscape is in relation to dominant ecological processes, such as invasive native scrub in western NSW (GHD and Cummings 2009) and the fire in the northern Australian savannahs (Andersen *et al.* 2005).

Two metrics will initially be used, based on Time Since Last Fire (TSLF). **Time since last fire (TSLF)** is a measure of the time since the particular area of vegetation was burnt. Within a vegetation type it is likely that sections will have been burnt at different times.

The **first metric** measures the mean observed TSLF, compared to the mean of the optimal TSLF (reference condition). It requires an estimate of the optimal TSLF. The observed mean TSLF can be calculated from the percent area of each TSLF in years.

The **second metric** measures the variation (or distribution) of different TSLF within the vegetation community. Spatial heterogeneity in fire frequency will allow the overall expected TSLF to be maintained, with some areas burnt recently whilst other areas should not have been burnt for a time longer than the expected TSLF.

The environmental accounts model relies on simple quantitative metrics based on a good understanding of the reference state. In this case, we may not know the pre--European state, therefore the best approach is to decide what the status quo of fire is, and then try to push it in particular directions based on what is believed to be good management.

If we accept that fire needs to be managed and that the status quo is unacceptable, metrics generated for a 10-year period without active management describes what is undesirable. So a reference condition could be the state of the metrics pushed away from status quo in qualitatively defined directions. For example, the reference condition for *time since last burnt* would be a flattening of the peak and a fattening of the tail of a distribution of age classes for the no-management period, because it would be assumed that having an even spread of age classes is desirable, this would apply to both under-burnt and over-burnt systems.

Therefore, a method was devised that assessed the age classes of each native vegetation type in a region to determine whether there was an even, desirable spread of age classes, or whether this had been affected by fire, and the degree to which it had been affected.

The template for calculating the metrics, described in these methods, is provided as an Excel spreadsheet.

It is important to note that these metrics focus on TSLF alone and do not yet include other important measures of fire condition such as the intensity (seasonality/severity) or patchiness of a fire event. However they represent an important first step in incorporating fire data into condition monitoring accounts.

Summary of Methods

Data Preparation

1. Access the Excel template to use with these methods. It can be downloaded from www.nrmregionsaustralia.com.au
2. Allocate time since fire to veg or IBRA regions (referred to unit of interest)
3. For each unit of interest calculate the area (km^2) for time since fire for each category (years since fire).
4. Elicit from local experts or literature the optimal TSLF (time since last fire) interval for each area of concern (for ecological condition).

Henceforth we refer to this optimal TSLF as the **expected TSLF.**

Table 15: Format for inputting the TSLF data (repeat for each vegetation type).

Vegetation Type:

Time since last fire (TSLF)	2011	
(years since fire)	Area (km^2)	% Area
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Unkown		
TOTAL AREA		100

General Notes

1. It is recommended that you use a separate file for each unit of interest (i.e. your vegetation communities/IBRA regions.
2. Enter data only in grey and blue cells
3. Generated numbers will appear in pink
4. Important results will appear in blue and yellow
5. Metric results will appear in red.
6. All the sheets are links so please enter data sequentially as per instructions

Initial Data Entry

1. Go to "**ENTER DATA**"
2. In **Column B**, under Data available, for known years with no fire: Enter '0'
3. For unknown years (i.e. data gaps): Leave blanks (so that total % area adds up to 100).
4. Enter in **Column C** that area (km^2) for each TSLF
5. Enter the year in **C3**
6. Enter your **total area** (in km^2: of unit of interest) into **cell C35**
7. The template will allow you to enter as many years as you have data for up until 30 years
8. The template will calculate the percentages.
9. Enter the **expected mean fire return interval (years)** into **cell H1 (blue)**

You can create a column graph of the TSLF data for your region, where time since fire is along the x-axis and % area in that category is along the y-axis. See below of an example. This is the observed distribution of TSLF for the area. It is the basis for calculating Metric 1 (comparing means of TSLF) and Metric 2 (comparing distributions of TSLF).

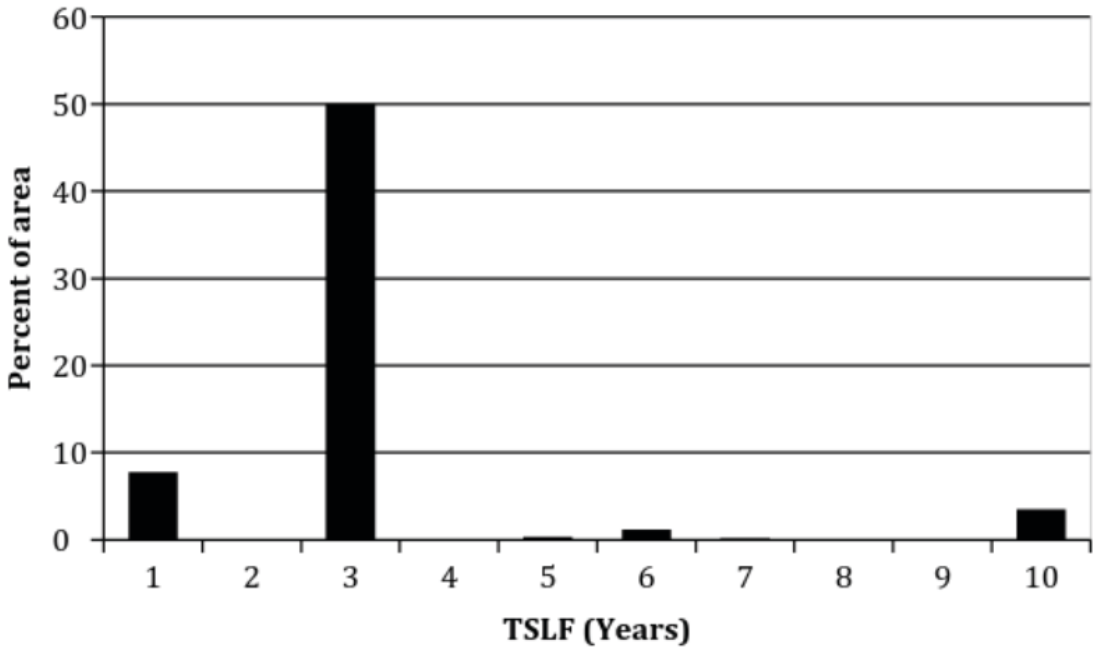


Figure 15: Example of the observed distribution of TSLF in the area.

Metric 1 – Mean TSLF (Time Since Last Fire)

This equation measures the **observed TSLF** (what you measure with MODIS) against the **expected TSLF** (what it should be) and gives a measure of how similar they are (i.e. near 100 means that the observed and expected values are very similar, and near 0 means they are very different).

You need to insert the **expected TSLF** for your area and estimate an observed mean TSLF from your data. The equation below calculates the metric (0-100).

As detailed records of fire events are not available prior to 1800, reference benchmarks for natural fire intervals or patterns should be derived from existing literature where possible, but will more likely be determined using expert opinion (including traditional knowledge) and models for each vegetation type in the region.

There is no gold standard with respect to what ecologically appropriate fire regimes might look like for different vegetation types, but some systems are well known and descriptions/guides are available. A good guide is Joe Walker's chapter in *Fire and the Australian Biota* (Walker 1981). Local expert knowledge is vital as fire regimes vary dramatically across different parts of Australia and metrics derived in one area may not be appropriate in another.

Vegetation-specific guidelines are also available for some areas (see The Clarke Connors Range Bushfire Consortium – *Fire Management Guidelines*) (The Clarke Connors Range Bushfire Consortium 2009). The methods we present here should assist in interpreting the current fire regime in the region, providing information towards the development of best practice fire management for biodiversity.

Steps For Metric 1

Box 1 Metric 1

$$Metric\ 1 = \left(\frac{|\mu o - \mu e|}{\mu e}\right)$$

where MIN $(1, \frac{|\mu o - \mu e|}{\mu e})$

μ is the mean and e is the estimated optimal TSLF and o is the observed TSLF

1. Go to worksheet **Metric 1 – TSLF**
2. Your observed mean fire return interval is in the highlighted **YELLOW BOX (L3)**
3. Your **Metric 1 result** is in the highlighted **RED BOX (L5)**
4. A figure showing the distribution of your **observed fire frequency** will appear

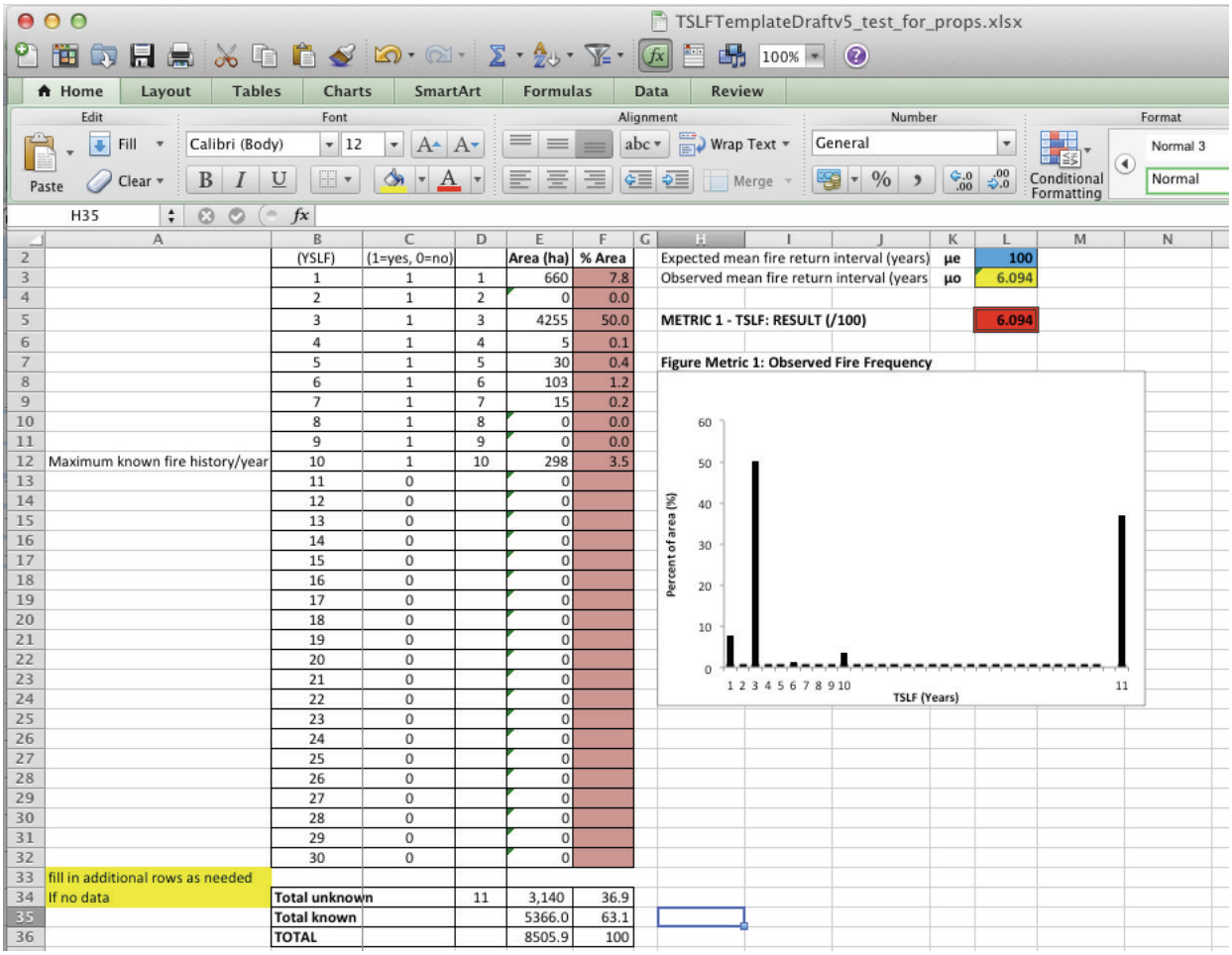


Figure 16: Metric 1 worksheet

Metric 2 – Comparing TSLF Distributions

This metric measures the diversity of TSLF across the landscape. Even if we want the landscape burnt with a particular average frequency, we still want diversity in timing – we want some areas burnt recently, and others that haven't been burnt for a while. We don't want the whole landscape burnt on the same year.

In order to estimate a measure of diversity, we use a probability distribution based on the optimal TSLF. For example, with an optimal TSLF of 10 years the distribution of fires would look like **Figure 17**. This is the expected distribution of fire across the landscape.

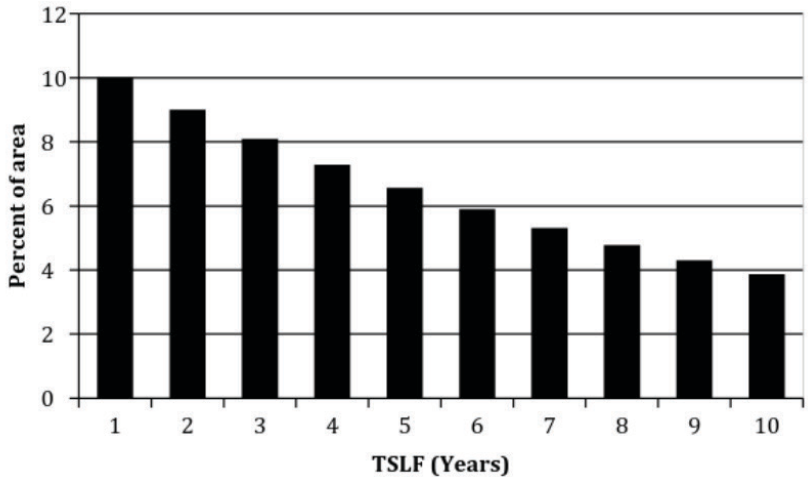


Figure 17: Expected fire distribution

This graph says that 10% of the area was burnt last year (column one) and about 9% was burnt two years ago (column 2).

Now you can compare your expected distribution to your observed distribution. This is where we use our observed distribution. Notice if that they look similar or very different.

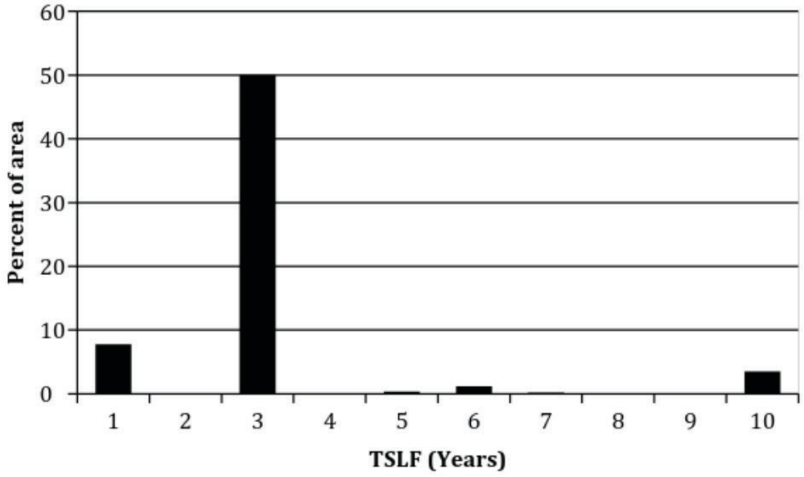


Figure 18: Observed fire distribution

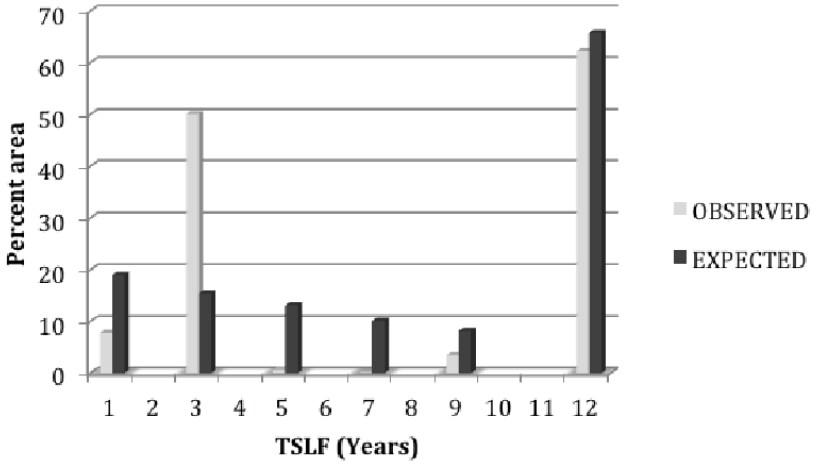


Figure 19: The observed and expected fire distributions for 2011

a) Calculating statistical difference

First it is helpful to calculate whether the observed two distributions are significantly different. The statistical test is a chi-square test. Note, this is not a metric. It is a statistical test to verify whether the difference between the observed distribution and the expected distribution is not just a result of variation and chance. It tells you whether the difference is real or not. Now we calculate a metric to measure how different the distributions are. If the result is less than 0.05 you know that there is a very high chance (95%) that the difference is not due to chance and it is a significant one.

b) Calculating Metric 2

Metric 2 gives a measure of how similar the two sets of data are out of 100. If Metric 2 is near 100 it means that the distribution of fire is very similar to what it should be.

We could compare the distributions as they are but since we probably don't care too much if the fire happened a year on either side of what we want, than we put them in groups of years. We therefore group them into categories according to geometric scaling (A). The first category (Ai) contains all the information for years 0- μ (for example, 0-10). The next category Aii contains μ - 2 μ (for example 10-20) etc.

Box 2 Metric 2

$$Metric\ 2 = 1 - \frac{\left(\Sigma \frac{A_{io}}{A_{ie}}\right)}{n - 1}$$

where $0 < \frac{A_{io}}{A_{ie}} \leq 0$

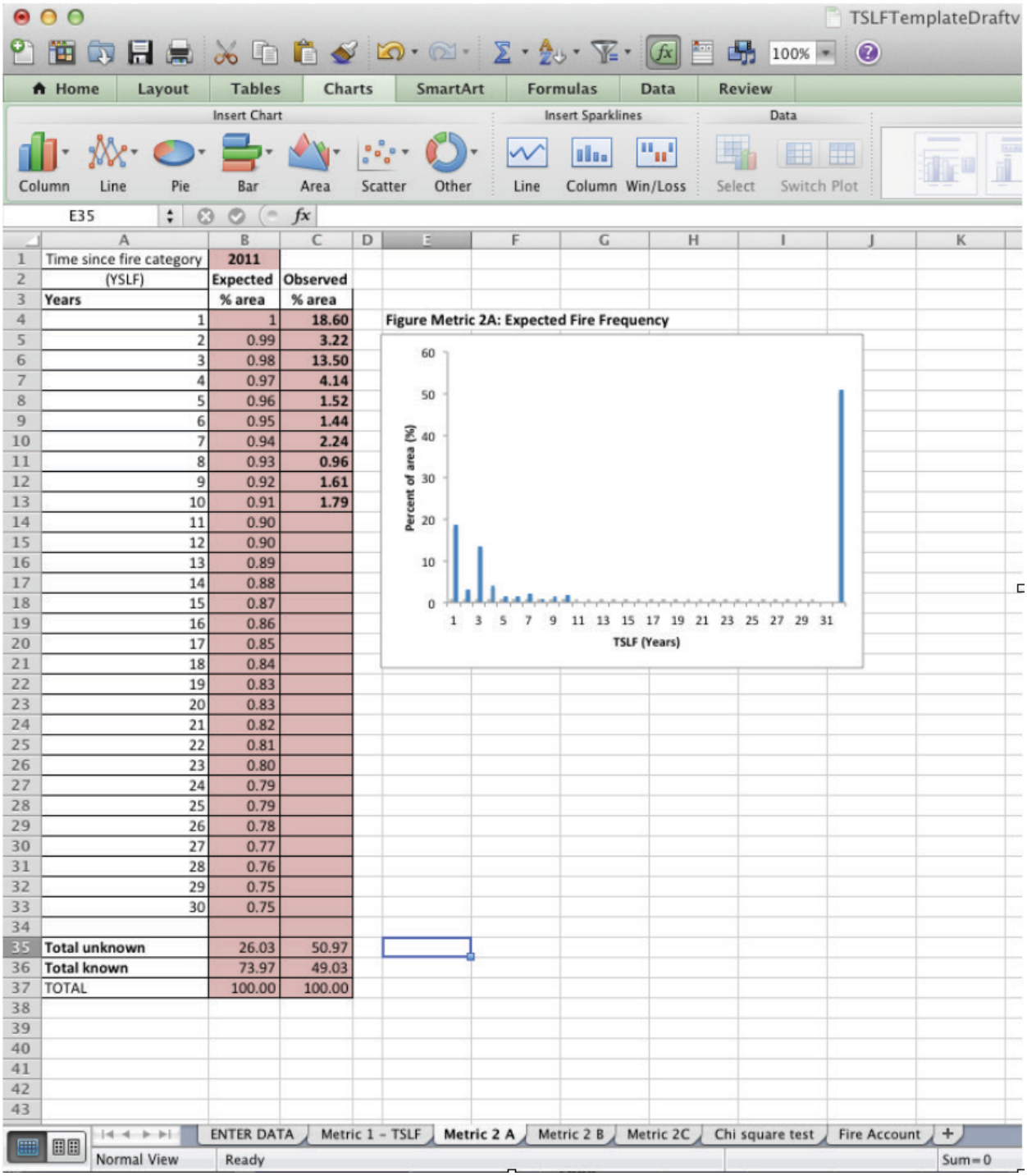
μ is the mean and e is the estimated optimal TSLF and o is the observed TSLF

Steps For Metric 2 (Enter Data Only in Grey Cells):

The expected distribution of fire is estimated as a probability as a function of the expected TSLF. The average proportion of the area burnt in each year will equal the expected number of fire events for a given period. For example, if you expect one fire every 10 years (an average TSLF of 10), then the probability of a fire is 1/10. If you expect one fire every 100 years it is 1/100.

Step 2A

1. Go to worksheet **Metric 2A**
2. An optimal fire frequency (**expected TSLF**) will be generated in Column B based on what you entered in the previous sheet
3. A figure showing the distribution of your **expected fire frequency** will appear

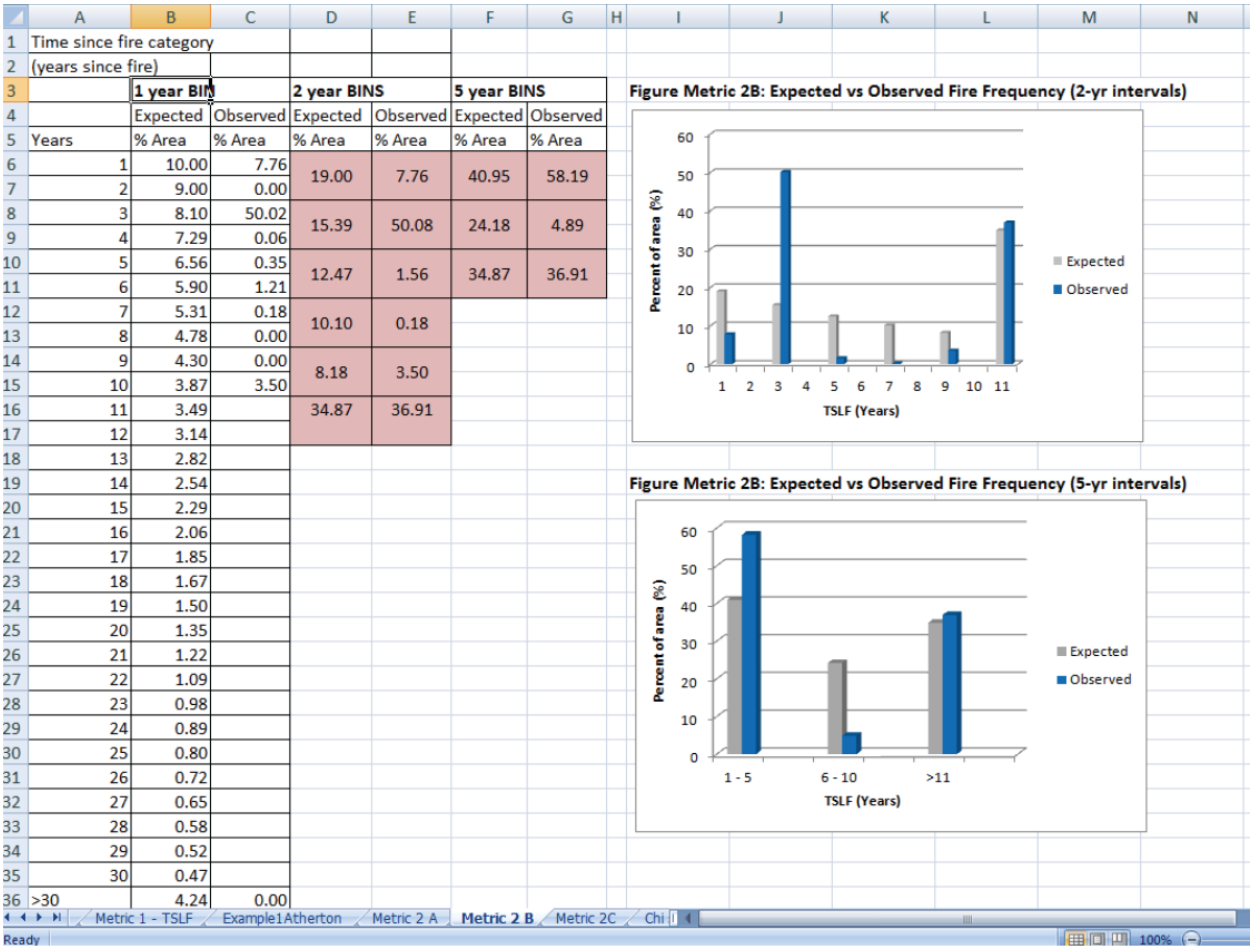


	A	B	C
1	Time since fire category	2011	
2	(YSLF)	Expected	Observed
3	Years	% area	% area
4	1	1	18.60
5	2	0.99	3.22
6	3	0.98	13.50
7	4	0.97	4.14
8	5	0.96	1.52
9	6	0.95	1.44
10	7	0.94	2.24
11	8	0.93	0.96
12	9	0.92	1.61
13	10	0.91	1.79
14	11	0.90	
15	12	0.90	
16	13	0.89	
17	14	0.88	
18	15	0.87	
19	16	0.86	
20	17	0.85	
21	18	0.84	
22	19	0.83	
23	20	0.83	
24	21	0.82	
25	22	0.81	
26	23	0.80	
27	24	0.79	
28	25	0.79	
29	26	0.78	
30	27	0.77	
31	28	0.76	
32	29	0.75	
33	30	0.75	
34			
35	Total unknown	26.03	50.97
36	Total known	73.97	49.03
37	TOTAL	100.00	100.00

Figure 20: Metric 2A worksheet

Step 2B

1. Go to worksheet **Metric 2B**
2. The pink cells will automatically update from the information you entered in Metric 1 and Metric 2A
3. Check that the **Total values** in **row 38** are **100**
4. A figure showing the distribution of your **observed fire frequency** will appear
5. Grey lines = expected frequency distribution
6. Blue lines = observed frequency distribution



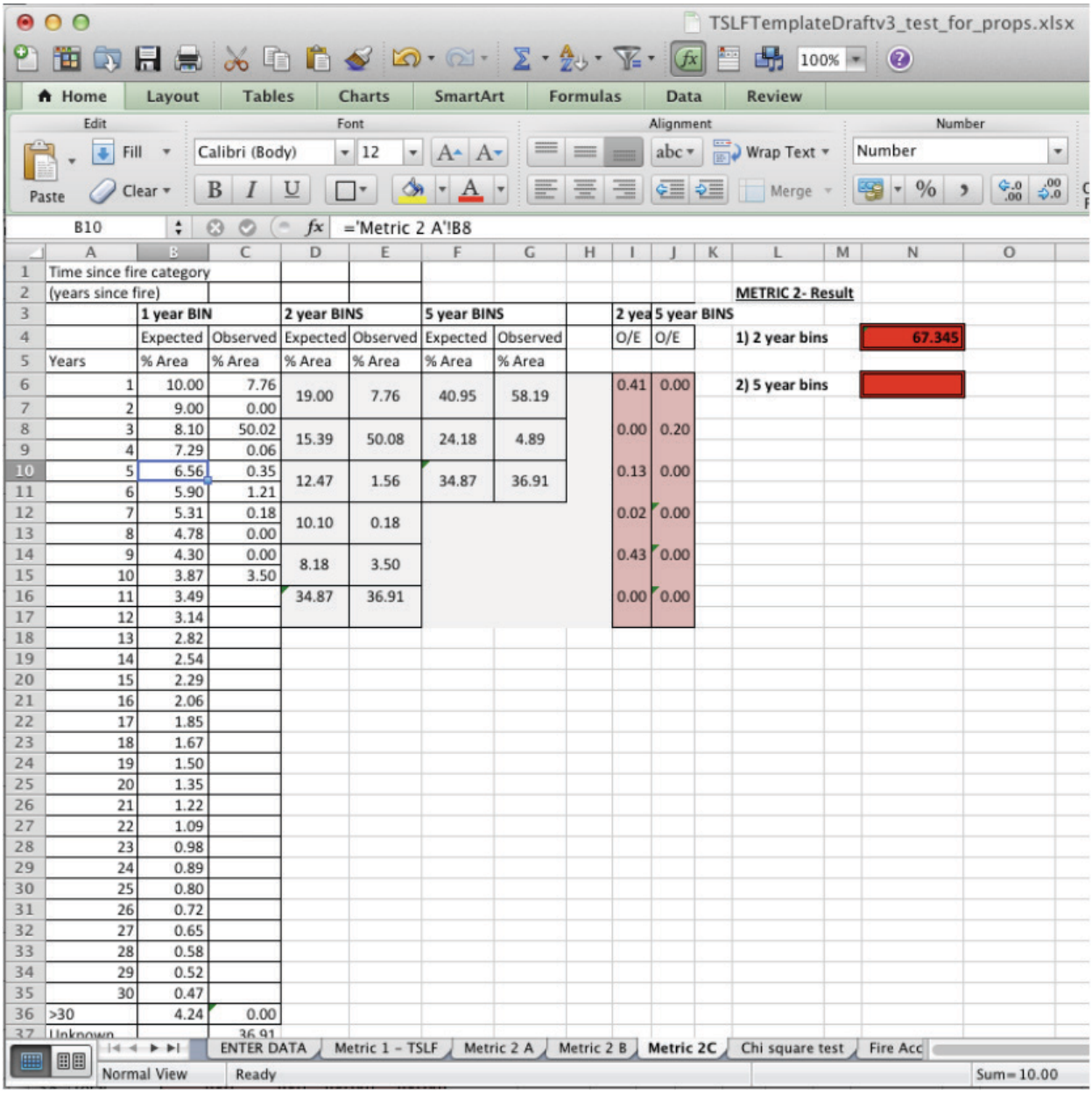
	A	B	C	D	E	F	G
1	Time since fire category						
2	(years since fire)						
3		1 year BIN		2 year BINS		5 year BINS	
4		Expected	Observed	Expected	Observed	Expected	Observed
5	Years	% Area	% Area	% Area	% Area	% Area	% Area
6	1	10.00	7.76	19.00	7.76	40.95	58.19
7	2	9.00	0.00				
8	3	8.10	50.02	15.39	50.08	24.18	4.89
9	4	7.29	0.06				
10	5	6.56	0.35	12.47	1.56	34.87	36.91
11	6	5.90	1.21				
12	7	5.31	0.18	10.10	0.18		
13	8	4.78	0.00				
14	9	4.30	0.00	8.18	3.50		
15	10	3.87	3.50				
16	11	3.49		34.87	36.91		
17	12	3.14					
18	13	2.82					
19	14	2.54					
20	15	2.29					
21	16	2.06					
22	17	1.85					
23	18	1.67					
24	19	1.50					
25	20	1.35					
26	21	1.22					
27	22	1.09					
28	23	0.98					
29	24	0.89					
30	25	0.80					
31	26	0.72					
32	27	0.65					
33	28	0.58					
34	29	0.52					
35	30	0.47					
36	>30	4.24	0.00				

Figure 21: Metric 2B worksheet

Step 2C

1. Go to worksheet **Metric 2C**
2. The pink cells will automatically update from the information you entered in Metric 1 and Metric 2A
3. Your **Metric 2** result (based on two year bins) is in the highlighted **RED BOX (cell P4)**

Note: Worksheet **Chi square test** gives you the results of a statistical probability test. A value in cell of 0.05 means that there is a 95% chance that the difference between observed and expected is not due to chance.

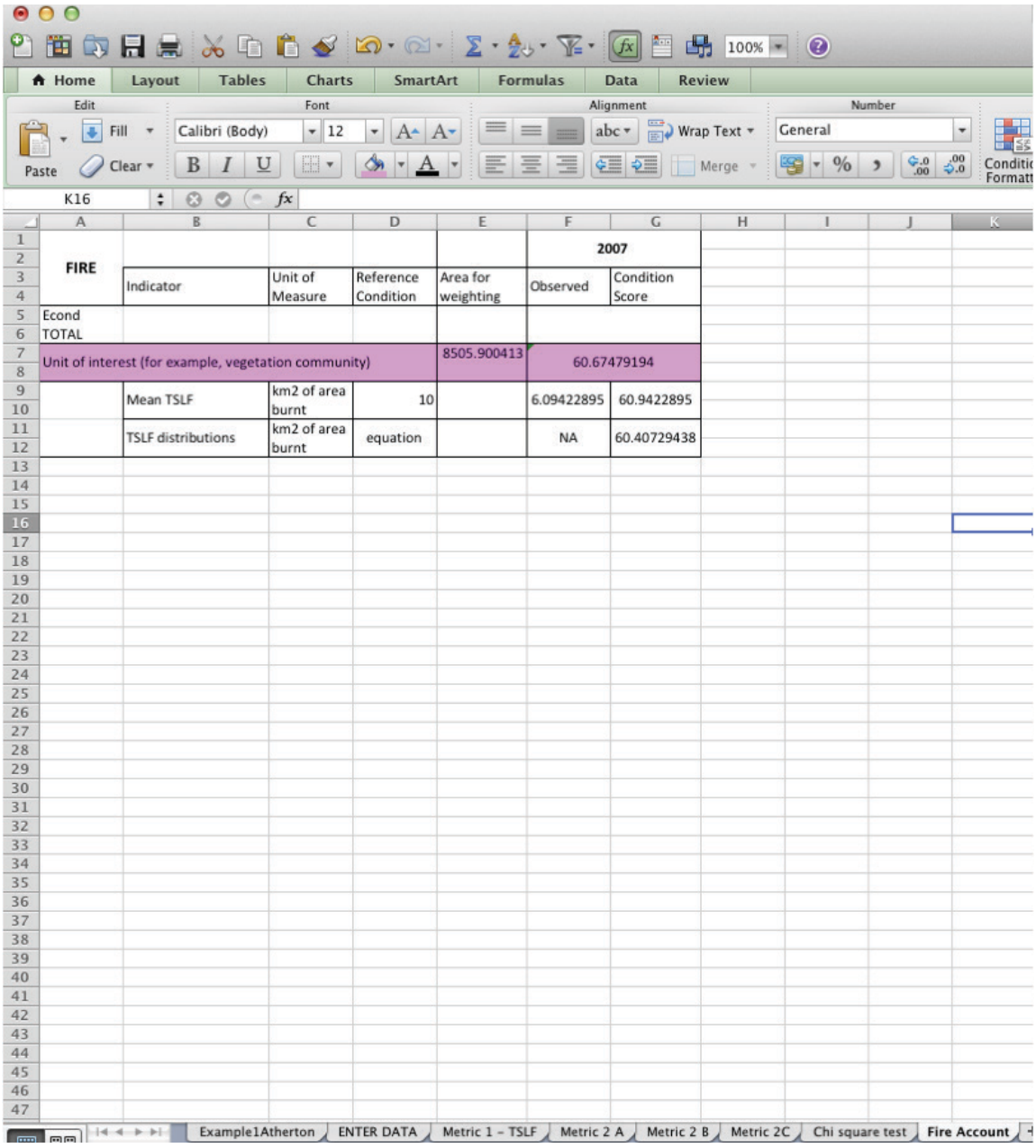


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Time since fire category														
2	(years since fire)														
3		1 year BIN		2 year BINS		5 year BINS			2 yea	5 year BINS					
4		Expected	Observed	Expected	Observed	Expected	Observed		O/E	O/E					
5	Years	% Area	% Area	% Area	% Area	% Area	% Area								
6	1	10.00	7.76	19.00	7.76	40.95	58.19		0.41	0.00					
7	2	9.00	0.00												
8	3	8.10	50.02	15.39	50.08	24.18	4.89		0.00	0.20					
9	4	7.29	0.06												
10	5	6.56	0.35	12.47	1.56	34.87	36.91		0.13	0.00					
11	6	5.90	1.21												
12	7	5.31	0.18	10.10	0.18				0.02	0.00					
13	8	4.78	0.00												
14	9	4.30	0.00	8.18	3.50				0.43	0.00					
15	10	3.87	3.50												
16	11	3.49		34.87	36.91				0.00	0.00					
17	12	3.14													
18	13	2.82													
19	14	2.54													
20	15	2.29													
21	16	2.06													
22	17	1.85													
23	18	1.67													
24	19	1.50													
25	20	1.35													
26	21	1.22													
27	22	1.09													
28	23	0.98													
29	24	0.89													
30	25	0.80													
31	26	0.72													
32	27	0.65													
33	28	0.58													
34	29	0.52													
35	30	0.47													
36	>30	4.24	0.00												
37	Unknown		36.91												

Figure 22: Metric 2C worksheet

Building the Fire Account

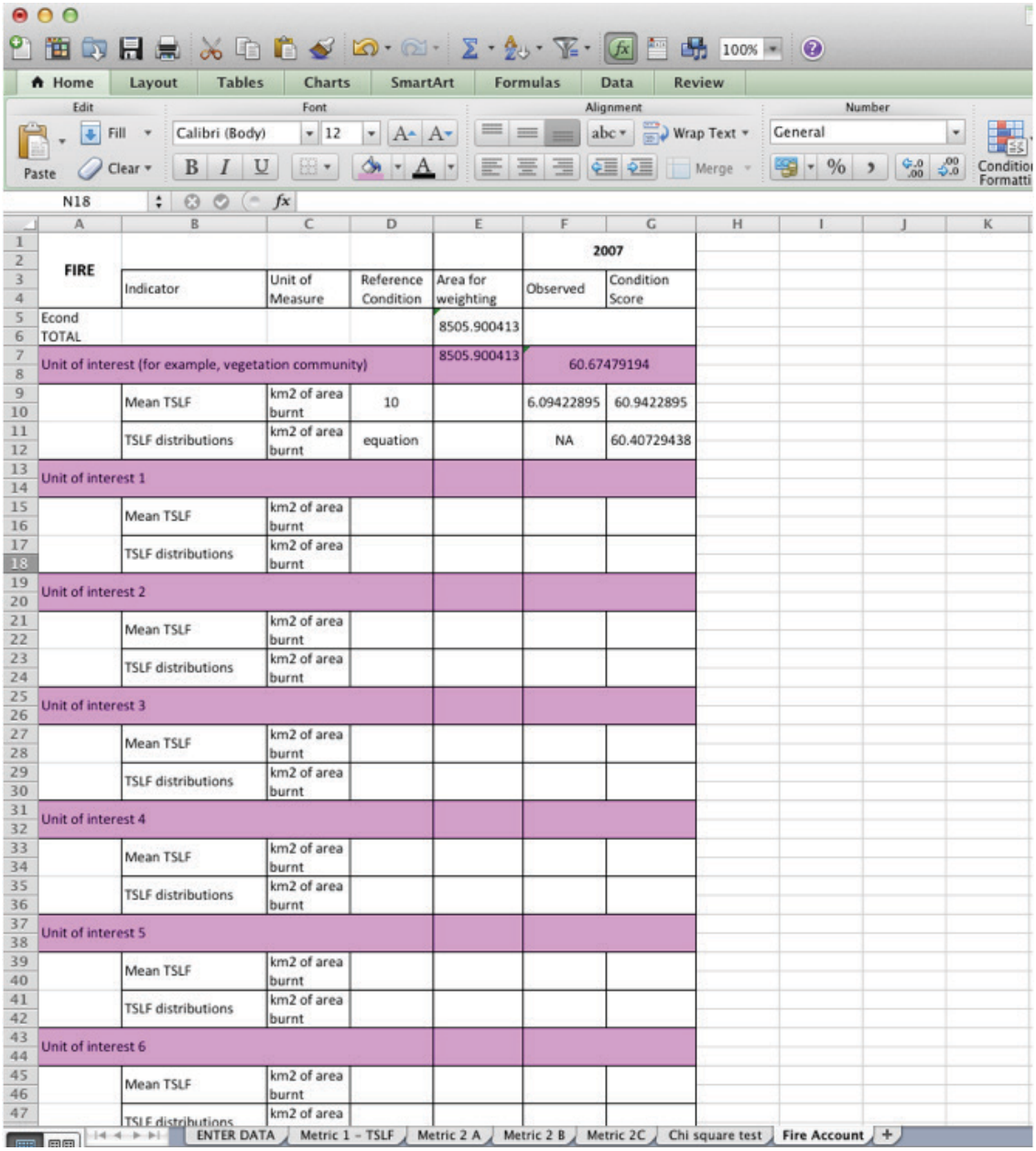
1. The results will automatically populate a table in worksheet **Fire Account.**
2. It is recommended that you use a separate file for each unit of interest (i.e. your vegetation communities).



	A	B	C	D	E	F	G
1						2007	
2	FIRE						
3		Indicator	Unit of Measure	Reference Condition	Area for weighting	Observed	Condition Score
4							
5	Econd						
6	TOTAL						
7	Unit of interest (for example, vegetation community)				8505.900413	60.67479194	
8							
9		Mean TSLF	km2 of area burnt	10		6.09422895	60.9422895
10							
11		TSLF distributions	km2 of area burnt	equation		NA	60.40729438
12							

Example1Atherton | ENTER DATA | Metric 1 – TSLF | Metric 2 A | Metric 2 B | Metric 2C | Chi square test | Fire Account

3. When you have completed a file for each unit of interest you will have a number of subaccounts for fire. You can easily copy and paste these to create one fire account for your region.
4. In order to calculate an Indicator Condition Score for your region, apply the following equation to cell F5: = ((F7*E7)+(F13*E13)+(F19*E19)…)/E5.
5. This should combine your condition scores weighted by area.
6. Check that E5 is the total area for your region. It will sum the column automatically so it should be right but it's a good way to check everything is entered correctly and the template is working.
7. Integration of the fire metrcis with other indicators of native vegetation condition should be discussed with specialists. Multiple techniques are available which can be used to communicate the importance of the fire indicator to the theme indicator condition score and the regional ***Econd.***



					2007		
FIRE	Indicator	Unit of Measure	Reference Condition	Area for weighting	Observed	Condition Score	
Econd TOTAL				8505.900413			
Unit of interest (for example, vegetation community)				8505.900413	60.67479194		
	Mean TSLF	km2 of area burnt	10		6.09422895	60.9422895	
	TSLF distributions	km2 of area burnt	equation		NA	60.40729438	
Unit of interest 1							
	Mean TSLF	km2 of area burnt					
	TSLF distributions	km2 of area burnt					
Unit of interest 2							
	Mean TSLF	km2 of area burnt					
	TSLF distributions	km2 of area burnt					
Unit of interest 3							
	Mean TSLF	km2 of area burnt					
	TSLF distributions	km2 of area burnt					
Unit of interest 4							
	Mean TSLF	km2 of area burnt					
	TSLF distributions	km2 of area burnt					
Unit of interest 5							
	Mean TSLF	km2 of area burnt					
	TSLF distributions	km2 of area burnt					
Unit of interest 6							
	Mean TSLF	km2 of area burnt					
	TSLF distributions	km2 of area					

Figure 23: Fire account worksheet

References

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Walker J. (1981) Fuel dynamics in Australian vegetation. In: *Fire and the Australian Biota* (eds A. Gill, R. Groves and I. Noble). Australian Academy of Science, Canberra.