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Application of fire history records to contemporary management issues in south-west Australian forests

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ABSTRACT: Records of the annual area burnt by prescribed fire and wildfire extending back to 1937 are available for much of the publicly-owned forest in the south-west of Western Australia. These records exist in the form of maps prepared at local forest divisional (later district) offices from first-hand knowledge of the extent of prescribed burning activities and wildfires. Original maps have subsequently been incorporated into a Geographic Information System providing a unique insight into regimes of fire frequency and seasonality at a landscape scale over more than half a century. In this paper we examine ways in which fire history information can provide a context for contemporary management decisions about the use of fire for fuel reduction, and the effects of fire on forest ecosystems. More detailed records of the patchiness of burn patterns within prescribed burns and wildfires would assist in understanding the effects of fire at a landscape scale.

1 INTRODUCTION

Fire management has been an enduring theme in Western Australian forestry since the proclamation of the Forests Act in 1919 (Wallace 1966, McCaw et al. 2003b, Lee and Abbott 2004). The decades of the 1920s and 1930s witnessed the development of a fire management organisation with capabilities for fire danger rating, fire detection, telephone communication, prescribed burning and fire suppression (O'Donnell 1939). Particular attention was directed towards the protection, regeneration and silvicultural treatment of forest areas already cut-over by the timber industry. By 1937 the Forests Department reported an area of 502 000 ha under fire control, of which 167 000 ha were classed as having been regenerated and tended (Kessell 1937).

The 1937/38 fire season also saw the commencement of systematic recording of the area subject to prescribed burning and wildfire. Maps showing the extent of burning within each forest division (later district) were prepared using the knowledge of local staff. Burnt areas were depicted on standard Forest Department maps at 1:63 360 scale using coloured washes to distinguish between prescribed burning in spring (yellow) and autumn (brown), and wildfires (red) (Figure 1). Other forms of burning were sometimes also depicted including top disposal burns associated with silvicultural treatment (Bradshaw 2004), and burning on private property adjoining State forest. In some cases, wildfires were identified with a number that corresponded to a written fire report. This procedure for recording area burnt continued until the 1994/95 fire season, albeit with a change to 1:50 000 as the standard mapping scale in the early 1980s following the introduction of the metric system.

From 1995 onwards spatial information about the extent of burning has been captured directly in an electronic data format.

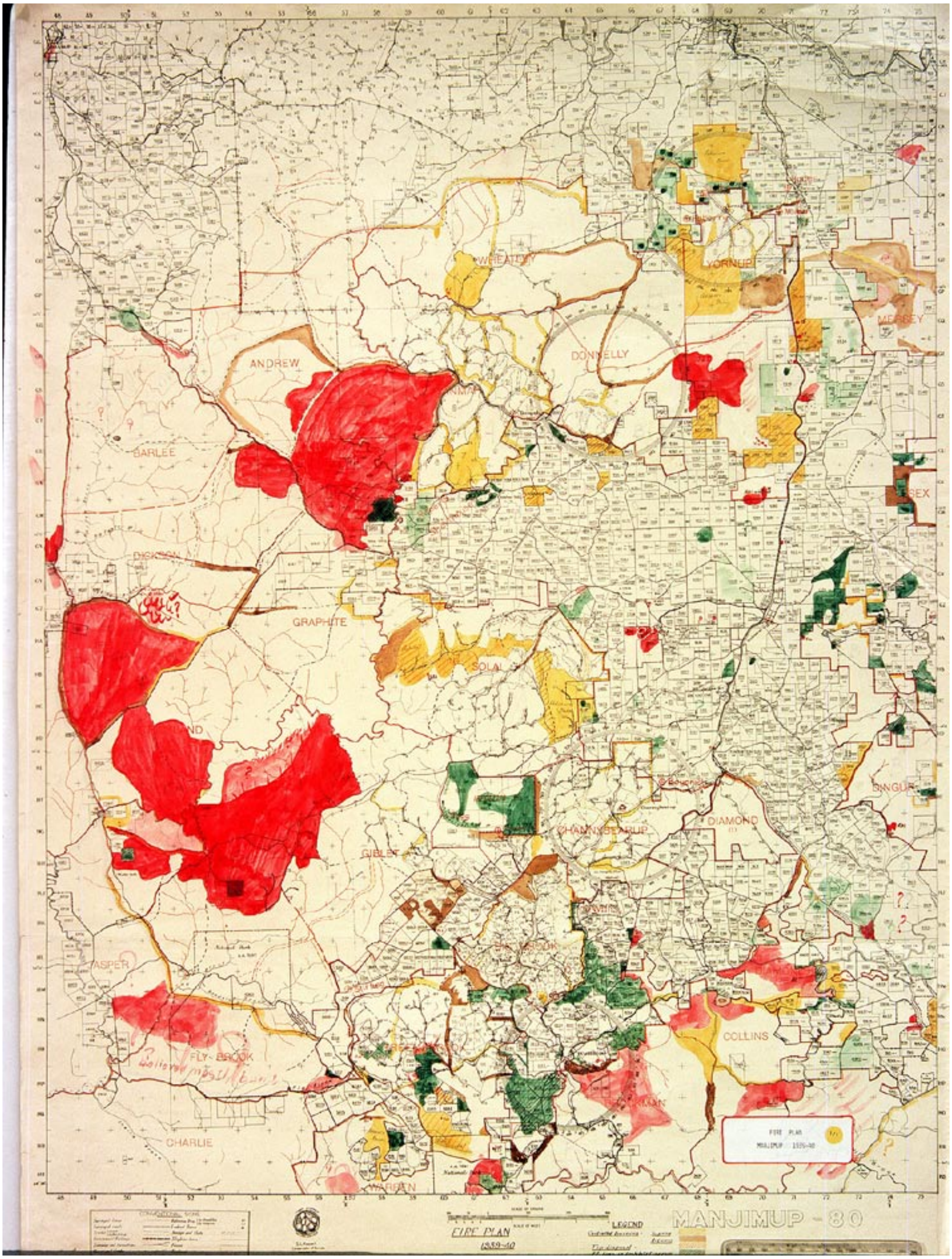

Figure 1. Annual fire plan for the Western Australian Forests Department Manjimup Division for 1939/40 fire season. Colours represent the extent of different types of fire as described in the text.

Knowledge of spatial patterns of fire occurrence can be derived using a variety of techniques including analysis of historical documents (Gill et al. 1997, Abbott 2003) and conventional map records (Gill 1986, Lang 1997, Robertson 1998), dendrochronology (Burrows et al. 1995, Swetnam & Betancourt 1990), and from interpretation of air photographs (Minnich & Chou 1997) and satellite imagery (Bowman et al. 2004). Each of these approaches has been employed for studying fire history in south-west Australian forests, with varying degrees of effectiveness. Application of dendrochronology has been limited because the major forest trees are fire tolerant and apt to record only the occurrence of more intense fires (Burrows et al. 1995). Similarly, rapid post-fire recovery by understorey and overstorey vegetation has restricted the effectiveness of conventional air photography to recording only those areas burnt at high intensity, and to the immediate post-fire period of a few months before the following winter.

Information from map records has been used in several previous studies of fire history in south-west forests. Lang (1997) assembled information from fire history maps for the Collie area and used the data to test several hypotheses about the effects of prescribed burning on forest fire regimes, finding a shift towards spring burning and reduced variability in the length of the inter-fire period after 1960. Robertson (1998) collated and analysed further data for a study area west of Manjimup that included the valley of the Donnelly River. The additional work described here has collated available fire history maps for all of the land managed by the Department of Conservation and Land Management in the Warren administrative region, an area of almost 1 million hectares bounded by the Donnelly, Blackwood and Hay Rivers. Fire history information has also been collated for the Department's Dwellingup District, and is being progressively extended to the remainder of the estate in the Swan and South West administrative regions.

The existence of spatial records of burning on State forest over a period of half a century or more provides the opportunity for valuable insights into past management practices and their effects on the forest environment. In this paper we briefly describe the process used to capture map records of fire history into a Geographic Information System (GIS) that can be interrogated to provide information about fire patterns and regimes at a landscape scale. We then consider several examples of how information derived from fire history records is being used to provide a context for examination of contemporary forest management issues in the south-west of Western Australia.

2 CONSOLIDATION OF ORIGINAL MAPS INTO DIGITAL FORMAT

Original maps were of variable quality and in some cases provided only an indication of the location and extent of burning, particularly for earlier decades in more remote areas of forest where there were few roads or other clearly-defined features that could be used as reference points in the landscape. Lineal burning along roads and tracks throughout the forest was also depicted in an indicative fashion as the extent to which fires spread away from tracks was not recorded. Reservation of further extensive areas as State forest continued throughout the 1950s and with it the establishment of a network of access roads that provided more definitive boundaries for fire management (White 1987). During the 1970s the advent of routine aerial surveillance by fire spotter aircraft provided hitherto unknown capability to map the perimeter of wildfires.

Copies of the original maps were transferred to microfiche during the 1970s and the microfiche data has subsequently been captured in digital form to facilitate interrogation in a GIS environment. Microfiche fuel age plans were geo-referenced and the boundaries of individual fires captured using the CAD package Microstation. Perimeters of burnt areas were captured as polygons through a combination of digitising directly from the geo-referenced map sheets and by copying line-work from existing vector data sets such as roads, streams or cadastral boundaries. This process offers significant advantages in terms of accuracy as it reduces the possibility of slivers being created between adjacent fires when successive years are combined for analysis.

Following boundary capture, each burnt polygon was attributed with a year of burn, fire type, season, ignition type, serial number, district and area burnt. This vector data was imported into the raster-based Forest Management Information System (FMIS) developed by the Department of

Conservation and Land Management for more sophisticated interrogation and analysis. Each pixel in FMIS is approximately 0.5 ha.

Anomalies in the data recorded on the fuel age plans were identified throughout the data capture process. Where possible these have been validated by reference to district records including burn prescriptions, field notes and park management plans. In some examples fire perimeters marked on one map did not extend onto adjoining map sheets, even though local knowledge indicated that this was likely to have been the case. Detailed notes have been kept specifying local information sources used and decisions taken regarding the probable shape of individual polygons for which information was uncertain. In addition, data have been validated against an independent dataset of year of last burn that has been maintained on an annual basis since the 1989/1990 fire season.

3 APPLICATION TO CONTEMPORARY FOREST MANAGEMENT ISSUES

3.1 *Quantifying fire regimes at a landscape scale*

There is growing awareness of the importance of studying fire impacts at a landscape scale to supplement the understanding gained through process-based studies and replicated burning experiments (Bradstock et al. 2002, Abbott and Burrows 2003). The ignition and spread of fires is influenced by a number of landscape scale factors including weather, terrain and landform, distribution and patterning of vegetation, and land use activities of human societies. Similarly, ecosystem responses to fire have a vital spatial dimension that is reflected in processes of recruitment, dispersal, re-colonisation and local extinction. Stream-flow, groundwater recharge and smoke dispersal are examples of other fire-affected environmental process that operate at a landscape scale.

Consolidation of fire history maps into a GIS environment has provided the opportunity to examine fire regimes in south-west forests over a period of five to seven decades. Fire regimes are defined by the frequency, intensity and seasonality of fire (Gill 1975). For a given locality the information available from the fire history maps makes it possible to resolve at least two components of fire history (frequency and seasonality) with some confidence. The third component, fire intensity, cannot be determined directly from the maps. Some inferences can be made about fire intensity if the nature and date of the fire is known, and relevant weather records are available.

Practical application of fire history information is being made through a research project being undertaken by the Department of Conservation and Land Management under the auspices of the Bushfire Cooperative Research Centre. As part of this project, fire regimes for the period 1953-2003 are being determined for several potential case study areas around Walpole that include parts of the Southern Hilly Terrain, South Eastern Uplands and Redmond Siltstone Plain Landscape Conservation Units defined by Mattiske & Havel (2002).

Landscape Conservation Units can be sub-divided into Vegetation Complexes (Mattiske & Havel 1998) mapped at 1:250 000 scale, and Ecological Vegetation Systems (Havel & Mattiske 1998) mapped at 1:500 000 scale. In the initial phase of the project potential study areas have been stratified according to the frequency of fire recorded over a period of five decades. Much of the landscape is recorded on maps as having burnt between four and six times over this period (ie. about once per decade) with extremes in fire frequency ranging from as low as one to as many as ten fires in the same period. Further work is underway to better characterise regimes according to type and season of fire.

Once characterized, fire regimes will be intersected with mapped vegetation complexes to identify sites that have a high level of ecological similarity but differing fire regimes over the past five decades. These sites will be subject to a comprehensive program of field sampling to describe the current condition of attributes that may be dependent on, or affected by, the fire regime. Attributes to be sampled include: vegetation structure; species composition (vascular plants, fungi, and cryptogams); soil seed bank composition; and the diversity and abundance of invertebrate and small vertebrate fauna. Sampling is to be replicated over two years to provide a measure of the effect of seasonal variation on abundance and species composition of transient components of the biota. This data set will be used to test the null hypothesis that the current condition of forest communities is independent of the fire regime experienced over the past five decades. The strength of this testing will be considerably affected by the degree to which the underlying ecological characteristics of these sites can be matched prior to sampling.

Most prescribed fires and some wildfires leave patches unburnt within the landscape (Underwood & Christensen 1981), and this must be taken into account when using the map records to determine fire regimes. Patches are more likely to remain unburnt during low intensity fires in mild weather conditions, when fuel and soil layers are moist, and when the landscape has varied topography which includes expanses of rock, scree and sparse plant cover (eg. dry lake beds). Differences in vegetation structure can affect the moisture regimes of litter and other dead fuel components, resulting in temporary barriers to fire spread that can persist for several months (McCaw & Hanstrum 2003). In the case of prescribed fires, the way in which an area is ignited also has a significant influence on the resultant pattern of burn out. Apart from lineal ignition along roads and tracks the fire history maps prepared at district office level have generally depicted the full extent of the management unit to which prescribed fire was applied and therefore provide an overestimate of the actual area burnt. Areas that are apt to remain unburnt by low intensity fires may in some cases be predictable because of their topographic position and edaphic conditions, but in other cases may simply represent the product of chance events. Satellite remote sensing offers an effective means of detecting and mapping the variability of fire impacts at the landscape scale (Li Shu et al. 2004). Remote sensing data are available for south-western Australia back to 1972 and offer the potential for more detailed validation of fire history maps prepared during this period.

3.2 Fuel age in the Dwellingup forest area at the time of the 1961 wildfires

During the 1960/61 season, bushfires burnt more than 506 000 ha in the South West Land Division of Western Australia. The largest single fire, known as the Dwellingup fire, originated from multiple lightning strikes caused by thunderstorms on the evenings of 19 and 20 January 1961. Although initially developing separately, a number of fire fronts subsequently coalesced into a firestorm that burnt 146 000 ha of forest and destroyed the township of Dwellingup and the settlements of Holyoake and Nanga Brook.

The 1961 Dwellingup fires represented, to a large degree, the outcome of decisions about fire management taken several decades previously (Wallace 1966). Systematic fire management had been extended to most of the Dwellingup Division by the end of the decade of the 1930s with State Forest divided into three zones for the purposes of fire management (O'Donnell 1939):

- Zone A which included regenerated stands and afforested areas (ie plantations). Fires in this zone were immediately investigated and, if necessary, forest workers were despatched to contain and suppress fire. Limited use was made of low intensity prescribed fire to reduce fuels, mostly in narrow buffer zones between protected compartments. These buffers were commonly located in areas of marginal forest and shrubland considered at the time to be unproductive.
- Zone B which included virgin forest awaiting sawmilling operations, or marginal forest not yet included in the general development programs. Fires in this zone were also suppressed as resources permitted, and broadscale prescribed burning was periodically undertaken to reduce fuel loads in the forest.
- Zone C which include areas of marginal forest and large expanses of shrubland referred to as flats. These areas were not envisaged to come under any form of organized management within the forseeable future and were burnt whenever possible. Fires in the remote eastern parts of the forest often burnt throughout the summer (Wallace 1966).

A Royal Commission was appointed to inquire into and report upon the fires under the direction of Commissioner G. J. Rodger, resulting in a comprehensive report that made 27 recommendations (Rodger 1961). Importantly, the Royal Commission examined the question of how the behaviour of the Dwellingup fires had been affected by previous fuel reduction (control) burning undertaken by the Forest Department, particularly during the period after 1954 when the Department embarked on an expanded program of broad-scale burning (Wallace 1966). In considering the cause of the fires and measures taken to prevent the outbreak the Commission's Report (page 15) identified that:

> Over recent years, the proportion of the area receiving complete protection has been progressively reduced and a system of compartment burning introduced. Nevertheless, when the 1960-61 fire season opened, there were still compartments which had not been burnt over for some 25 to 30 years. Some of these were reserved from fire for the protection of regeneration and others for purposes of scientific research. Except for these long protected compartments, most of the forest in the Dwellingup division had been controlled burnt in recent years, and the litter on various parts of the forest represented accumulations generally speaking, of from 0 to 8 years.

The Royal Commission was assisted in the technical aspects of its work by Alan McArthur of the Commonwealth Forestry and Timber Bureau in Canberra. McArthur compiled a detailed map of the Dwellingup fires based on Forests Department records and first hand accounts of forest officers and bush workers engaged in fighting the fires. This map attempted, to the best extent possible, to plot the development and spread of the fires at 6 hourly intervals from ignition through to the time that the fires were extinguished by rain on 25 January. McArthur also sought to identify examples where differences in the age and condition of fuels in the forest had resulted in demonstrable differences in fire behaviour. These examples were presented in a technical appendix that accompanied the report of the Royal Commission, and later in a leaflet published by the Forest and Timber Bureau (McArthur 1962) that laid the foundation for the practice of fuel reduction burning over the coming decades (McCaw et al. 2003b).

Forest fire management, and in particular the use of prescribed fire, remains a topic of considerable debate within the scientific and broader community. The current level of public interest in fire management is perhaps at the highest level for several decades, with a series of reports tabled by Federal and State inquiries investigating the bushfires of the 2002/03 fire season in south-eastern Australia (McLeod 2003, House of Representatives 2003, Esplin et al. 2003, Council of Australian Governments in press). In Western Australia, fire management is also the subject of reviews initiated by the Auditor General for Western Australia (2004) and the Environmental Protection Authority (Environment Protection Authority 2004). A common theme throughout most of these reviews is the role that prescribed fire should play in managing fuel accumulation in publicly-owned forests.

Although the issue of fuel ages in the Dwellingup area was central to the findings and recommendations of the Royal Commission as they applied to the Forests Department, the Commission's report was not accompanied by a map that provided information about fuel age or year of most recent burning. This is understandable given the difficult task of manually compiling such information, particularly at a time when staff would have been in demand for a wide range of post-fire recovery tasks. Consolidation of fire history records in a GIS environment provided the opportunity to generate such a map from the original fire history data that extended back to 1937/38 for most of the Dwellingup area. In generating the map we initially displayed the fire history information as a series of annual layers, but this proved difficult to interpret because of the large number of layers required to depict 23 years of data. For the final map, the year of last burn prior to spring 1960 was grouped into classes that represented different periods since fire (0-3, 4-8, and 9-23 years since fire) as well as areas with no recorded history of burning. These fuel age classes were chosen to reflect distinct stages of fuel development that have been linked to fire behaviour through experimental research (McCaw et al. 2003a). Private property was depicted as a separate category because there was no reliable fire history information for this tenure.

The fuel age map revealed a pattern generally consistent with the statements made in the Royal Commission report (Figure 2). Much of the forest in the eastern and southern parts of the Dwellingup Division had been burnt by prescribed fire between 1954 and 1960 and carried fuels less than 8

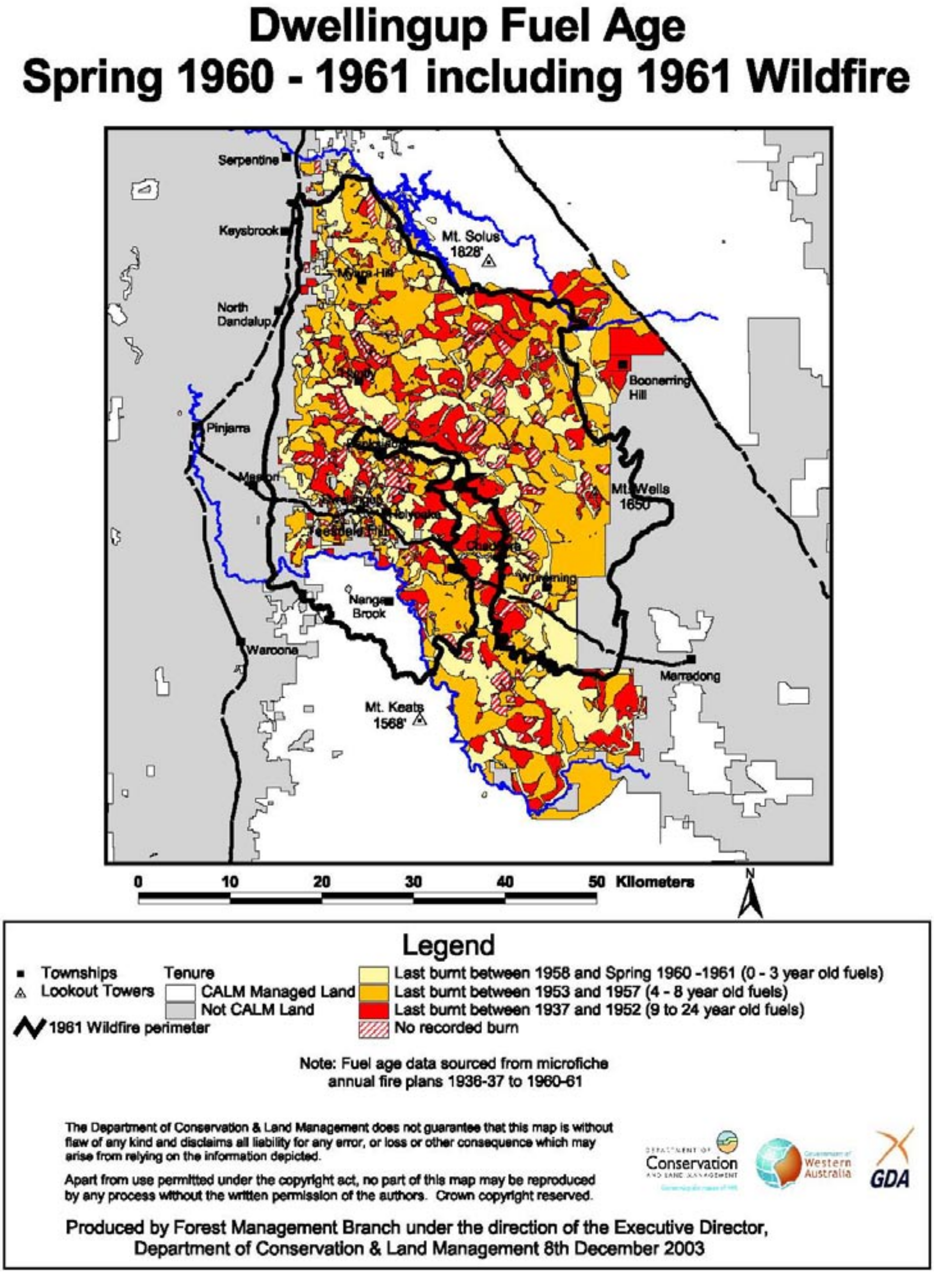

Figure 2. Map of fuel age categories in the Dwellingup area of south-west Western Australia at the time of the 1961 wildfires.

years old. The map also confirmed the existence of a number of compartments that had been unburnt for 9 or more years, or had no record of fire since 1937. The area 15-20 km north of Dwellingup is of particular significance because this is where most of the fires began, and where the initial fire suppression effort was concentrated between 19 and 23 January. Substantial parts of the Torrens, Wilson, Scott, Turner and Marrinup forest blocks had been unburnt since before 1950 or had no record of fire since 1937. Forest to the north of Dwellingup also provided the source of the massive spotting that took place on the afternoon of 24 January, eventually leading to the destruction of the town. Jarrah has a fibrous bark that continues to increase in thickness and spotting potential for several decades after fire (Ellis 2003) and substantial accumulations of bark probably existed on trees in compartments from which fire had deliberately been excluded for a decade or more.

While spatial records of fuel age contribute to our understanding of the condition of the forest at the time of the 1961 wildfire, there are other factors that deserve consideration. The nature of prescribed burning undertaken in the decade prior to 1960 is also likely to have had a significant influence on fuel conditions in the forest. Wallace (1966), a forester with extensive experience in fire research and management, described the practical difficulty of conducting mild burns in long-protected compartments, noting that much of this early burning was done during the winter months in an effort to avoid damage to the regenerating forest. For this reason consumption of litter fuel on the forest floor was often incomplete. The effectiveness of these initial very mild prescribed fires in reducing the intensity of a summer wildfire would therefore be less than might otherwise be expected from contemporary experience in forest that has experienced periodic fire over several decades.

3 CONCLUSION

The fire history records available for publicly-owned forests in the south-west of Western Australia represent a valuable resource which has been made more accessible with the advent of digital technology and Geographic Information Systems. Spatial information about fire history can provide important insights into past practices that continue to influence contemporary forest management. Spatial records can also provide the framework for retrospective studies into the impacts of fire at a landscape scale. In both cases, it is important to recognize the original context in which the information was collected and the resultant limitations that this imposes. These limitations can be overcome to some extent by making use of other independent sources of information.

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