

## **PRESCRIBED BURNING: HOW EFFECTIVE IS IT IN THE CONTROL OF LARGE FOREST FIRES**

**Rick Sneeuwjagt**

**Department of Environment & Conservation, Perth WA, Australia**

### **Introduction**

The south-west of Western Australia has a Mediterranean climate with regular hot, dry and windy weather during five to seven months of each summer. These conditions in combination with the highly flammable forest fuels are ideal for the start and spread of intense forest fires. Every year more than 400 bushfires are started by lightning, arson or mischance.

The combination of these fire factors should result in a high incident of large uncontrollable bushfires that threaten lives, destroy properties and severely damage forests, plantations, water catchment and ecosystems.

However this is not the case, the south-west of Western Australia has a good record in forest fire control since 1961. There have been no forest fires greater than 30,000 hectares, no lives lost and few injuries, and only one instance of multiple property losses.

The same cannot be said of other forested lands in south-eastern Australia where many large bushfires (wildfires) occur on a regular basis resulting in loss of life, very significant damage to property, infrastructure and the environment, and a substantial expenditure of resources in fire suppression and recovery.

So what differences exist between the south-east and the south-west Australia that contribute to this markedly different fire control records? In Western Australia the topography is relatively flat and undulating making it easier to undertake rapid attack on initiating fire. But there is no practical difference in the structure and flammability of the forest fuels, and the fire behaviour in long unburnt forests can be just as severe and destructive in the West (eg: Dwellingup fires in 1961) than in south-east Australian forests.

The main difference in approach to fire management between the south-west and south-eastern Australian states is the scale and frequency of prescribed burning undertaken by the land management agencies. In Western Australia between 6 to 8 percent of the forested crown lands are prescribed burned each year, compared with less than 2 percent in other States.

The level of prescribed burning undertaken over more than 47 years in south-west Western Australia have enabled fire managers to achieve a high level of protection to the community assets and natural values on and near the lands managed by Department of Environment and Conservation (DEC). There have been numerous examples where the fuel reduction burning program has resulted in significant saves even under extreme fire weather conditions.

Despite this impressive record, both the effectiveness and the effects of prescribed burning continues to be challenged. Penman et al (2008) have suggested the existing data relating to the effectiveness of prescribed burning throughout Australia indicate that “prescribed burning has limited value in affecting the total area burnt but may assist in reducing fire severity”.

Such a conclusion could only apply where the areal extent of prescribed burning is limited either to few and narrow, small and/or very patchy burns, or where burning has not been effectively applied across the landscape.

Forest fire managers who are directly involved in fire control operations have no doubt about the value of fuel reduced areas in reducing the intensity of bushfires and in providing safe conditions to apply effective fire suppression tactics.

Whilst the contribution of prescribed burning to bushfire control may be obvious to the fire practitioners, some academics continue to question its value and call for the need to have statistical evidence to validate the effectiveness of prescribed burning. Some critics of prescribed burning offer anecdotes of severe bushfires burning through recently prescribed burned areas and have concluded that in order to be effective against major conflagrations burning under extreme weather conditions, fuel reduction burning has to be repeated every 2 or 3 years.

Contrary to the claims made by Penman et al (2008) that there is insufficient evidence to support the value of fuel reduction burning, there exists in Western Australia a range of information that validates the effectiveness of prescribed burning.

This paper provides a brief summary of West Australian evidence which ranges from previously published and new case studies that assess the effectiveness of prescribed burns and an analysis of the effectiveness of annual prescribed burn program areas on the area of wildfires in subsequent years. The latter statistical study on the relationships between prescribed burning areas and wildfire areas is able to be undertaken for the WA forests as these have been subject to a landscape-scale burning program since 1961 that has varied over time from a high of 450,000 hectares in the 1960's to a low of 78,000 hectares in the late 1990's.

The current annual program has a target of 200,000 hectares, which incorporates biodiversity conservation and community protection burns. Figure 1 shows the trends on the annual area of prescribed burning achieved from 1961/62 to 2007/08.

### **Relationships between Fuel Structure and Fire Behaviour**

From the inception of regulated forest management in south-west Western Australia in 1918, the threat of bushfires demanded a better knowledge of the fire environment and fire behaviour. The early focus for research that commenced in the 1930's was to quantify and predict fire behaviour of low intensity fires from fuel and weather variables. The Dwellingup fires of 1961 clearly demonstrated the variation in fire behaviour and impact between forests long unburnt and those that had recently prescribed burned. In response to the recommendation out of the Royal Commission into the 1961 fires for the Forests Department to carry out more research into both the technical and practical side of fire control, the south-west WA forests became the focus for the development of sophisticated prescribed burning guides for a range of forested vegetation fuel types (McArthur 1962, Peet 1965, 1968; Sneeuwjagt and Peet 1976).

In 1964, the Forests Department of Western Australia, in collaboration with CSIRO, developed the technique of aerial ignition (Baxter et al 1966) so that low intensity fire could be safely applied for fuel reduction over forest blocks of more than 8,000 hectares (Packham and Peet 1967).

Developments in the scientific approach to broadscale fuel reduction burning were accompanied by a series of studies into aspects of fuel dynamics, fire behaviour, and the effects of fire on the environment (Peet 1971). Fire behaviour studies that had previously been focused on the dry (Jarrah/Marri) forest were extended to the heavier fuel and dense understorey of the Karri and southern Jarrah forests (Sneeuwjagt 1971, 1973). Major fire behaviour research programs in these southern forests lead to the development of the Forest Fire Behaviour Tables (FFBT) known as the Red Book (Sneeuwjagt and Peet, 1976).

The fire behaviour studies, supported by operational experiences gained in fighting fires in WA's dry forests has indicated that provided fine fuel weights are below 8 tonnes per hectare, the flame height and fireline intensity is sufficiently low for bushfires to be controlled by either direct attack if the fire danger is moderate, or by progressive attack along the flanks if the fire dangers is higher (Underwood et al 1985).

Fire behaviour studies by Burrows (1999) indicated that headfire spread rates of large fires burning under summer conditions were considerably faster than predicted by the FFBT or the McArthur Forest Fire Danger meter, and that headfire rates of spread were independent of litter fuel quantity (McCaw et al, 2003). The experimental finding was contrary to field experience of fires in fuels of different ages and observations of wildfires burning into areas that had been fuel reduced by prescribed burning.

In order to better understand the reason for these anomalies, the Department of Conservation and Land Management of Western Australia and Commonwealth Scientific, Industrial Research Organisation (CSIRO) initiated a major collaborative fire behaviour research project (Project Vesta) in 1996 to quantify the changes in fire behaviour in dry forests as fuels developed with age, and to revise the algorithms describing the relationship between fire spread, wind speed and fuel characteristics including load, structure and height.

The Vesta studies involving 104 large experimental fires at two sites in the south-western WA, have recently been published and have provided a significant advance in the understanding of forest fire behaviour (Gould et al, 2007). The Vesta findings indicate that rate of fire spread is directly related to the structural fuel characteristics of the surface, near surface and understorey layers, but is only weakly related to fuel load alone. The study demonstrates that hazard reduction by prescribed burning reduces the rate of spread of bushfires, as well as the flame height and fire intensity, and number and distance of spot fires by changing the structure of the fuel bed and reducing the total fuel load. The persistence of this effect is determined by the rate of change in fuel characteristics over time. These effects may persist for a considerable time (up to 20 years) in forests containing rough-barked trees and shrubby understorey that are the main source of fire brands and spot fires.

The Vesta study has quantified what field practitioners have known from practical observation: by reducing the amount and structure of the fuel, the rate of spread and interaction of a bushfires is reduced making it easier to control.

## Past Case Studies

The extent to which fuel reduced areas may assist in the suppression of unplanned fires depends on the interaction of several factors including the fuel reduction achieved, the location and patchiness of fuel reduced areas within the forest, and the suppression capability and speed of response of the fire suppression forces. In addition the severity of the fire weather conditions prevailing at the time when the wildfire encounters a fuel reduced area is important in determining the effect on fire behaviour. Experimental study of these interactive factors is complex and hazardous and for this reason the contribution of fuel reduction to fire control has generally been illustrated by means of case studies of wildfires. Whilst they may be descriptive and lack replication, well documented case studies have an important role in validating field observations and a reliable source of research data and training aids.

There have been numerous examples when the fuel reduction program has enabled forest fire managers to control major fire events and prevent serious impacts on lives, properties and environmental values.

The most outstanding example of the contribution of fuel reduction burning occurred in 1978 following Cyclone Alby which caused 92 fires to burn out of control near forest lands in the south-west of WA. Wind speed of up to 130 km/hour caused fires to run at speeds of up to 8,000 metres per hour with extensive spotting. Although the total area burnt was more than 54,500 hectares, the rate of spread in the State forests where fuels were kept at low levels by prescribed burning, were so reduced that only about 7,000 hectares of native forests were burnt. Most of the fires were allowed to burn in the low fuel areas, whilst fire suppression resources were directed at those fires which posed a greater threat to communities and high values.

The effectiveness of prescribed burning in wildfire control has been documented for nine case studies in south-west of WA by Underwood et al (1985). These case studies were drawn from fire records maintained by the WA Forests Departments over the period 1969 to 1984. The case studies selected included a wide range of forest fuel types in which major fire runs as well as smaller fires with high damage potential had run into areas that had been prescribed burned in past 6 years or less. The study projected each fire in the absence of a fuel reduction burn based on the weather prevailing at the time. The study clearly demonstrated that in every case a larger fire would have led to a serious social and economic cost to the community. A similar finding was made in a study by McCaw (1988) on two wildfires that posed a severe threat to property and community assets near Perth.

There has been several published case studies in eastern States that have clearly demonstrated the contribution to fire control made by prescribed burning for fuel reduction. These include Billings (1981), Rawson (1983) and Rawson et al (1985), CSIRO (1987).

The Tasmania fire scientist Tony Mount compared the fire management achievement in south-west Australia with that in similar forests in Tasmania over the period 1951/52 to 1983/84 (Mount, 1983). Over that period he found the average Tasmanian wildfire was 270 hectares in size, whilst that in Western Australia was 15 hectares. During this period in Tasmania there were 4 years in which the total annual area burnt by forest fires exceeded 100,000 hectares, while Western Australia experienced this on only one occasion in 1961.

Mount attributed these differences to the fact that fuel reduction burning was undertaken much more extensively in Western Australia than in Tasmania.

### **Recent Case Studies under Severe Conditions**

Although there are many examples of case studies that demonstrate the potential for fuel-reduction burning to modify fire behaviour under average summer conditions, there are also anecdotes of severe bushfires burning through areas that have been treated by such fuel reduction burning under extreme weather conditions. For example in the 2006/07 Victorian fires, the extreme weather conditions drove the fires into areas of the 2002/03 fires in the Victorian Alps. Fire intensity and the rate of spread were certainly reduced as the bushfire burned through these areas, but as there were no fire fighting resources present to take advantage of the lowered fire behaviour to contain the bushfire the fires continued to spread.

Two new case studies involving very high intensity forest fires burning under severe weather conditions in south-west Western Australia are presented below.

#### ***Mt Cooke Fire – January 2003***

The Mt Cooke fire in the Monadnocks Conservation Park on DEC-managed land about 60 kilometres south-east of Perth resulted from a lightning strike at the top of the granite monadnock. Large sections of this reserve had been excluded from fire for 17 years, and burnt as a crown fire under the severe weather conditions (maximum temperature 36°C; low humidity; gusty north-west winds from 25 to 35 km/hr). The fire burnt fiercely up the slopes and along the spine of Mt Cooke and southwards for about 25 kilometres and eventually burnt out 18,000 hectares in 24 hours. The heat was so intense that granite rocks cracked and flaked under the extreme temperature. The fire defoliated and killed a vast majority of the mature jarrah and marri trees within the long unburnt forests (Burrows, 2004). When it reached forest blocks that had been prescribed burned 7 years before, the intensity reduced considerably and fire fighting forces equipped with bulldozers were able to attack the flanks of the fire, but not the headfire. Even though the weather conditions remained severe, the fire was able to be contained when it slowed after reaching those areas that had been prescribed burned for fuel reduction three to five years before.

A spatial analysis of the impact of the Mt Cooke fire on the forest canopy and understorey vegetation based on the Landsat satellite data clearly demonstrates the reduction in fire intensity and crown damage within fuel reduced areas. See Figure 2. Long unburnt forests and woodlands with heavy fuel loads were the hardest hit with trees completely defoliated. Fire intensities were significantly lower in forests that had been prescribed burnt in the previous five years. Few trees were defoliated unlike the forests that had not been burnt for more than 10 years. This wildfire has drastically simplified the mosaic of vegetation, and habitat structures over a large area. It will take more than 100 years for the forest to return to its former over storey structures. Some impacts such as loss of topsoil in the subsequent winter rains, are practically irreversible.

### ***Mundaring-Karragullen Wildfire – January 2005***

The Mundaring-Karragullen fire which burnt during 15-25 January 2005 provides another example of a high intensity forest fire that was eventually contained with the advantage of numerous prescribed burns. The fire was the result of seven arson-caused ignitions on land managed by DEC east of Karragullen and within 20 kilometres to the east of the Perth Hills suburbs. These spot fires joined up on the first night (15/16 January) and burnt under the influence of strong easterly winds. A period of very strong (28 km/hour) north-easterly winds that preceded the passage of a trough line on 17 January carried the fire across the Brookton highway and posed a major threat to the township of Roleystone and adjacent communities of Araluen, Bedforddale and Gosnells.

A detailed study of the fire behaviour of the Mundaring-Karragullen fire was undertaken by fire scientist Phil Cheney (2008 in prep) to reconstruct the fires during the initial westerly and south-westerly spread on 15-17 January 2005. This analysis showed that the fires burnt vigorously in forest fuels that ranged in age from 16 to 26 years old. The fire was estimated to spread at 600 to 1,600 m/hour, during the first 24 hours. In the early morning of the 17 January (some 36 hours after the initial fires starting) the fire broke away from its southern flank under the influence of strong north-east wind. Three major tongues of the escalated fire traveling at an average rate of spread of 900 m/hour burned towards the Brookton Highway and the Hills suburbs of Roleystone and Araluen. When it reached the Brookton Highway the fire ran into two and four year old fuels resulting from recent fuel reductions burns, where its spread was either stopped completely or checked to such a degree that suppression was easy.

Cheney found that the fuel reduction program carried out by DEC in the preceding years enabled the suppression forces to safely contain the fire before it burnt into the Perth Hills suburbs of Roleystone and Gosnells.

The mosaic of fuel reduced areas throughout the forest areas impacted by the Mundaring-Karragullen fire that had been prescribed burnt in previous 6 years covered about 40 percent of DEC managed lands. These burns were distributed throughout the landscape to provide strategic protection to the neighbouring residential and farm communities as well as to the forest, park and water catchment values. These low fuel areas meant that fire controllers were left with the greatly reduced task of undertaking direct attack on those sections of the fire perimeter that were not favoured by low fuels. As a result the fire which could have destroyed hundreds of homes and threatened lives was able to be contained with minimal damage to property. See Figure 3 showing the perimeter of the fire in relation to the fuel reduced areas and the Perth metropolitan area.

Cheney was able to reconstruct the projected fire perimeter in the absence of fuel reduction burning in the past 20 years. Such a scenario was commonly encountered in the ACT, NSW and Victorian fires of 2003 and the Victorian fires of 2006. Cheney used the expected rate of spread calculated by the new fire spread equations developed during Project Vesta (Gould, McCaw, Cheney 2006) and the observations of the difficulty of suppression experienced in older fuels during the Mundaring-Karragullen fires. Under the 20 year old fuel scenario, it is most likely that no suppression would have been possible due to the severe and erratic fire behaviour burning at speeds of between 1,800 and 5,000 m/hour. Cheney estimated that the fire would have burnt over the Darling escarpment and into the suburbs of Roleystone and

Gosnells in less than 24 hours after ignition. Figure 4 displays the location of the projected fire under a 20 year old fuel scenario, in comparison with the actual final fire perimeter.

The Mundaring-Karragullen fire event illustrated the realistic potential threat of fire to the forest-urban interface of the Perth Hills, and has highlighted the importance of managing fuels in the forested parks and State forest close to suburban development. This case study has demonstrated that for fuel reduction burning to be effective under severe summer conditions, burning must be regularly undertaken within large blocks throughout the forest landscape and not just immediately adjacent to the communities.

### **Analysis of the Effectiveness of Prescribed Burning Program**

There have been very few statistical studies within Australia into the relationships between the extent of unplanned fires and different levels of prescribed burning applied across the landscape.

As Cheney (2008) pointed out in a guest editorial in the *Journal of Australian Forestry*, the reason why such an analysis of the effectiveness of prescribed burning programs is very difficult is that for any landscape-scale trial of prescribed burning to be undertaken, it has to be applied on such a large scale that it is impossible to have an adequate control.

One difficulty in determining the relationships between the unplanned fires and prescribed burning is that there are other fire control factors that can influence the areal extent of unplanned fires in any year.

The seasonal conditions, in particular the dryness of deep litter beds, logs and living vegetation may affect the severity of the fire behaviour. In those years that experience prolonged droughts the fire danger levels are likely to be at very high levels for most of the fire season, and wildfires will be difficult to contain to small sizes.

The forests of south-western Australia have been the focus of several studies on the changes of fire regimes. In one such study by Gill et al (1997) used the fire records of the Department of Conservation and Land Management and its predecessor, the Forests Department dating back from the 1940's to 1987 to determine the changes in fire regimes (fire cycles, seasons, scale, intensity) as a result of changes in fire management policies and applications. This period included a period of the "complete protection" era (1918 to 1954) and the prescribed burning era (1954 to present), when changes in burning policies and strategies occurred over time.

Gill's et al (1997) analysis did not identify a significant relationship between the extent of prescribed burning and the extent of unplanned fire for the period of the study. However, there was no attempt by Gill et al to determine whether a relationship existed between the area of low fuels as a result of prescribed burning in the preceding years and the area of unplanned fires in subsequent years. Such an analysis which is provided later in this paper would have identified the significance of any contribution that prescribed burning may have on the extent of fires in the following years.

A second study conducted by Sebastian Lang (1997) involved a spatio-temporal analysis of the jarrah forest fire patterns based on fire records in the Collie District of the Department of Conservation and Land Management (now DEC) over a 50 year period from 1937 to 1987. The Collie District was selected as it contains 90 percent jarrah dominated forest and has been less fragmented by agriculture and urbanization than other CALM Districts.

Figure 5 taken from Lang's thesis indicates the changes in prescribed burning practices applied in Collie Division with the first 15 years (1937 to 1951) characterized by small scale burning with a gradual decline towards the late 1940's. The increase in prescribed burning occurred from the mid-1950's and increased dramatically in the 1960's with the advent of aerial burning. The levels remained high ranging from 15,000 per annum (about 9 percent) to 25,000 per annum (about 15 percent) in the period from 1961 to 1987.

Lang's analysis was confined to a comparison of the area of prescribed burning and unplanned fires in the same year. Figure 6 taken from Lang's thesis indicates that a rapid decline in areal extent of unplanned fires occurs once prescribed burning programs covers more than 10,000 hectares or about 6 percent per year of the Collie Division. Lang's study did not attempt to determine whether relationships existed between the area of prescribed burning over several years and the area of unplanned fire in the years following the burns.

Another useful analysis of the effectiveness of prescribed burning for fuel reduction to minimize wildfires was undertaken by Abbott (1993) as part of a study on Leaf Miner infestations in WA Jarrah forests. His study of the prescribed burning and wildfire history in the Perup study area east of Manjimup from 1940 to 1990 dramatically showed the decline in the size and number of serious wildfires which occurred in the study area after the introduction of prescribed burning by Forests Department from 1958 to 1990.

### **Quantifying the Effectiveness of Prescribed Burning at a Landscape Scale**

The contribution of prescribed burning to fire control is likely to persist for several years and any comparison between the areal extent prescribed burning and wildfire areas should include a spread of years. An investigation into the possible relationship between the areal extent of prescribed burning in preceding years and the unplanned fires over subsequent years was undertaken on the south-west forest data from 1961/02 to 2007/08.

This period covers the start of the application of prescribed burning to wide areas, with high levels in the 1960's and 1970's and gradual reductions as the burn program became more refined and targeted to achieve integrated biodiversity conservation and community protection objectives.

The variations in the extent of the annual prescribed burning programs over the 47 years of this study provides sufficient data to determine whether the different levels of annual burning have an impact on the total area of wildfires that occur in subsequent years.

The analysis that was undertaken examined the relationship between the area of prescribed burning achieved over multiple years, against the total areas of wildfires that occurred in a series of the following years. This approach was taken to test the hypothesis that the contribution of prescribed burning to fire control persists over multiple years.

A further analysis was undertaken on the relationship between the average annual area of prescribed burning undertaken in the previous two to five years, and the average area of wildfires in the years immediately following the period of prescribed burning.

The results of these two approaches are illustrated in following figures. Figures 8 and 9.

The results of this analysis indicate that the area of wildfires is influenced by the amount of prescribed burning that has been achieved in the preceding period. The strongest correlation between prescribed burning and wildfire areas occurs between the area of prescribed burning achieved in one year and the accumulated area of wildfires averaged over the following 5 years ( $R^2=0.74$ ). Strong correlations were still evident for the accumulated areas of wildfires that occurred over the following 8 years.

The results of analysis on the contribution of the areas of prescribed burning and wildfires in past years on the area of wildfires in the next year, and in subsequent years also demonstrated a strong relationship.

The strongest correlation occurs between the average of 4 accumulated years of prescribed burn areas, and the average of 4 accumulate years of wildfires. See Figure 8. This correlation, as expressed as a polynomial relationship, is remarkably strong despite the inherent variations from year to year in wildfire areas that may be due to confounding influences other than the amount of fuel reduced areas that is present across the landscape.

By converting the absolute areas of prescribed burns and wildfires into a percentage of the protected estate, the graphs can be of direct value to other regions of Australia containing large tracts of eucalypt forests. In the case of south-west WA, the annual prescribed burning target of 200,000 hectares converts to about 8 percent of the DEC-managed estate.

To assist fire managers in other regions of Australia the data has been converted from the absolute areas to a proportion (%) of the landscape that is managed by the agency.

The WA analysis indicates that in order to restrict the extent of wildfires from impacting less than one percent of the landscape each year (or 5 percent over 5 years), the proportion of the landscape that needs to be fuel reduced is between 8 to 10 percent per year (or 40 to 50 percent over 5 years).

There are many ways that the nominal annual target of prescribed burns can be achieved. The selection of strategies that may range from the ignition of a large number of small areas, or fewer large areas, or varying combinations of small, medium and large areas will depend on the land management and conservation objectives, and the fuel types, terrain, access and burn resources available. There are many constraints and challenges that need to be addressed before, during and after the burn programs are applied. These matters will be the subject of a future paper.

## **Conclusion**

The statistical analysis shows that the contribution that prescribed burning programs make to the reduction in the area of unplanned fires is very strong and can persist for at least 8 years. The WA data indicates the strongest correlation exists where the average area of prescribed

burning achieved over 5 years is compared with the average area of unplanned fires in the following 5 years. The current level of annual burning that applied to restrict unplanned fires to present levels in south-west WA presents about 8 percent of the DEC-managed estate, and if this is maintained over time, the area of unplanned fire is likely to remain at low levels of between 0.5 and 1.5 percent of the estate.

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**Figure 1: Area of Prescribed Burns on DEC-Managed Lands 1961 to 2008**

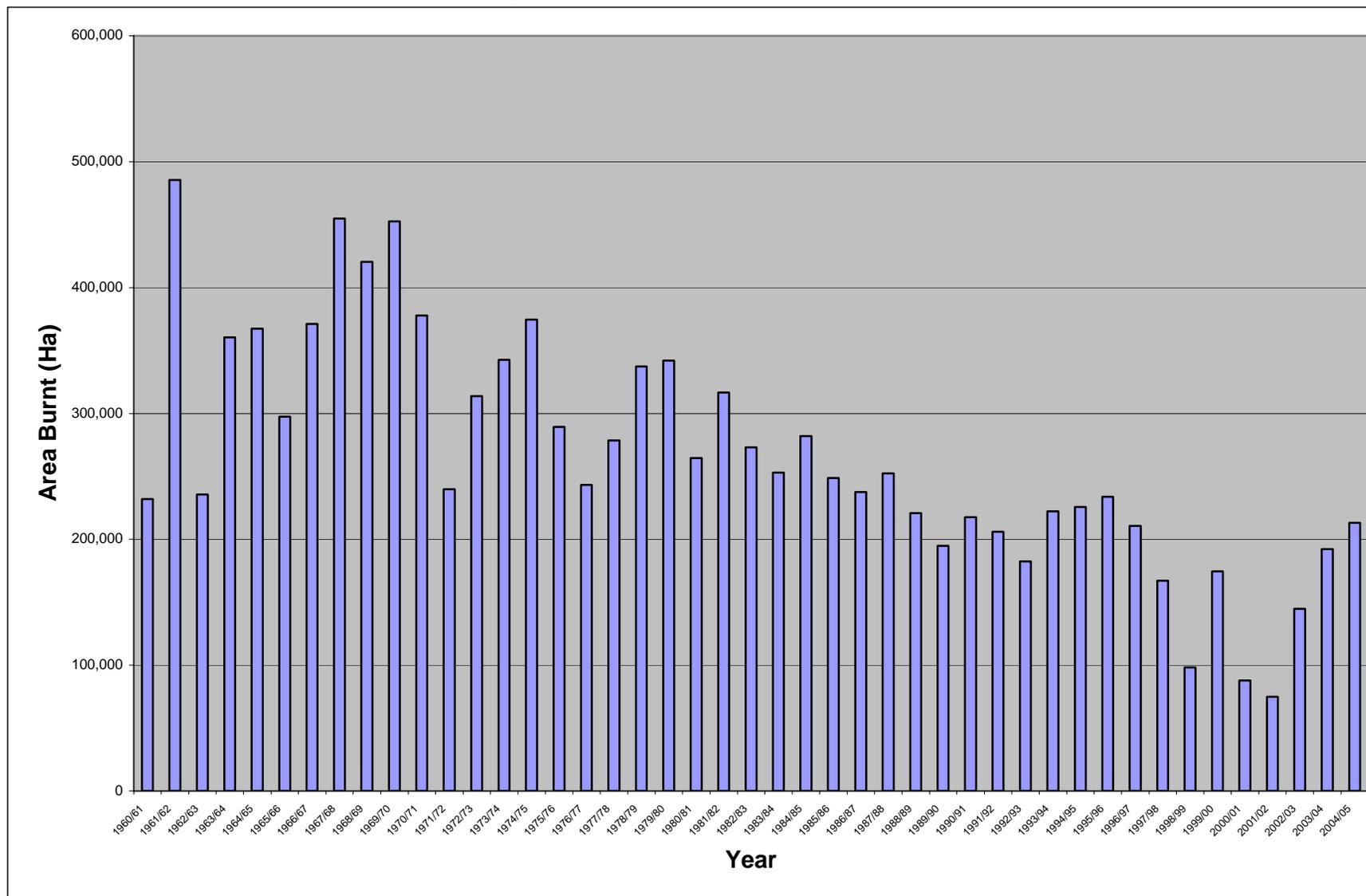


Figure 2: Landsat Image of Mount Cooke Fire Showing Fire Intensity

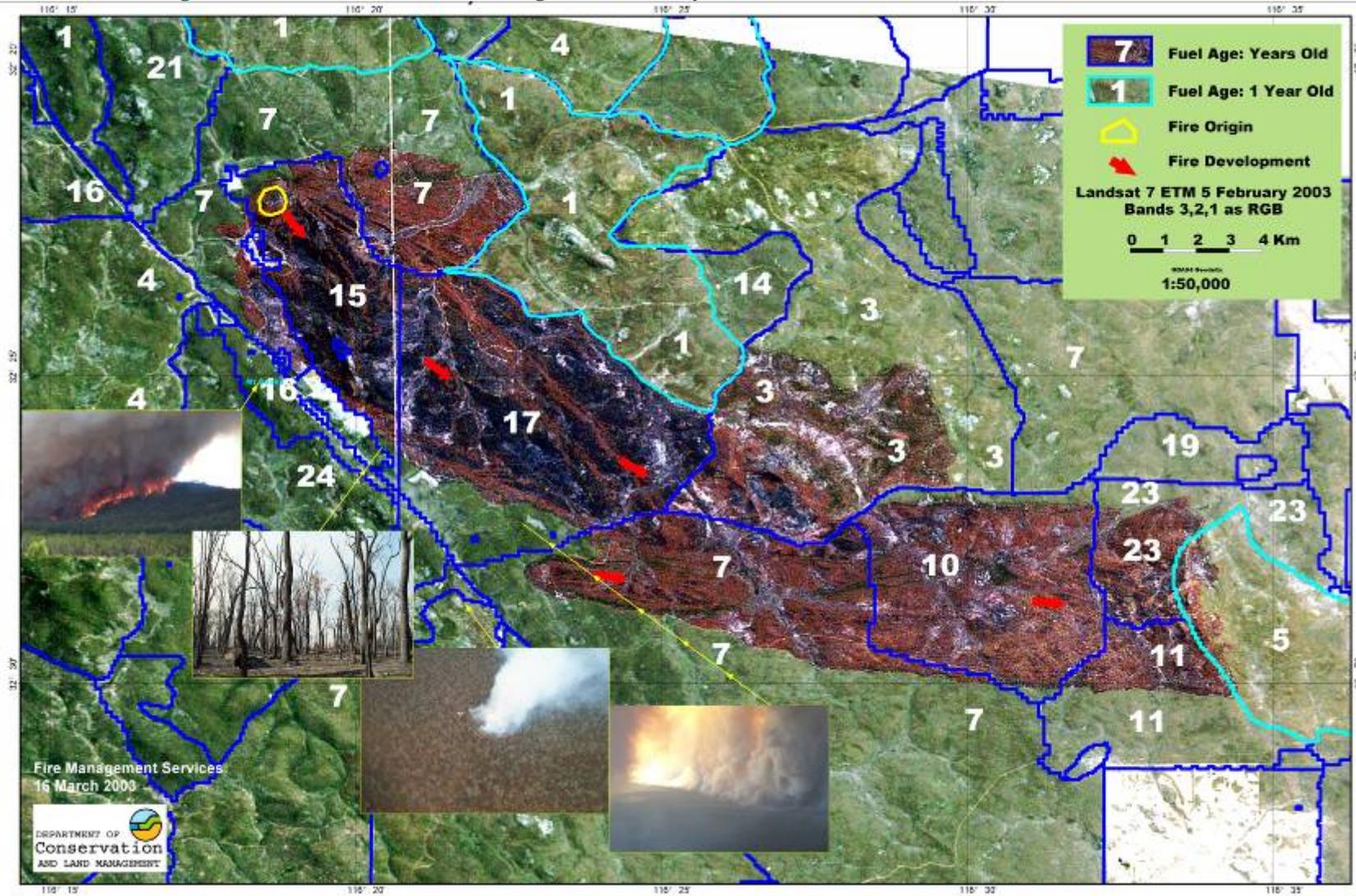


Figure 3: Mundaring-Karragullen Fire East of Perth and Fuel Reduced Areas

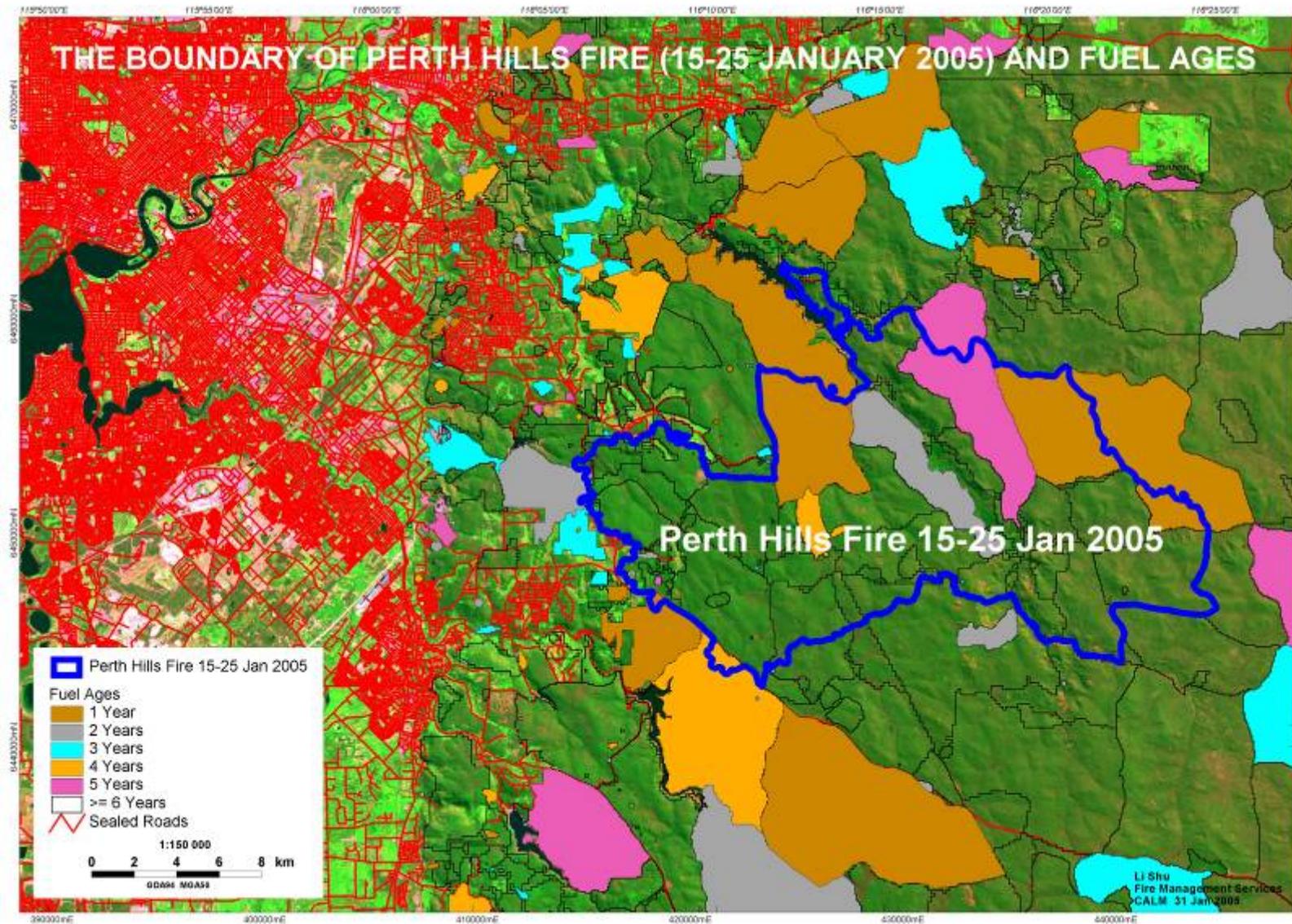
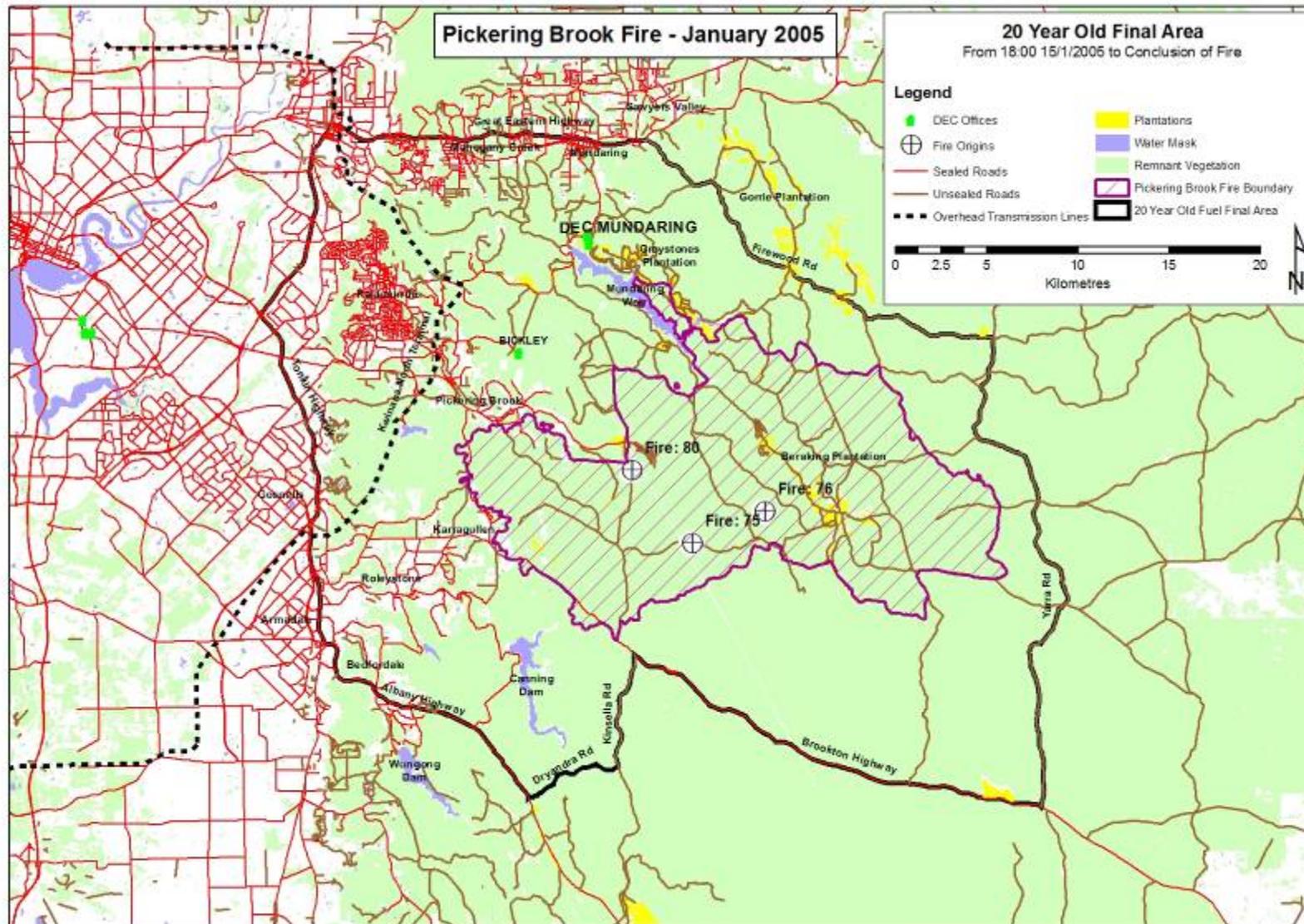
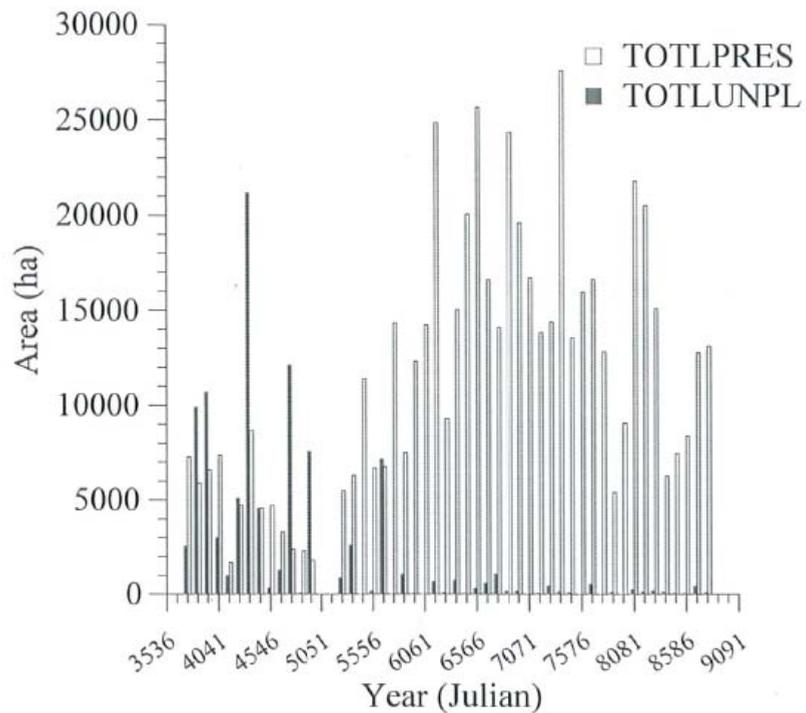


Figure 4: Projected Fire Perimeter under a 20 Year Old Fuel Scenario



**Figure 5: From Lang (1997)**



**Figure 4.3** The area burned by prescribed burning (TOTLPRES) and unplanned fires (TOTLUNPL) on public land from 1937-38 to 1987-88.

Figure 6: From Lang (1997)

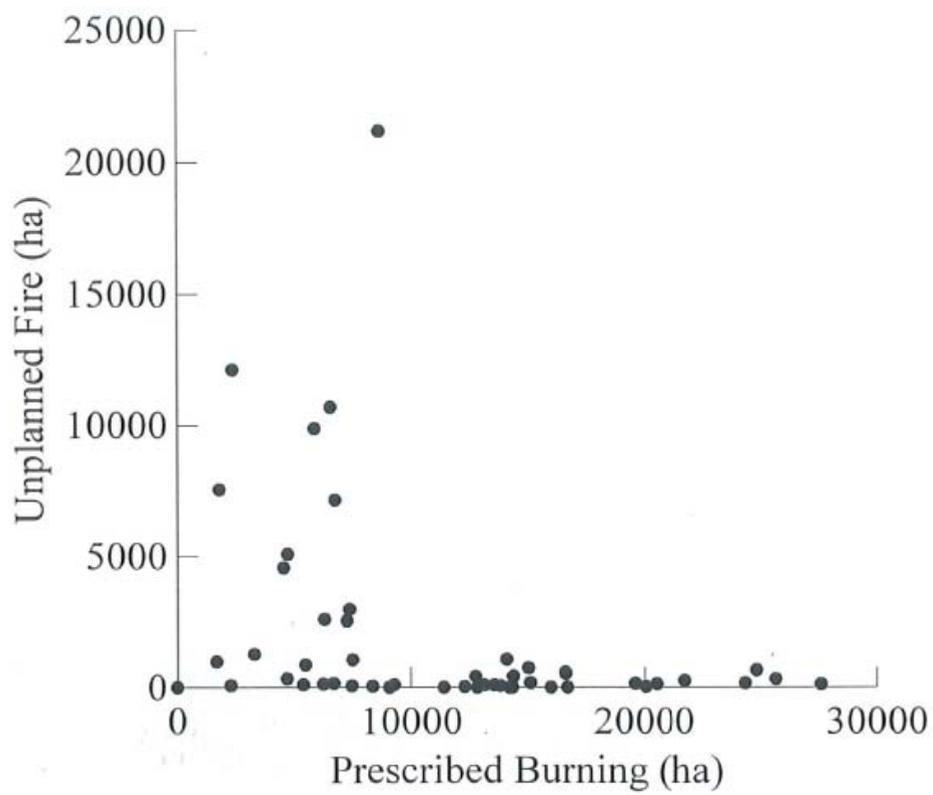
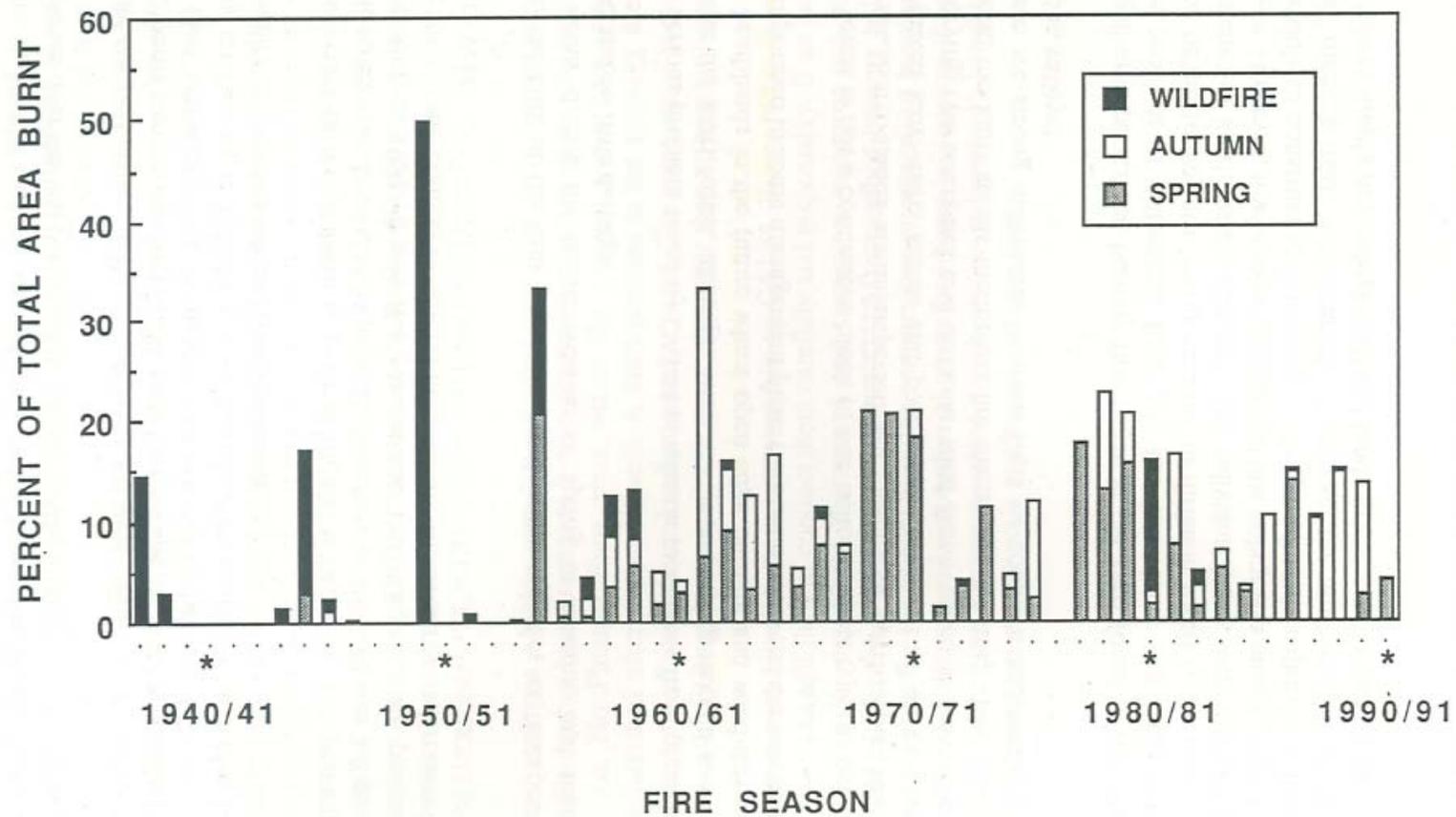


Figure 4.5 A scatterplot plotting area burned by unplanned fires per year against area burned by prescribed burns per year.

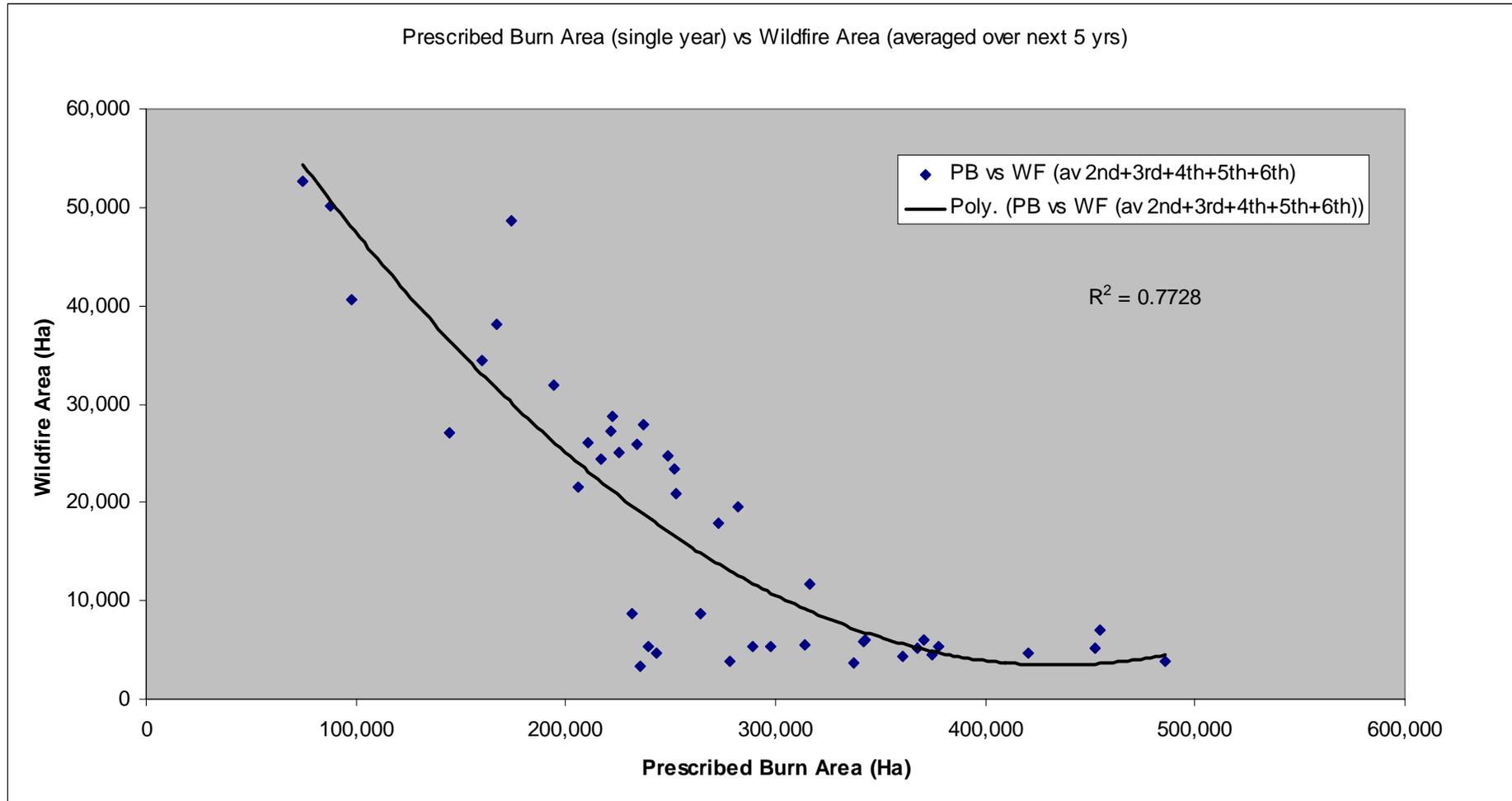
Figure 7: From Abbot et al (1993)



Wildfire and prescribed burning history in the Perup area (from Abbott et al. 1993)

Figure 9

**Figure 8: Relationship between Prescribed Burning Area (single year) and Wildfire Area (average over next 5 years)**



**Figure 9: Relationship between Prescribed Burn Area (averaged over 4 years) and Wildfire Area (averaged over next 4 years)**

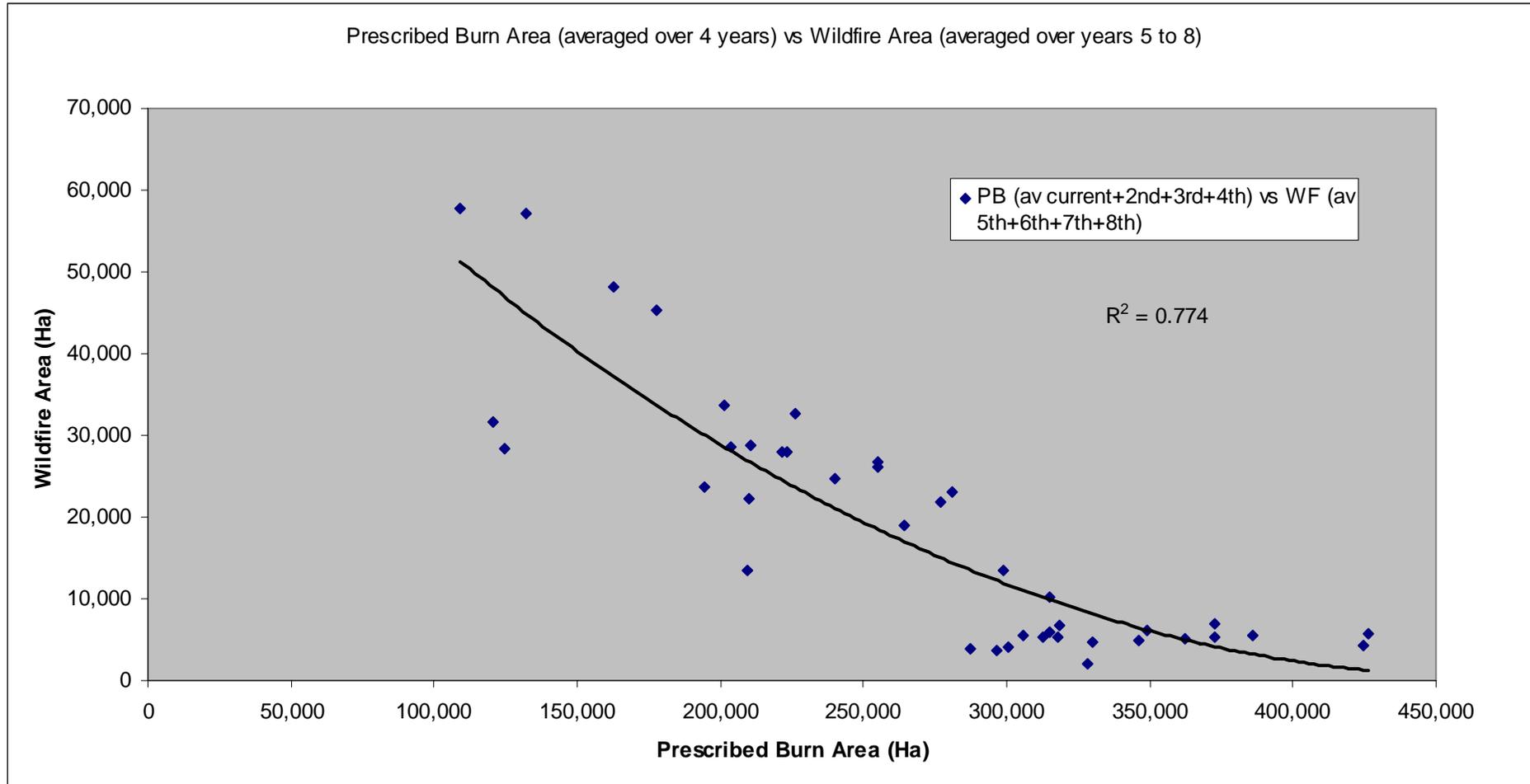


Figure 10: Prescribed Burn Area Percentage (average over 4 years) vs Wildfire Area Percentage (average for 4 years)

