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The timing of vegetation fire occurrence in a human landscape

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ABSTRACT

Vegetation fires in urban and peri-urban (human) landscapes damage property and infrastructure, threaten lives and incur considerable suppression costs. This study investigated the timing of fires burning in vegetation within and around the city of Perth, Western Australia. The timing of fires from 16 different cause types were investigated at hourly, daily, monthly and annual scales, and using fire danger indices and fuel moisture. Ignitions from most causes were shown to have hourly and monthly profiles that reflect fire danger and fuel availability. Some causes with low heat outputs, such as cigarettes and sparks from cutting and welding, were more sensitive to fire danger and fuel availability than others. Causes related to arson and recreational activities, such as camp fires, were more likely to occur on weekends and public holidays. Arson prevention measures appear to have reduced the incidence of deliberately lit fires, and may have reduced the number of fires occurring on days of total fire ban, although these days have much higher rates of ignition than other days. High profile fire events also increase public awareness and reduce ignition rates. Lessons learned from analyses of fire occurrence can help fire agencies more effectively apply prevention and mitigation programs.

1. Introduction

Vegetation fires burning within and around urban areas threaten life and property and require significant resources to manage. These fires originate from a range of causes and occur in a variety of areas, such as parks, reserves, gardens and road verges. Knowledge of the temporal patterns of vegetation fires that originate from different causes assist fire prevention and response by allowing fire agencies to proactively focus their efforts at times when fires are more likely to start [3,15].

Fire agencies undertake a range of activities to prevent fire ignitions. These include implementing fire restrictions, such as total fire bans, issuing permits for private burns, and undertaking public education and awareness campaigns. Total fire bans are declared on days where the weather is conducive to ignition and rapid fire growth, and are set when the forecast daily maximum level of the Forest or Grassland Fire Danger Index [22,23] exceeds a critical point (usually 50) [8]. For most jurisdictions it is illegal to ignite outdoor fires or undertake some activities that may cause a fire for the 24 h period of a day of total fire ban. Restrictions are also used to prevent agricultural and fuel reduction burns on private land from being undertaken on days of elevated fire danger, when the chance of escape is high. Public fire education campaigns are mostly undertaken during the fire season to increase fire safety awareness, reduce accidental ignitions and to increase the reporting of suspicious behaviour related to deliberate ignitions.

The ease and sustainability of ignition of vegetation is related to fuel moisture content [26] particularly for dead fuels [30,12]. The occurrence of wildfire ignitions has been linked to the moisture content of dead surface fuels in many analyses of wildfire incident data [37,41,42,35,20]. The moisture content of dead fuels vary with that of the surrounding atmosphere and typically undergo a diurnal cycle with the highest values attained in the morning and lowest values attained in the mid afternoon.

Many studies focussed on wildfire occurrence have tended to consider anthropogenic and lightning ignitions separately (e.g.: [38,35,42,20]). These have generally not investigated the different anthropogenic cause categories, other than some that have specifically focussed on the timing of arson ignitions (e.g. [32,33]).

There has been little research on the effect of timing and weather on the occurrence of fires in vegetation from different causes in human landscapes. Some studies have investigated spatial and temporal distributions of a range of fire incidents in urban areas (e.g. [9,3,11]; Wuschke et al., [43]) but have not considered how these vary with cause. Structure fires occur more frequently during winter periods and vegetation fires occur more often in summer and during drier conditions [7,18,10,11]. While some of these studies have considered vegetation fires, they have

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not specifically considered variation in timing due to ignition cause, weather or fuel availability.

This research investigated the timing of vegetation fires from different causes in the urban and peri-urban areas within and surrounding the city of Perth, Western Australia. Timing was considered at hourly, daily, monthly and annual scales and with weather variables related to wildfire danger and fuel availability. Ignition causes with unusual time profiles were identified and investigated. The long-term influence of fire prevention measures on ignition rates and the impact of a high profile fire event on fire occurrence were also examined and discussed.

2. Study area and data

Perth is the largest city in Western Australia with a current population of 1.9 million people [1]. The city has experienced rapid economic and population growth over recent decades with significant urban expansion along the coast and the outer fringe (Fig. 1). There are considerable amounts of public open space within these areas including sections with remnant native vegetation [16]. The greater area considered in this study also covers a variety of other land uses, including forest and conservation reserves and agricultural and industrial areas. Vegetated areas in and around the city take a variety of forms including pasture grasses, dry eucalypt forest and woodlands, shrubland and suburban parks and gardens. It is these areas where the fire ignitions considered in this study have occurred.

The region experiences a Mediterranean climate with a long dry period over the summer and autumn and a wildfire season extending from mid-October to mid-May. The majority of fires and emergencies are managed by the Department of Fire and Emergency Services (DFES[1]), while bushfires that occur on state owned land are managed by the Department of Parks and Wildlife (DPaW[2]).

Records for fires burning in vegetation were obtained from DFES for the three metropolitan management regions. The records used in this analysis cover the period from 1 July 2004 until 30 June 2012 and conform to the Australian Incident Reporting Standard (AIRS) [2], a national data standard that many fire agencies in Australia use for collecting, recording and reporting information about fire incidents.

The AIRS data fields used here were 'ignition heat form', 'ignition factor' and 'report time'. The ignition heat form field lists the heat source that caused the ignition, and may include items such as matches, cigarettes or hot sparks. The ignition factor field categorises the reasons for ignition heat sources combining with combustible material and starting fires. Both of the ignition fields require the ignition point to be located and assessed by a senior firefighter who has undertaken fire investigation training. The assignment of an ignition factor requires some judgement to be made in order to determine if human caused fires were accidental or deliberate.

The report time field identifies the time (to the nearest minute) that the agency was notified of the fire, typically by the public as an emergency phone call. In most cases detection and reporting are likely to come soon after ignition due to the relatively dense population in the study area, however some ignitions may lead to smouldering fires or may grow very slowly and go undetected for some time. Some ignition sources, such as campfires and pre-existing fires that are not fully extinguished, may persist for long periods before initiating a fire spreading in vegetation.

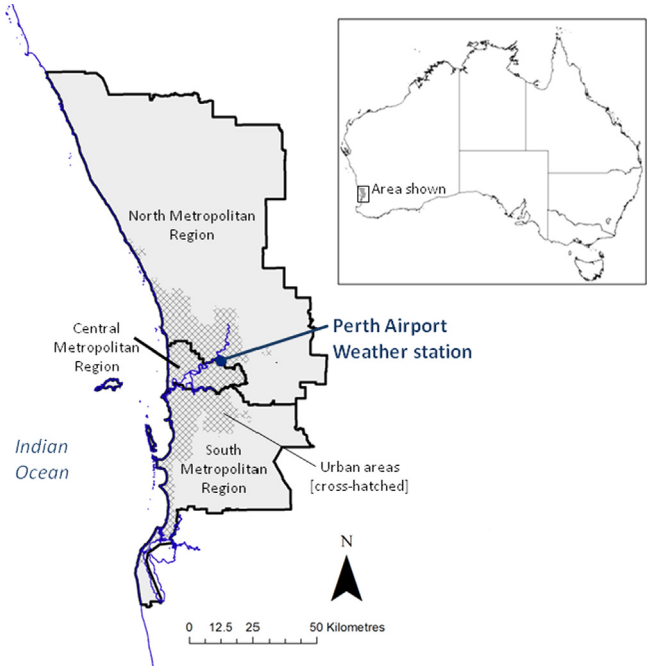

Fig. 1. Location of the study area and the weather station used. The cross-hatching shows urban areas.

The DFES database contained 87 specific ignition heat form types and 85 specific ignition factor types. These were used to determine 16 ignition cause categories (Table 1), including two natural, three deliberate and 10 accidental categories. There were two other categories for ignitions that were either listed as "other" or where the cause was not determined. The ignition cause categories were the smallest categorical units that the data could be broken down into based on the AIRS fields. Records from DPAW were not used because they had fewer categories for ignition cause and these did not readily translate to those available in the DFES database, particularly with the many types of accidental ignition cause. DPAW fires only comprised of 5.5% of the total vegetation fires that occurred in the study region and timeframe.

Day type attributes were compiled for each fire in the database. These were day of the week and binary categorical descriptors based on the occurrence of work days (all days except public holidays and weekends) and school days (all days except public holidays, weekends and school holidays).

Hourly weather data were obtained from the Perth Airport Bureau of Meteorology weather station (−31.93°S, 115.98°E) for the period from 1 January 2000–30 June 2012. Missing weather observations were supplemented with observations from the nearby Perth Metropolitan weather station (−31.92°S, 115.87°E). These were used to calculate Grassland Fire Danger Index (GFDI) [22], Forest Fire Danger Index (FFDI) [23] and fuel moisture content for the study period, with early observations (pre July 2004) used to stabilise drought indice inputs. GFDI and FFDI were calculated using Noble et al., [27] equations, with GFDI calculations based on an assumption that grass was constantly in a fully cured state. This assumption was required as there were no records of curing available to the study and would have led to a significant over estimation of GFDI in the cooler and wetter times of the study period. The drought factor input for FFDI was calculated using the Soil Dryness Index [25], which is the preferred drought index for Western Australian fire agencies [5]. The surface fuel moisture content (SFMC) of the litter layer was used to indicate the

[1] The Department of Fire and Emergency Services was known as the Fire and Emergency Services Authority until 31 October 2012.

[2] The Department of Parks and Wildlife was known as the Department of Environment and Conservation until 30 June 2013.