Australian Government

Bureau of Rural Sciences

What burns when?
Distribution of non-forest bushfires across Australia

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Executive summary

Fires across Australia's non-forested landscapes from 1997 to 2003 were analysed in relation to land use, land tenure, vegetation cover, and climatic regions. The Western Australia Department of Land Administration (DOLA) Fire Affected Area dataset provided the data on frequency, extent and area of fire. The following were observed:

- Around 31 million hectares (ha) of non-forested land were burnt annually. 55% of fires occurred in the arid regions of central and Western Australia. 45% occurred in the wet and dry tropics of northern Australia. Only 0.6% occurred in the temperate southern regions.

- There was a notable difference in the attitude towards fire management between southern Australia and northern Australia. The relatively small number of fires in the southern temperate regions of Australia attracted most concern and media attention. Additionally:

    - Fires during summer in the southern temperate regions mainly occurred in nature conservation areas.

    - Most fires in water catchments occurred during winter and early spring.

- Indigenous land was the most frequently burnt land use category. 11% of this area burnt annually throughout central and northern Australia.

- 91 million ha of land in central and western Australia is minimal use crown land. Population density and property values in these areas are low, and no capacity exists to suppress many of the fires. Fires in these areas therefore burned the largest patches per individual fire in Australia. 8% of this area was burnt annually.

- 43% of the fires in areas associated with urban land use occurred during winter. Due to the high infrastructure values and high population densities, these areas were the focus of fires deliberately lit for fuel reduction in attempts to lower the risk of high intensity fires burning later.

- In some areas of northern Australia, along the Gulf Coast and Dampierland, grazing lands were burnt frequently by large fires. Fires occurred in four to five years out of seven in this region.

The limitations of the datasets are discussed, including the use of remotely sensed data for fire monitoring. There was a lack of reliable data for fire monitoring on a continental scale across Australia. This report builds on earlier work done to assess the availability and suitability of fire information reporting on the Montreal Process Indicator 3.1: '*Fire: area and per cent of forest affected by processes or agents beyond the range of historic variation*'. A fire monitoring programme is needed to collect, compile, monitor and report fire extent, severity and intensity across all of Australia.

Introduction

The aims of this project were to:

- assess the distribution of fire events across Australia and investigate any patterns and trends;
- analyse occurrences of fire across Australian land uses and tenure;
- assess the need for a national fire monitoring programme.

During the study period (1997–2003), an average of around 31 million ha of land across Australia was burnt by wildfires annually, making it one of the most fire prone environments in the world. Despite the extent of fires, there is a general deficiency in the national data available to report on fire regimes (Walsh et al 2001). Distribution patterns and trends of wildfire occurrence across land use and land tenure in Australia are examined in this report.

Wildfires can greatly influence agricultural and forest industries throughout Australia. Large, intense wildfires damage infrastructure and affect production capacity. Furthermore, fires are an influential factor on forest health and productivity. It is necessary to understand the extent to which fires can affect ecosystems. There is also a lack of information available as to the correlation between annual wildfire occurrence and the associated contribution to greenhouse gas emissions. That is beyond the scope of this report but is the subject of other research projects being funded through the Australian Greenhouse Office.

Western Australia's Department of Land Administration (DOLA) has been recording the area affected by fire across Australia since 1997 using NOAA AVHRR satellite[1] imagery, providing a continental scale fire history database (Marsden et al 2001). To report distribution of wildfires across production industries, the DOLA fire affected area data from 1997 to 2003 were combined with the 1996–97 National Land and Water Resource Audit data for land use and land tenure, as well as agro-ecological regions and integrated vegetation coverage. These data allowed analysis of the distribution of fire events across Australia for this report.

For determining fire occurrence on a continental scale across Australia, there are two main datasets available: the fire affected area and 'fire hot spots'. Studies by Gill et al 2002 reported on the inaccuracies of using fire hot spot data on a continental scale, commenting that the hot spots consistently missed many actual fires. While the fire affected area also has limitations, it is an area based measurement that allows for comparison of other area-based covers such as land use or land tenure and was therefore chosen in preference to the fire hot spot data.

Although fire affected area data can be used to assess the extent of fires from 1997 to 2003, its accuracy is limited for a number of reasons:

[1] NOAA is the National Oceanic and Atmospheric Administration, United States of America. NOAA's Advanced Very High Resolution Radiometer (AVHRR) satellite can take daily images of atmospheric and surface conditions.

1) NOAA AVHRR has a very coarse grid resolution. It consistently misses a large majority of fires that are smaller than one pixel (1 km^2) in size (Yates and Russell-Smith 2002, Riva et al 2004).

2) Remote sensing of fire disturbance has limited value as it cannot accurately discriminate in the understorey components of a forest. Many small, low intensity fires beneath a canopy may not be detected (Chuvieco and Congalton 1989, Gill et al 2002, Pereira 2003).

3) The 1997–2003 dataset may not provide adequate information to characterise average years in areas where regimes and trends extend for more than seven years. The accuracy of summary statistics is therefore limited (Myers et al 2004).

In order to limit the inaccuracies generated by the affected area method, lands with a forest canopy cover greater than 20% projected foliage cover were excluded from analysis. This report focuses on all areas with a vegetation canopy cover of less than 20% (Figure 1).

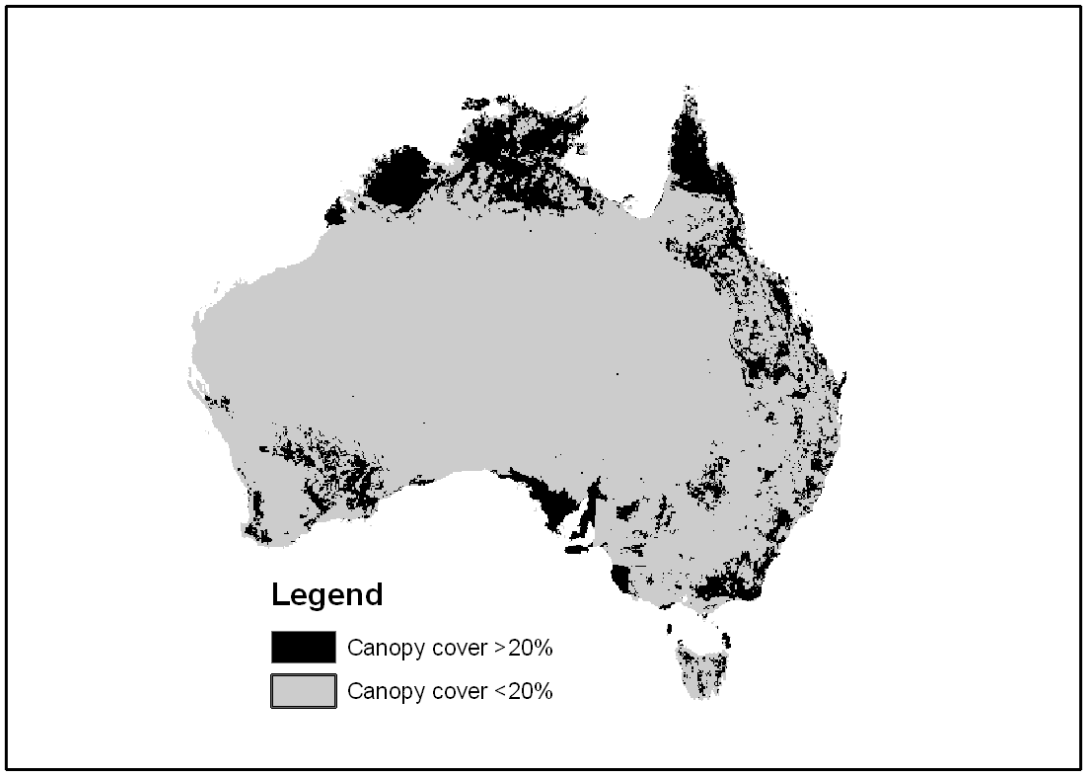

Figure 1: Areas of Australia with a vegetation canopy cover < 20%

Method

The following datasets were used to assess fire occurrence and distribution across land use and land tenure in Australia:

1. 1996–97 Land Use of Australia, Version 2, *National Land & Water Resources Audit* (Stewart et al 2001).
2. Forests of Australia 1997 (National Forest Inventory 1997), Bureau of Rural Sciences, Canberra.
3. 1997–2003 DOLA Fire Affected Area Database. *Continental mapping of fire risk across Australia using the NOAA-AVHRR* (Marsden et al 2001).
4. 2002 State of Environment, Agro-Ecological Regions (Craig et al 2002).
5. Integrated Regional Vegetation Information, *a compilation of vegetation types for National Action Plan and National Heritage Trust regions.* Bureau of Rural Sciences, Canberra (Thackway et al 2004).

Forest cover < 20%

To reduce the inaccuracies associated with determining fire occurrence beneath a forest canopy cover greater than 20%, a mask was created over these areas. A land use classification based on the National Forest Inventory 1997 was reclassified to separate areas with a tree canopy greater than 20% and less than 20%. This excluded 21% of the continent from the analysis (Figure 1).

Land use and tenure

Numerous classes of land use and tenure are provided in the National Land & Water Resources Audit file: Land Use of Australia. Rather than use them all for this project, the classes were simplified. Land use was reclassified from 31 classes to 9 (Figure 2 Table 3). Land tenure was reclassified from 15 classes to 7 (Figure 3, Table 4).

Agro-ecological regions

The agro-ecological classes used by Craig et al for the 2002 State of Environment report were used to create the general tropical, arid and temperate coverage used for this report (Figure 4).

1997–2003 fire affected area

The reclassified land tenure and land use coverages were combined with the DOLA 1997–2003 monthly fire affected area coverage to assess the extent of fire occurrence across each land use and tenure class. The fire affected area coverage was also combined with the climate coverage and integrated vegetation coverage to investigate the causes for variance in extent of fire across land use and land tenure classes.

These data were then statistically analysed to assess trends in fire occurrence and frequency.

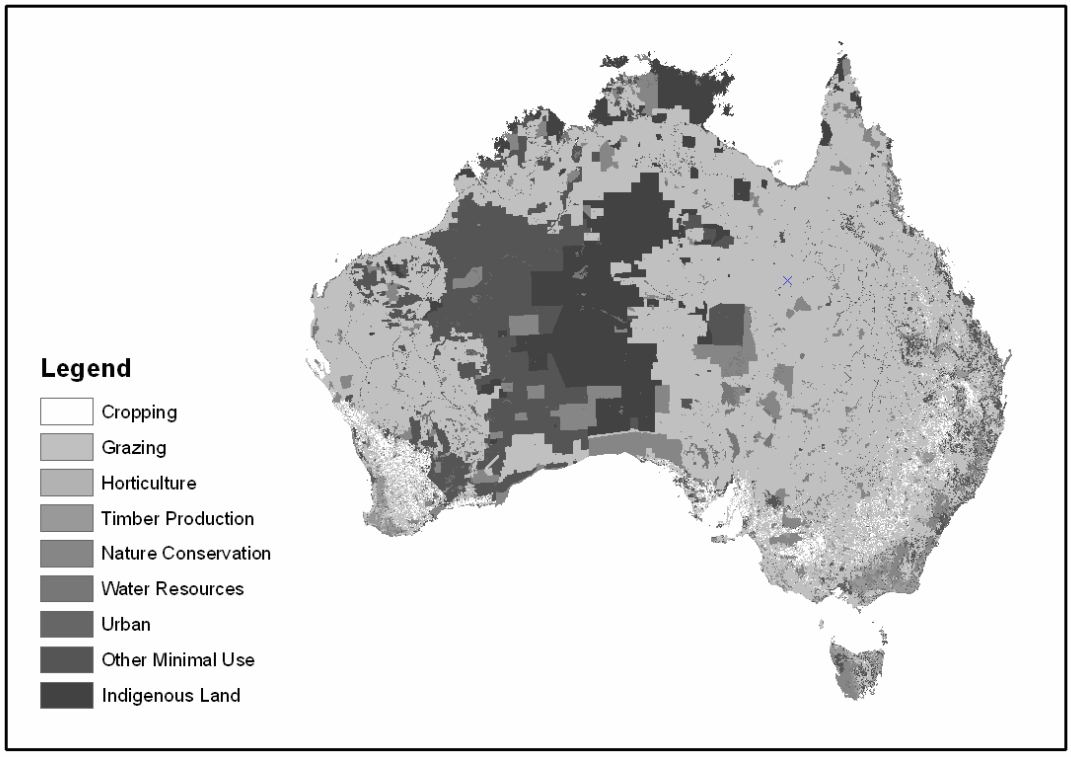

Figure 2: Australian land use classification

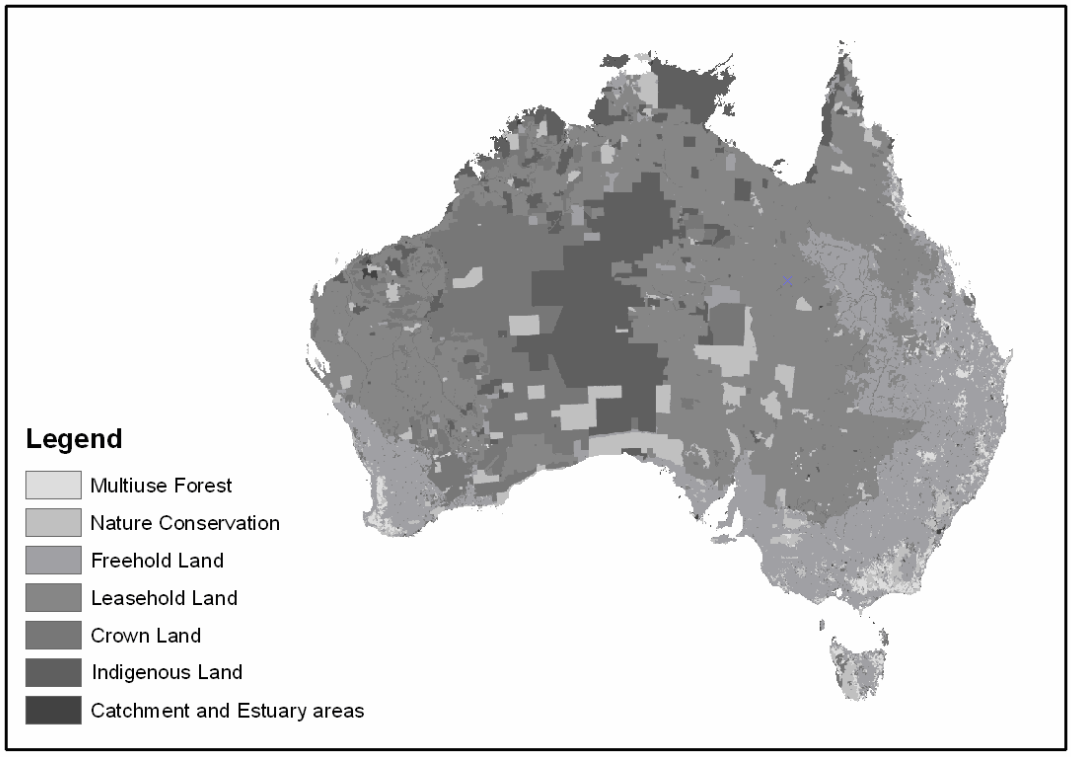

Figure 3: Australian land tenure classification

Table 3: Reclassified land uses

	Reclassed land use	Description
1	*Cropping*	Cropping Irrigated cropping
2	*Grazing*	Livestock grazing Grazing improved pastures Irrigated improved pastures Intensive animal production
3	*Horticulture*	Perennial horticulture Seasonal horticulture Irrigated perennial horticulture Irrigated seasonal horticulture Intensive horticulture
4	*Timber production*	Production forestry Plantation forestry Farm forestry Irrigated plantation forestry Irrigated farm forestry
5	*Conservation*	Nature conservation
6	*Water resources*	Lakes Dams Rivers Canals and aqueducts Marshes and wetlands Estuaries and coastal
7	*Urban*	Manufacturing and industrial Residential Services Utilities

	Reclassed land use	Description
		Transport and communication Waste treatment and disposal
8	*Other minimal use*	Other minimum intervention use
9	*Indigenous*	Managed resource protection

Table 4: Reclassified land tenure

	Reclassified tenure	Description
1	*Leasehold land*	Private leasehold
2	*Freehold land*	Private freehold
3	*Crown land*	Reserved crown land — not elsewhere classed Reserved crown land — defence reserve Reserved crown land — mine reserve Other crown land — vacant Other crown land — institutional
4	*Indigenous land*	Private freehold — Aboriginal Reserved crown land — Aboriginal Private leasehold — Aboriginal Private freehold — Aboriginal non agricultural Private leasehold — Aboriginal non agricultural
5	*Nature conservation*	Nature conservation
6	*Multiuse forest*	Multiple use State Forest
7	*Water resource management*	Water production

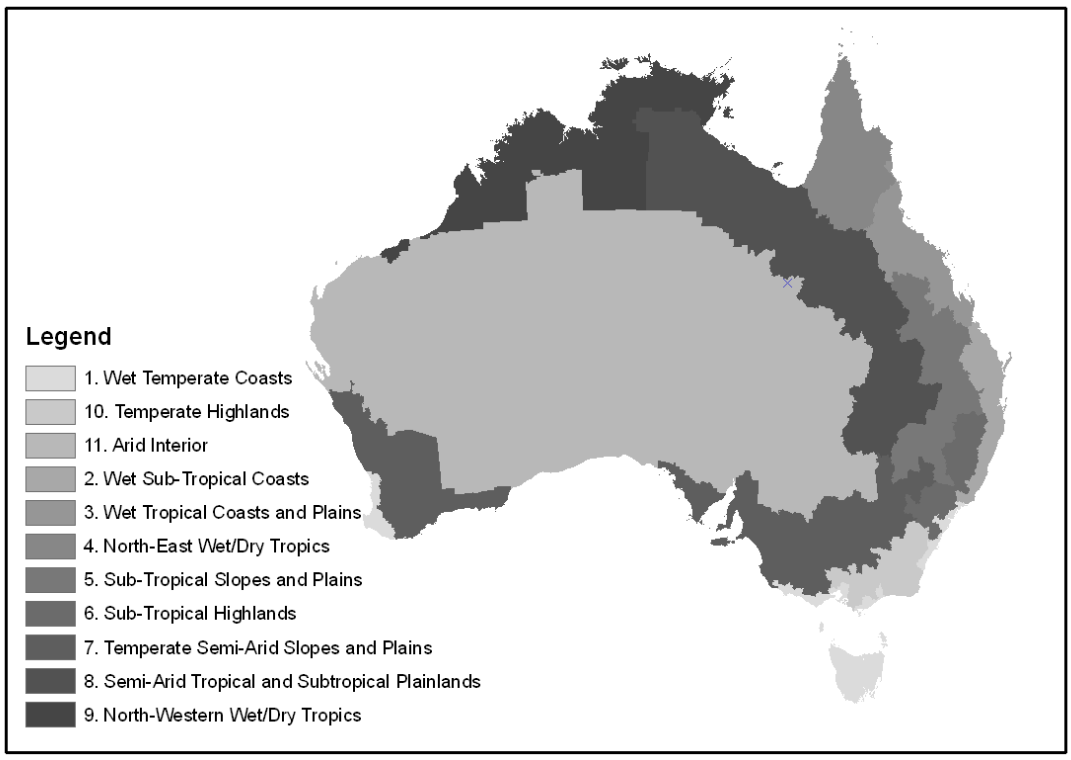

Figure 4: Agro-ecological regions of Australia

Results

Patterns and trends of fire occurrence across Australia

The frequency and extent of fires vary greatly across Australia. To best assess frequency and extent on a continental scale, regimes were grouped and assessed by the tropical, arid and temperate climatic regions based on the agro-ecological regions defined by Craig et al 2002 (Figure 4). These broad groups exhibit distinct variations in seasonality, extent and frequency of the fire regimes. A similar analysis of these regions was conducted for the State of Environment Report 2002 (Russell-Smith et al 2002).

Across the tropical wet/dry regions of northern Australia, fire occurrence is strongly connected to dry season fuel accumulation and curing, with large areas of land being burnt annually in the late dry season through October to November (Russell-Smith 2002). Fire occurrence throughout the arid interior of Australia is closely linked to periods of high rainfall and high fuel accumulation, with potential fire frequency estimated between 5 and 50 years (Williams 2002). By comparison, in the southern areas of Australia, bushfires tend to occur in the hotter, drier summer months. While the extent of these fires may be smaller, the potential fuel loads can be much higher (Gill 2002). As shown in Table 1, while the area burnt annually varies, fire clearly influences the Australian landscape.

Table 1: Area burnt, Australia, 1997–2003

	Total area burnt (ha)	Proportion of continent (%)
1997	25,971,900	4
1998	10,546,500	2
1999	29,895,000	5
2000	51,225,600	8
2001	49,850,300	8
2002	39,589,200	6
2003	8,064,900	1

Tropical regions

The fire regime in the tropical regions of northern Australia (Figure 5) is distinctly different to that of the southern, temperate regions. The monsoonal conditions in the tropics lead to distinct variations between the wet and dry season, influencing fuel accumulation and curing rates (Vigilante et al 2004). The largest and most frequent fires in Australia occur in the tropical savannas. 44% of all fires occurring in Australia each year are in this region.

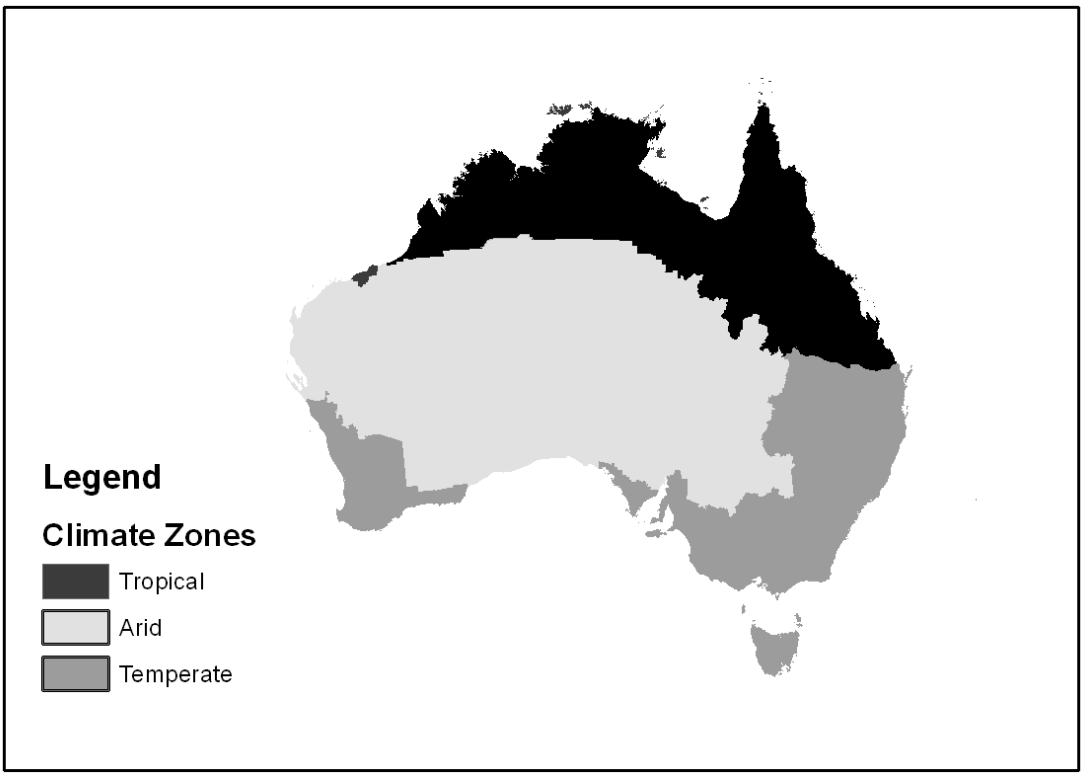

Figure 5: Climate regions of Australia

During the wet season, from December to March, the climatic conditions associated with the monsoon rains greatly lower the frequency and extent of fires in northern Australia. While some fires do occur, they are much smaller than those in drier months. As the monsoon rains leave, the vegetation begins to dry. Growth promoted by the high rainfall creates a highly flammable fuel load (Paltridge and Barker 1988).

As the fuel load cures and climatic conditions are milder during the early dry season, fires are encouraged by managers of indigenous land and pastoral properties. A fire in the early dry season reduces the available fuel and lowers the risk of high intensity fires in the late dry season. Early dry season fires occurred largely in the grazing land in Dampierland and the Ord Victoria Plains as well as indigenous land in the Tanami region.

From September to November, the late dry season, the fire regime is different. Fires frequently burn large areas of land at much greater intensity (Bowman et al 2004, Crowley and Garnett 2000, Russell-Smith et al 2000, Smith et al 1998). Across the tropics, large fires occur on pastoral properties, indigenous land and nature conservation areas. In many of these areas the same land is burnt two or three years out of seven.

Arid regions

Arid regions stretch throughout central and western Australia and comprise 62% of the total area of the continent. As this region is so large, it is not surprising that 55% of all fires were within this region. However the process of fuel accumulation and the seasonality, extent and frequency of fire events differ considerably from fires in the tropical regions of northern Australia. Fuel accumulation within the arid regions is closely linked to periodic periods of high rainfall and the high fuel loads that result (Williams 2002). The fire interval in these regions can be between 3 and 30 years (Allan and Southgate 2002).

In March 2001, there were numerous fires that burned extensive areas throughout the Great Sandy Desert on indigenous land. As autumn progressed, these fires moved gradually north from the arid interior into the tropical regions. The frequency of fire occurrence in some of these regions was higher than in areas further south, with some areas being burnt in two to three out of seven years.

During the cooler months of winter, fire occurrence throughout the arid interior was much less. Only a few small scattered, infrequent fires occurred on indigenous land. Those fires may have been lit to reduce fuel to lower the potential risk of high intensity fires under more extreme conditions. Fire occurrence across the arid interior increased significantly as temperatures rose in early spring. Across the Central Ranges and Gibson Desert, the frequency of fire events was much higher throughout September, as large areas of land were burnt frequently. This pattern continued through October as fires burned across minimal-use crown land in Western Australia and indigenous land in central Australia.

The extent and frequency of fire events reduced significantly by late spring. As summer progresses, these fires became smaller and more scattered, as shown in Figure 6.

Temperate regions

The fire regime associated with the temperate regions of southern Australia is distinctly different to that in the arid and tropical regions further north. While only 0.6% of all fires across Australia annually occur in the temperate regions, these fires attract the most attention due to the high infrastructure and property values and high population densities of these areas (Gill and Williams 1996). Although fire frequency is much lower than in northern Australia, the intensity and severity of these fires are much greater. Due to the high monetary values of these areas, the extent of fires was much lower because greater resources were available for fire suppression (Gill and Williams 1996). In many areas of the arid region of central and Western Australia, fires are not suppressed and so their extent is much larger (Figure 6).

Fires in the temperate regions of Australia mainly occur during the hotter, drier summer months when climatic conditions are most severe. This was especially evident during late January and early February (Figure 7). Of all the fires that occurred in summer between the years 1997 to 2003, most were in nature conservation areas. In summer across the south east and south west coasts, fires occurred in the Australian Alps, Sydney Basin, Warren, Murray Darling Depression and Swan Coastal Plains. During the cooler autumn and winter months, fires were mainly for fuel reduction burning.

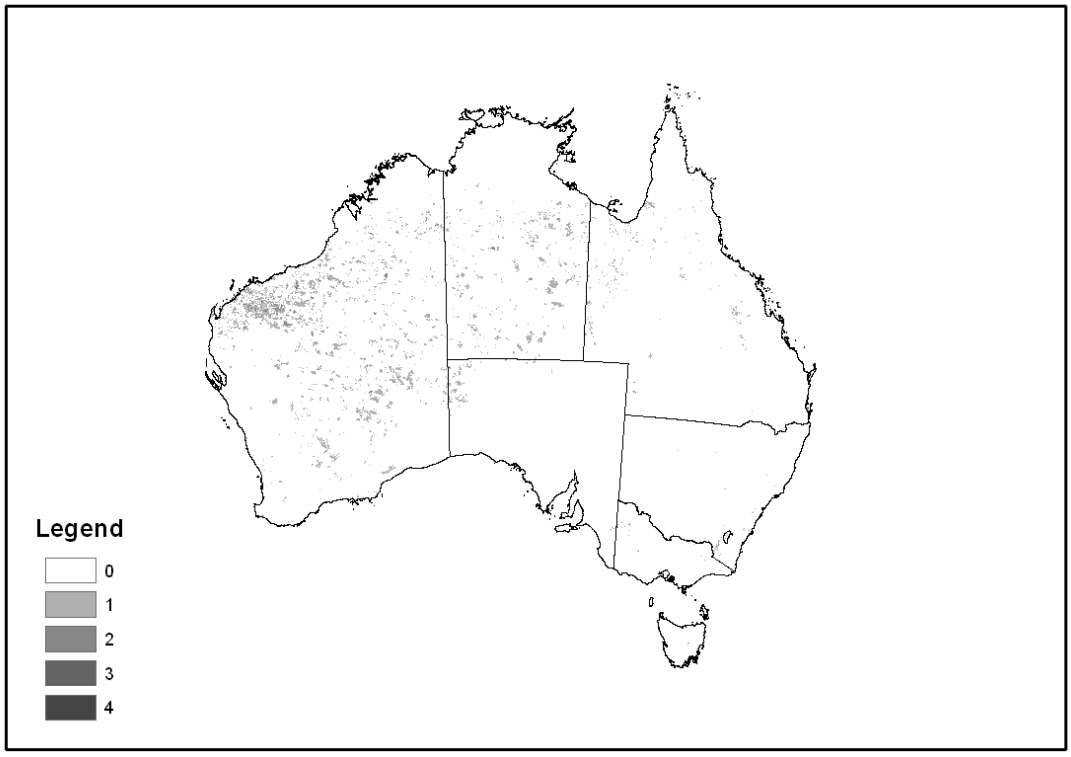

Figure 6: Summer fire frequency

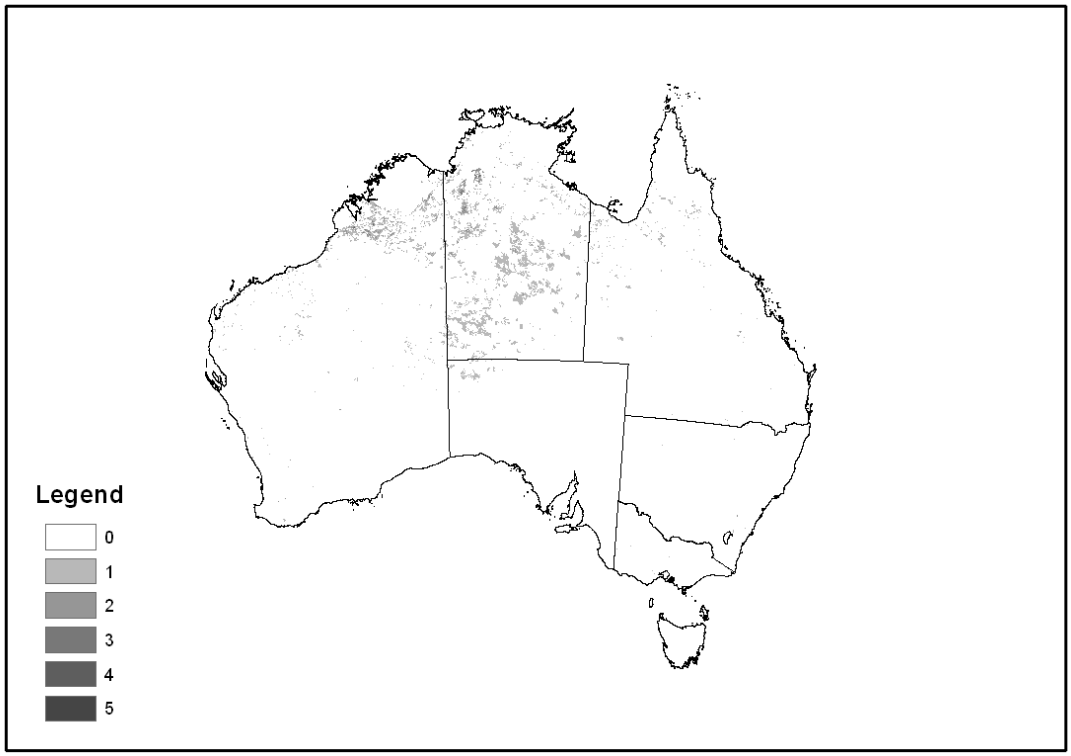

Figure 7: Autumn fire frequency

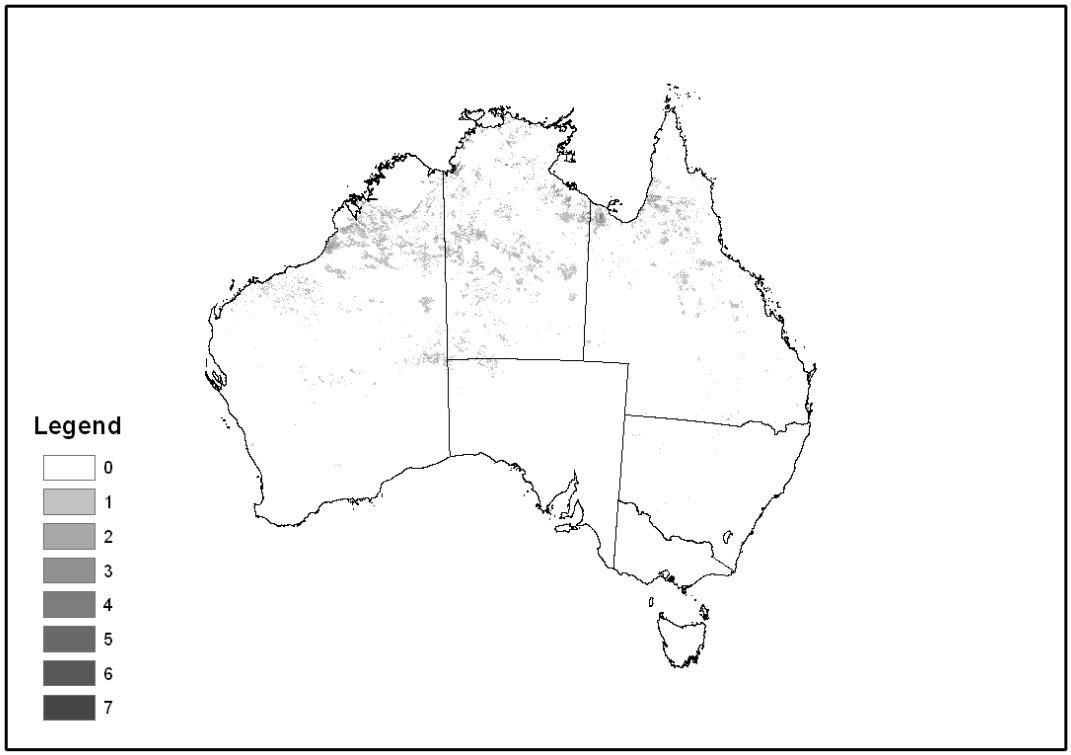

Figure 8: Winter fire frequency

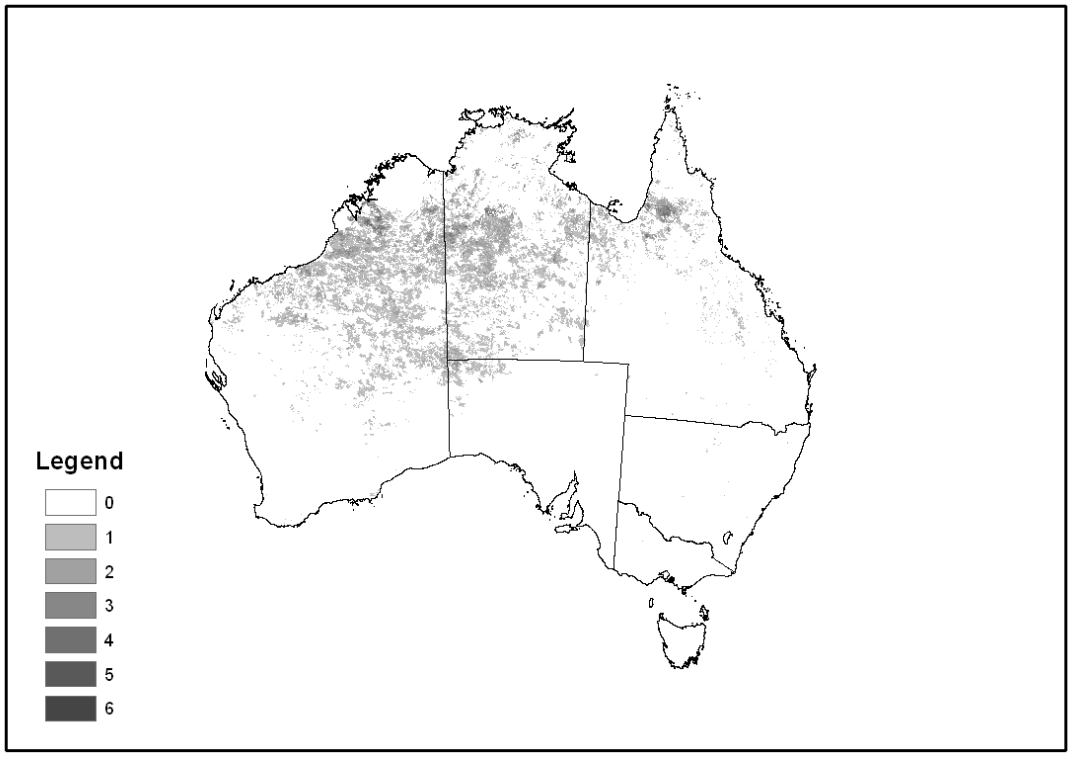

Figure 9: Spring fire frequency

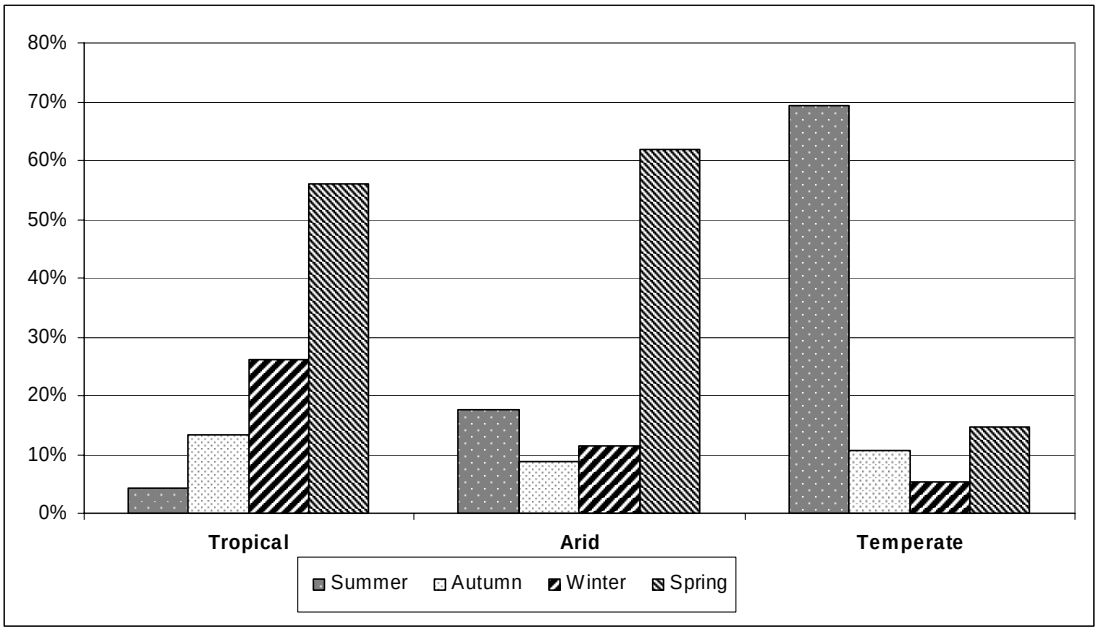

Figure 10: Seasonal distribution of fire by climatic region

Patterns and trends of fire occurrence across land use

Across Australia there are clear relationships between fire regimes and climatic regions. Climate influences the frequency and extent of fires. At a regional scale, there are also connections between land use and the frequency and extent of fires.

For this study, land uses were grouped into nine different classes: cropping, grazing, horticulture, timber production, conservation, water resources, urban, other minimal use and indigenous (Table 3). The distributions of these land uses are shown in Figure 11 and the proportion of land under each use is presented in Table 2. The purpose of this study was to investigate patterns and trends between these generalised land uses and fire distribution.

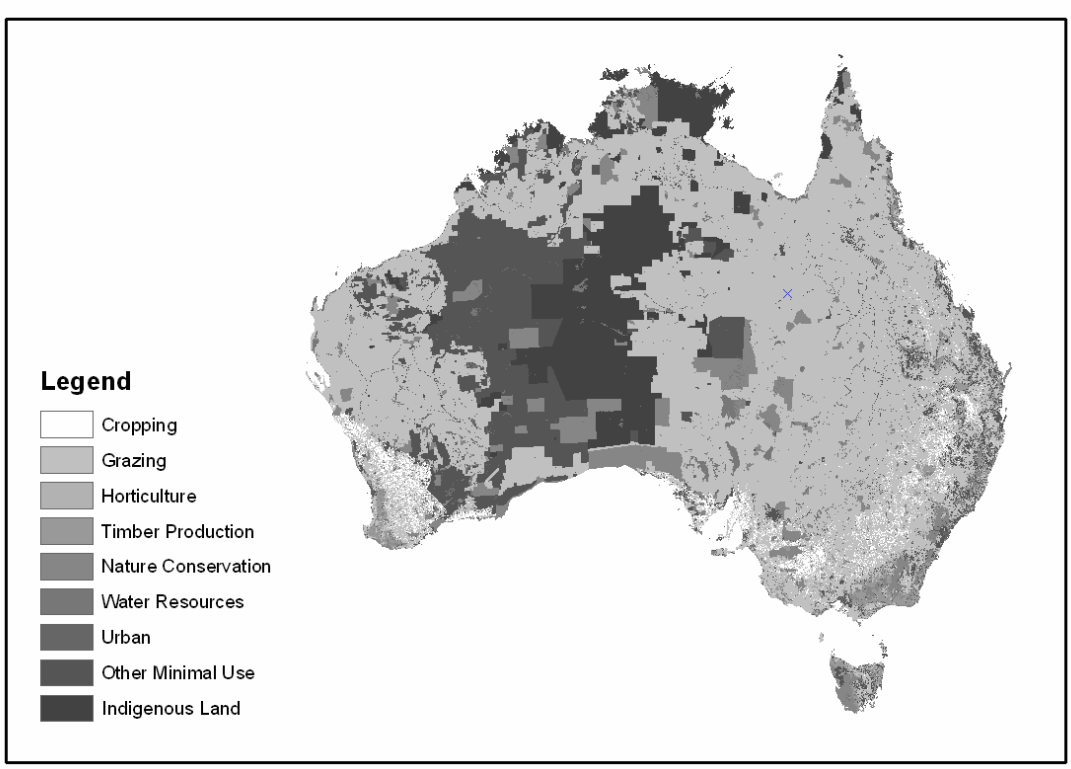

Figure 11: Australian land use classification

Table 2: Extent of land uses in Australia

Land use	Proportion of continent (%)
Grazing	61
Other minimal use	15
Indigenous	12
Conservation	6
Cropping	3
Water resources	2
Timber production	0.2
Urban	0.1
Horticulture	0.05

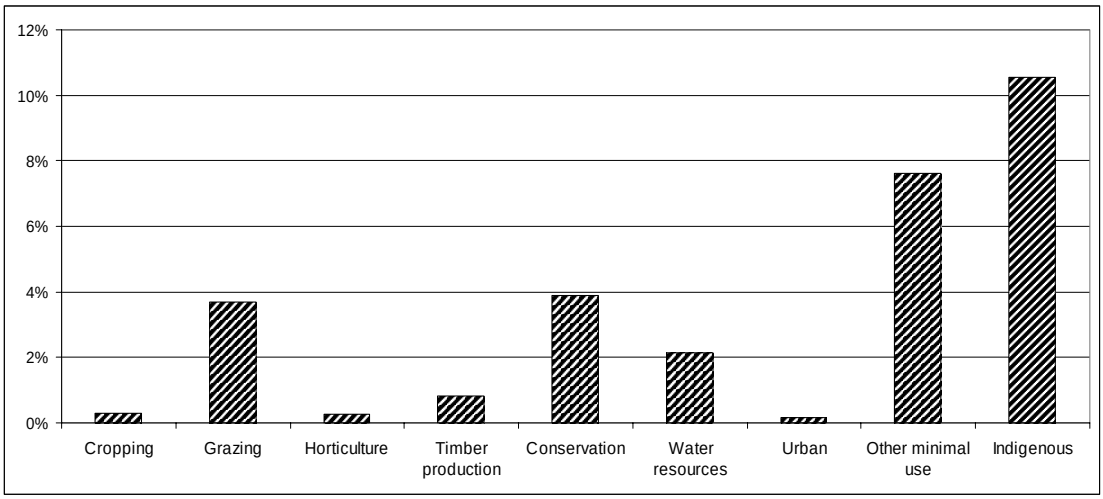

Figure 12: Proportion of non-forest land in each land use category burnt annually, 1997–2003

Grazing

Around 372 million ha of land in Australia are used for grazing, making grazing the most extensive land use activity, involving around 61% of the total area of the continent (Table 2). As shown in Figure 11, grazing occurs across a range of climatic regions, throughout the wet/dry tropics of northern Australia, across the arid interior of central and Western Australia and into the temperate regions of southern Australia. Severe wildfire events have the potential to destroy livestock, damage infrastructure and cause huge financial losses across all climatic regions in which grazing occurs (Dyer 2000). There is a need to understand the distribution, frequency and severity of fire for this land use. However, this study is unable to report on the severity of fire

events as these data are not available on a national scale (Walsh et al 2005). These fires are not evenly distributed.

Monsoonal conditions in the tropics of Australia lead to distinct variations between the wet and dry season, influencing pasture growth and fuel availability (Vigilante et al 2004). While only 24% of the area used for grazing is located in the tropics, 32% of all fires on grazing land occurred in the tropics. These areas experienced the highest frequency of fire. In some areas such as the Gulf Coast, fires occurred every year from 1997 to 2003. Introducing pastoral-based grazing systems to these areas has encouraged late dry season fires which are typically more intense, as pastoralists experience conflicts between the need to provide food for livestock, and the need to burn pasture to lower fuel loads (Bowman et al 2004, Fisher et al 2003, Russell-Smith et al 2000). Areas used for grazing in the tropics of northern Australia therefore have a fire frequency which is much higher than many other areas of Australia (Noble and Grice 2002). The majority of the fires occur in spring.

Around 62% of grazing in Australia occurs within the arid interior, across large areas of native grasslands, shrublands and heath. Of all the grazing land burnt, 52% of fires occur on properties in the arid region. Fires occurring in these areas tend to be much larger than fires in other areas of the continent because property sizes are large and there are few resources available for suppressing fires. Spatial information used for fire monitoring and reporting in these localities has proved to be a great asset for landowners managing extensive areas of land. An internet based satellite monitoring programme established in Western Australia links property contact information with fire mapping. This enables effective fire warning on large properties. While fires in these areas tend to be much larger than in other climatic regions, the frequency of fires is lower than in the tropical regions further north.

As shown in Figure 11, grazing is an extensive land use across the southern temperate region of Australia, with 14% of all grazing occurring in this region. Because property values per unit area are high in this region, more effort is made and higher capacity is available to suppress fires. The extent of individual fire events is much less than in northern areas. Of all the fires that occur on grazing land, 16% occurred in the temperate regions of Australia.

Indigenous

Historically, indigenous groups across Australia promoted fire to lower fuel loads, encourage lower intensity fires and create landscape diversity (Kershaw et al 2002, Russell-Smith 2002). Fire is much more frequent in many areas under indigenous management. Most indigenous land is in the arid and tropical regions of central and northern Australia. Of the 1997–2003 fire affected area data, 11% of indigenous land was burnt annually. As indigenous land is 82 million ha, or 12% of the Australian continent, it is the most frequently burnt land tenure (Figure 12). The areas with most frequent fires are in the Central Ranges and Great Sandy Desert of central Australia. In these areas, fuel accumulation is strongly linked to rainfall after fire and the time since the last fire (Allan and Southgate 2002). 61% of these fires occurred in spring or the late dry season in the north of Australia (Figure 10).

Minimal use

There are extensive areas of minimal use Crown land throughout central and Western Australia. This land is 91 million ha, or around 15% of the continent. Most areas of minimal use Crown land have a low population density and low utility value. There is little capacity to fight fires and many large fires are therefore left to burn without effort to suppress them. For this reason, an average of 8% of minimal use crown land is burnt annually (Figure 12). The majority of these fires occurred in spring.

Most of these areas are found in the arid interior climatic region and the vegetation is largely native grasslands. Although the extent of fires is large, their intensity is much lower than in higher rainfall woodland regions. Around 69% of fires occurred during spring or the late dry season in the north of Australia, when fuel loads and temperatures were highest.

Conservation

The data collected in this study show that most non-forest fires in southern Australia occurred in nature conservation areas during summer. An average of 4% of this land use burnt each year (Figure 12).

Many nature conservation areas have a forest canopy cover greater than 20% and are therefore not included in this study. However, conservation areas with forest canopy cover less than 20% comprise 6% of the continent. There are large nature conservation areas with a canopy cover less than 20% throughout central and South Australia and in Tasmanian heath communities.

There is ongoing argument over the need to encourage fuel reduction fires in nature conservation areas for the management of biodiversity, protection of cultural assets and fire abatement. It is thought that lack of appropriate fuel management has led to large, high intensity bushfires such as those experienced in 2003 (Gill and Williams 1996, Dexter and Hodgson 2005). However, as the data collected in this study do not include areas with a forest canopy cover greater than 20%, those concerns cannot be assessed for forested areas.

Cropping

Cropping is mainly limited to the east and south west coasts of Australia, covering around 3% of the continent. As shown in Figure 12, only 0.3% of this area is burnt annually. As NOAA AVHRR imagery consistently misses fires that are less than 1 km^2, this 0.3% does not include small scale crop burning (Yates and Russell-Smith 2002). The DOLA fire hotspot instrument is better able to detect smaller fires, such as crop fires, than the fire affected area dataset used for this study (Craig et al 2002). Hotspot mapping detects a fire front by sensing the heat signature of a pixel, rather than sensing whether a pixel has been burnt.

Water resources

Water resources areas include lakes, catchments, estuaries, wetlands and reservoirs. These areas are important for providing water for agricultural production and domestic use. Unless fuel loads are managed carefully, fires can remove vegetation

cover and siltation can lower water quality. While water resources areas only comprise 2% of the continent, 2% of this area is burnt annually (Figure 12). This is a high proportion considering the importance of these areas. However, almost 40% of these fires in southern Australia occur during the winter season when fuel moisture is higher and temperatures are lower. These fires were therefore likely to have been deliberately lit for fuel reduction.

Timber production

Land used for timber production has been largely excluded from the data assessed in this project because crown cover of that land is usually greater than 20%. Timber production land included in this study encompassed 0.2% of the continent. In comparison approximately 2% of the continent is multiple-use State Forests managed for timber production and in commercial timber plantations.

Areas included in this study are in Victoria, New South Wales, the south west coast of Western Australia and parts of Tasmania. An average of 1% of this area is burnt annually (Figure 12), with fires occurring mainly in summer and autumn. Fires in these locations occurred consistently in the years 1997–2003. Cooler season fires were associated with fuel reduction burning in the southern areas of the country.

Urban areas

Urban areas assessed in this study encompassed only 0.1% of the continent. Because property and infrastructure values are high, these areas are the focus of fuel reduction burning. 43% of the fires that occurred in these areas were in winter when fuel moisture is higher and temperatures are lower (Figure 13). Fuel reduction burning lowers the potential risk of high intensity fires burning large areas and causing extensive damage during drier months. Of the 0.1% of land associated with urban areas, only 0.2% was burnt annually (Figure 12).

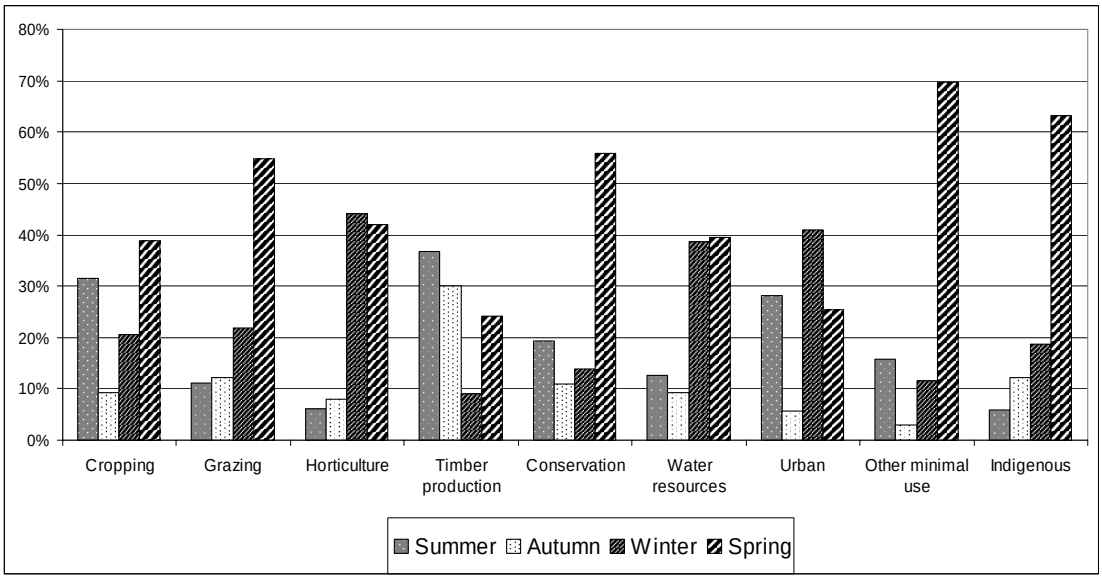

Figure 13: Average seasonal distribution of fire occurrence by land use

Discussion

Limitations of this study

The purpose of this report was to investigate the distribution and trends of fire occurrence across non-forested landscape in Australian. Data from the NOAA AVHRR satellite showing the area affected by fire were used to determine the area of land burnt. There are limitations using this method.

Unlike other fine scale remote sensing satellites, such as Landsat or SPOT, NOAA AVHRR consistently misses a large majority of individual fires that are smaller than one pixel (1 km^2; Riva et al 2004, Yates and Russell-Smith 2002). While AVHRR fire hotspot data may be better suited for detecting smaller fires, its accuracy is also affected by similar limitations. Furthermore, fire affected area data cannot accurately discriminate the understorey component of a forest (Chuvieco and Congalton 1989, Pereira 2003). For this reason, many small, low intensity fires beneath a canopy may not be detected on satellite imagery.

Fire regimes across Australia are associated with fuel accumulation during periods of high rainfall, as well as the time since the last fire event. In some areas of the continent, such as the arid interior, fire regimes may occur over periods of time greater than the seven year data history available from DOLA. The 1997–2003 database may therefore not provide adequate information to characterise average years in areas where regimes and trends extend for periods of time greater than seven years (Myers et al 2004). In order to create a comprehensive fire history, information such as fire severity and intensity are of high importance. Neither was able to be assessed in this study.

While the limitations of NOAA AVHRR remotely sensed fire data have been widely discussed in numerous papers, the 1997–2003 DOLA fire history databases are the most extensive and complete continent scale databases available, and while these data are limited, they are the best available (Smith et al 1998, Craig et al 2002, Domenikiotis et al 2002, Gill et al 2002, Yates and Russell-Smith 2002). In order to limit some of the inaccuracies generated by this method, forested areas with a forest canopy cover greater than 20% were masked, and not included in this study. As a result the statistics presented in this report do not include most areas of high population density and high property value along the east and south west coasts of Australia.

Limitations of the technology

The results of this project indicate the extent of bushfires on the Australian continent annually. There is a need to monitor fire occurrence across Australia. Given the size and the remoteness of many areas of Australia, the most cost effective option is to use satellite imagery (Smith et al 1998). Although this method has limitations, as discussed earlier, it can provide extensive information on a wide range of issues associated with fires. While the DOLA fire extent dataset was a satisfactory tool for this project, improvements in technologies for detection and mapping of bushfires and compiling time series of fires across the continent are being considered, such as resolution of smaller fires and detection of fires beneath tree canopies.

A number of published papers discuss ways in which satellite data imagery can be used to determine fuel loads, assess the fire intensity, monitor grass curing rates, determine fire intensity and assess other important indicators for fire management (Paltridge and Barber 1988, Allan et al 2003, Brandis and Jacobsen 2003, Chafer et al 2004). At present, the DOLA fire affected area data illustrates the area burnt each month since 1997. However, without information on fire intensity and severity, it is difficult to generate a practical fire history model (Walsh et al 2005). An understanding of the past fire occurrence in a region is important for assessing fire danger because it is needed to statistically compare and analyse patterns of fire that are associated with human factors compared to those that are related to environmental parameters for example (Riva et al 2004).

National fire monitoring

Given the information presented in this report, and the area of land affected by fires annually, there is a need across Australia to provide accurate information on fire for land managers, policy makers and emergency services. There is no centralised data base from which to examine fire occurrence across Australia (Gill et al 2002). While state and territory agencies record fire data, each uses different techniques and has different agencies responsible for analysing it (Walsh et al 2005).

Within Australia at present there is a need for greater coordination between state government agencies that manage spatial datasets. The limitations discussed in this paper suggest that to distribute accurate fire data to land managers, a national agency needs to be established to examine satellite imagery across the whole continent and cross reference this with regional data to allow monitoring of fire patterns and trends.

At present there are numerous regional groups that have taken responsibility for mapping fire regimes in forested regions. However, for the same reasons given in this report, these areas have largely been excluded. Due to the limitations of using satellite imagery to determine fire regimes, a method similar to that adopted by Walsh et al (2005) would be more appropriate for determining fire extent.

Walsh et al (2005) examined the extent of fire monitoring and reporting in Australia and discussed the availability, reliability, quality and quantity of fire-related data from state agencies. They suggested that a national fire monitoring programme be established and that that could be achieved by:

- compiling state and territory data collection from aerial photos and satellites for accurate fire history mapping at a sufficient scale and resolution to capture small low intensity fires

- developing the use across Australia of higher resolution satellite remote sensors, such as MODIS, which may overcome the limitations of the coarse scale of AVHRR

- incorporating the use of detailed vegetation modelling, such as the National Vegetation Information System, to provide a model for fire regimes across different vegetation communities.

Conclusions

The extent of fire in Australia's non-forested landscapes showed a consistent pattern in the years 1997–2003, with an average of 31 million ha of land burnt annually. Most fires occurred in the arid regions of central and Western Australia (55%), 45% occurred in the tropics of northern Australia. Only 0.6% occurred in the temperate southern regions. Climate influences the frequency and extent of fires.

Patterns of fire were examined across the nine land use classes: cropping, grazing, horticulture, timber production, conservation, water resources, urban, other minimal use and indigenous. The most extensive and frequent fires were on land under indigenous management.

While the NOAA AVHRR fire footprint dataset is known to consistently miss a large majority of individual fires that are smaller then one pixel (1 km^2) it nevertheless represents the most extensive and complete continent scale database available for longer term (greater than six years) fire history across Australia. In order to create a comprehensive fire history, information on fire severity and intensity are of high importance; both of which could not be assessed in this study. Additional work will be required to collect, monitor and report on fire severity and intensity, especially in forest areas.

Forested areas with a forest canopy cover greater than 20% were masked and not included in this study. The statistics presented in this report unfortunately therefore do not include many areas of high population density and high utility value along the east coast and south west coast. These forest areas were removed at the outset from NOAA AVHRR fire footprint dataset because it was known that this satellite imagery cannot accurately discriminate many small low intensity fires beneath a canopy of a forest. The method used in this report should be expanded to assess the sensitivity of the NOAA AVHRR fire footprint dataset in forested Australian landscapes depicted in Figure 1. This could be done using increasing percent increments of projected foliage cover commencing with 20% projected foliage cover.

This study has shown that there is a need to provide accurate information on the extent, severity and intensity of fires for land managers, policy makers and emergency services across Australia. While state and territory agencies record fire data, each state employs different techniques and has different agencies responsible for analysing it. There is currently no national coordination across Australia's climate zones, land uses and land tenures to enable these data to be compiled, analysed and assessed in regard to key questions of natural resource condition.

This study has shown the benefit of having a national report on the extent of fire in regard to Australia's climate zones, land uses and land tenures. A national fire monitoring programme is needed to collect, compile, monitor and report fire extent, severity and intensity across Australia. Such a monitoring and reporting programme should be cross referenced with regional data to encourage assessment of patterns and trends of fire in relation to land management practices and the outcomes of natural resource management. These issues are fundamental to reporting on several of the matters described in the National Monitoring and Evaluation Framework and the indicators of forest health under Australia's commitment to the Montreal Forest Process.

Further work is also needed to document the use of fire for land management across the different land uses and tenures. While this study has shown that most fires in water catchments occurred during winter and early spring, this is only an inference and is presumably due to the high infrastructure and population densities and the risk of sediment contamination where bare soil is exposed. These areas would appear to be a focus for fuel reduction fires aimed at lowering the risk of high intensity fires. Once these land management practices are documented for each of the land uses and tenures it would be desirable to develop consistent national guidelines on the use of fire to achieve multiple outcomes for land managers in different agro-ecological regions of Australia.

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