THE INFLUENCE OF LAND USE PRACTICES ON WILDFIRE OCCURRENCE

A case study of the 2019/20 bushfire crisis in New South Wales

ABSTRACT

In 2019/20, Australia was hit with one of the worst wildfire crises in modern history of the country with New South Wales being one of the worst hit states. This study looks into the influence of land use practices on wildfire occurrence in New South Wales. This is achieved through spatial and statistical analysis where a binary logistic regression model is applied to find the increased likelihood of wildfire occurrence as a result of prescribed burning activities or general land use activities. The study found that with the closer one gets to native vegetation rich environments, such as conservation & natural environments or production from dryland agriculture, the likelihood of wildfire occurrence can increase considerably. The influence of prescribed burning did not lead to conclusive results which is thought to be due to the exceptional climatic conditions which aided the severity of the crisis.

Key words: Wildfire, Land cover, Australia, Land Management, Prescribed Burning

Seska Trip

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1 Introduction

Wildfires are an important aspect in many ecosystems around the world for a multitude of reasons such as carbon cycling (Van der Werf, Randerson, Collatz, & Giglio, 2003) or the regeneration of vegetation (Gill, 1979; Rickards, 2016). However, wildfires also come with their challenges as they can pose severe threats to human life and properties (Altangerel & Kull, 2013), increase CO2 emissions (Adams, 2013; Williams, 2013) and more. Research is showing that wildfires are becoming more frequent and with increasing intensities this is becoming a more pressing issue (Viedma, Moreno, & Rieiro, 2006; Williams, 2013). This was, for example, apparent in the 2019/2020 bushfire[1] season in Australia where more than 3,5 million hectares of land burned in New South Wales alone (SEED, 2020). For this and other reasons, such as the imminent threat wildfires pose to endangered species, it is important to research where these wildfires occur. There are three main factors that determine fire occurrence; a source of ignition, fuel availability, and weather which influences the dryness of said fuel (Bond & Wilgen, 1996). The source of ignition can vary, sometimes caused by natural phenomenon like lightning strikes but in the present-day, humans are seen as one of the main causes of fires (Bond & Wilgen, 1996). The fuel aspect depends on the amount of vegetation and vegetation litter present on the ground. This is naturally linked to the type of land use present. Land use practices can hugely influence fire regimes in general but also specifically the occurrence of wildfires (Gallardo, Gómez, Vilar, Martínez-Vega, & Martín, 2016). One of the main drivers behind wildfire occurrence resulting from land cover changes is the management of forests, or lack thereof, which leads to an accumulation of burnable material (Fanin & van der Werf, 2015; Viedma, Moreno, Güng, Cosgun, & Kavgacı, 2017). Other types of management that can hugely influence wildfires are the

[1] Bushfire is used in Australia instead of the more common word worldwide wildfire.

implementation of prescribed burning practices (Altangerel & Kull, 2013; Andersen et al., 2005; Bradstock et al., 2012; Clode & Elgar, 2014). Prescribed burning is used as a way to regenerate soils and vegetation and/or decrease the amount of fuel available for a potentially uncontrollable future fire it also disrupts the natural fire regime. However, as an old technique used by indigenous communities (Birch, 2016) it's potential value must not be understated. A second driver of wildfires is how much an area is used and/or visited by humans as they can accidentally light fires in a(n) (sometimes already vulnerable) area (Badia, Pallares-Barbera, Valldeperas, & Gisbert, 2019; Levin, Tessler, Smith, & McAlpine, 2016). The changes in land cover due to the expansion of the wildland-urban interface are an important subcategory of this as this also influences the pressure humans can exert on an area (Gallardo et al., 2016). Land use changes that have occurred over time can therefore be used as an additional indicator to determine why wildfires are occurring more as land covers might change to uses that are more prone to wildfires. Besides these land management practices, general land use types also have a considerable impact on wildfire occurrence. These types can vary from built up areas to different types of agricultural uses or (almost) untouched natural areas. All of these bring about their own risks for fires to occur and spread potentially to the degree that they did in 2019/2020 with all the consequences that brought about. A final driver of wildfire occurrence is the influence of the climate on an area as e.g. drought can lead to more flammable material (Aldersley, Murray, & Cornell, 2011). However, this last factor is extremely complex and will not be studied extensively in this research as a full understanding of these smaller scale factors is necessary before expanding the research field. Overall, this is a relatively well-studied field within the Mediterranean and Amazonian regions. However, research is still lacking on the effects in Australia, a country that experiences many wildfires every year.

This paper will research the influences land use practices have on bushfire occurrence with a case study focusing on the Australian state New South Wales. The analysis relies on a detailed spatially explicit description of the occurrences of wildfires in the case study region in the summer of 2019/20 and aims to explain these from equally detailed information on land cover and land management practices. With this knowledge, (management) strategies can be improved to deal with wildfires in the future.

2 Literature Review

2.1 Wildfires and land use

Wildfires can occur for a variety of reasons, one of them being the type of land use at the location of the fire or the distance to certain types of land uses that influence e.g. the possibility of fire spread or the risk of ignition (Levin et al., 2016). The relationship between wildfires and land use can vary between land use types. This section will look into the main land use in New South Wales and their relation to wildfires as found in existing literature. The first land use looked at is built up areas. Secondly, a land use that covers a large area of the state, the relation between agricultural lands and wildfires. Additionally, since Australia prides itself on its diverse and unique biodiversity that is already considered to be under threat (Natural Resource Management Ministerial Council, 2010) it is of great importance to investigate the relation between wildfires and these vulnerable lands. Therefore, low productivity lands such as conservation areas will also be analyzed.

2.1.1 Wildfires around built up areas

Despite being one of the largest countries in the world, Australia has low population numbers in comparison with the other “mega states” in the world such as China, Russia, or the United States. The circa 25 million people live mostly around the coastal areas where big cities such as Sydney, the state’s capital, are located. These different-sized clusters of people can have significant influences on the surrounding landscape through various processes such as urban sprawl or urban-rural residential areas which can lead to a fragmentation of natural landscapes (Badia et al., 2019; Marchi et al., 2018). On the other hand, increased population density in built up areas can also increase the risk of wildfires due to the additional pressures brought by the rising population which makes management strategies all the more difficult (Marchi et al., 2018). Despite urban sprawl clusters being important, it is often also more rural communities that have been found to have a significant influence as they increase the fragmentation of these areas even further. This shows the lack of consensus on the influence of the spread and density of built up areas.

Additionally, an important and somewhat troubling fact mentioned by Williams (2013) and Aldersley, Murray, & Cornell (2011), is that the cause for fire ignition can often lie with people as unfortunately arson is not yet a thing of the past. This was even seen in the 2019/2020 bushfire crisis in Australia where a firefighter was charged with lighting fires (BBC News, 2019). Overall it was found that if not ignited by people purposively, fires are likely to start near built up areas for example due to incorrect disposal of flammable waste by individuals. (Levin et al., 2016). Lastly, it is important to look at built up areas and wildfires as these are the places where most damage will be done to humans directly which is often prioritized above e.g. conservation goals or the general protection of natural landscapes (Rickards, 2016).

2.1.2 Wildfires and agricultural lands

Agriculture is a very important land use type all around the world and also in New South Wales where different forms of agricultural practices cover more than half of the state's land (see figure 1 in methods section). As a critical industry, it is important that wildfire risks are minimized in these regions as well as in built up areas as research argues these have an impact on the number of fires that occur in an area (Bajocco, Pezzatti, Mazzoleni, & Ricotta, 2010). Land owners around the world are known to manage their lands using maintenance fires to, for example, increase the amount of nutrients in the soil (Gill, 1979) or reduce the amount of fuel that can build up and increase the fire risk (Fanin & van der Werf, 2015). Therefore, changes in agricultural land use can hugely impact the chance of wildfire occurrence as land abandonment leads to fuel accumulating in otherwise cleared out areas (Gallardo et al., 2016; Marchi et al., 2018). This is further enhanced by changes within different types of land use practices as changes from intensive to more extensive cattle farming can decrease grazing pressures which can also create a slow built up of flammable material (Levin et al., 2016). However, Nunes et al. (2005) argued that agricultural lands used for cropping are also sometimes avoided by wildfires creating an interesting division within agricultural wildfires.

2.1.3 Wildfires and conservation areas

Australia has unique and diverse ecosystems around the country due to its location and the subsequent ability for flora and fauna to develop without certain pressures that were present elsewhere in the world (Alexandra, 2012). Since it is so unique, it is also very vulnerable and therefore an important asset to protect also for economic reasons as it can generate a substantial income through tourism for the economy. In order to do this, its influence on wildfire occurrence must be understood so appropriate management strategies can be put into place based on this information. As was previously mentioned, fragmentation of natural landscapes can influence wildfire occurrence. There is no full consensus on the influence of this fragmentation on wildfire occurrence, however, Bentley & Penman (2017) noted that fragmentation can increase the occurrence of wildfires along the edges of forests and conservation lands. In conservation areas, vegetation is often left to grow freely as it is a natural area. Therefore, these areas can provide extra fuel for fires that start on the edge of these regions. Additionally, one of the unique characteristics of Australian vegetation such as the Eucalyptus and Acacia species that are widely spread throughout the country, are the oils these trees contain. These oils are very flammable and can create sparks that can shower surrounding vegetation and aid wildfire spread (Logan, 2015). Conservation areas that have an abundance of vegetation like these are therefore highly influential in wildfire occurrence.

2.2 Land management

Australia has a long history with Aboriginal communities inhabiting the continent and forming the lands to aid their survival for many years previous to European occupation. However, it is the latter that started the large amount of changes in land use that have mostly led to the country as it looks today (Lesslie & Mewett, 2018). In the early days of the occupation, European settlers had relatively unrestricted access to claim lands they wanted and e.g. transform them into cropping or grazing lands for their own (economic) benefits (Lesslie & Mewett, 2018; Neldner, 2018). These changes have, as mentioned in the previous section, had important influences on wildfire regimes. Additionally, these settlers wanted to replicate the lives they left behind in Europe and use the landscape in the same manner as before (Alexandra, 2012). Since Australia has an incredibly different landscape, climate, etc. this has over time manifested into a variety of problems such as drought struck areas due to inappropriate changes to the natural lands (Alexandra, 2012). Lastly, in recent years, land use changes have become more intensified and this, in combination with climate changes, forms a potential recipe for disaster for Australia due to the possible increase in wildfire occurrence as a result of changes to more wildfire prone uses (Mackey, 2018). There must be an understanding of the underlying policies set up to understand how these risks are incorporated to determine how a good balance can be found between human induced changes and wildfire risks to come to an adjusted form of land management.

2.2.1 Land management policies in Australia: an overview

This section provides an initial overview of land use change laws in Australia. This is the framework in which the fire risks regarding land use changes are incorporated into law.

Australia is made up of six states, New South Wales, Victoria, South Australia, Western Australia, Tasmania and Queensland, and two territories, the Northern Territory and the smallest of the bunch, the Australian Capital Territory. Each of these has control over their land and can, therefore, decide on their own land use strategy and management practices. The national government is the umbrella organization that oversees and coordinates this somewhat and aids in communication between parties but it is the state that has the jurisdiction (Hicks, 2018; Thackway, 2018). With the current projections for population growth to steadily increase for the next decade or more (Healey, 2016) more and more people want to move out of the busy coastal cities and into the ‘hinterland’. This pushes for more land use change in the outskirts of cities and conversion of agricultural or semi-natural lands to built-up areas (Thackway, 2018). These changes have knock-on effects on other things such as water or soil resources (Hicks, 2018), the Australian Collaborative Land Use and Management Program (ACLUMP) was set up in 2000 in order to coordinate this amongst the different jurisdictions as these resources are not bound by state or territory borders. Furthermore, the National Reserve System (NRS) provides further protection nationwide by illegalizing and/or constricting land use changes to occur on these lands. These lands do not only include nature conservation areas, but also indigenous protected areas. The latter is cause for concern in land use change policies as the management for these lands are in the hands of traditional owners. Unfortunately, research conducted for the Australian government has admitted that many of these lands do not receive the protection they should (Mackay, 2017). Additionally, the NRS can find itself in competition for land as areas can have huge potential for economic development such as mining, for example, making land clearing sometimes unavoidable – as was seen in neighboring state Queensland regarding the highly controversial exploitation of the Galilee Basin (Reside, Cosgrove, Pointon, Trezise, & Watson, 2019).

The state of New South Wales has its own legislation as they are, as was previously mentioned, the main agency to control land use policies. The most recent legislation put in place in the state for this purpose was the "*State Environmental Planning Policy (Primary Production and Rural Development)*" in 2019. Three points of significance of this policy are:

"(a) to facilitate the orderly economic use and development of lands for primary production;
(b) to reduce land use conflict … by balancing primary production, residential development and the protection of native vegetation, biodiversity and water resources;
(c) to identify State significant agricultural land for the purpose of ensuring the ongoing viability of agriculture on that land, … considerations"

Source: State Environmental Planning Policy 2019 (NSW)

Other legislation of significance in New South Wales are the Environmental Planning and Assessment act of 1979 (NSW) which covers a wide array of topics including housing, the natural environment, (indigenous) community engagement, and the sustainable use of land. The piece of legislation highlighted is the Right to Farm Policy (2015, NSW) which was set up to, amongst other things, support land use planning in the state while avoiding conflict amongst stakeholders.

2.2.2 Incorporating increased fire risks in land use policies

The response to and management of fire is often included in national and state legislation with varying degrees of success. The Australian national government, for example, committed to increasing the number of protected areas across the country making land clearing illegal or much harder to perform and as of 2015, this goal was being met by having around 37% of the Australian continent marked as a conservation area, national park or other protected land (Thackway, 2018). However, wildfires can still have a huge impact on these lands for which coordination is still necessary and when funds run out, these areas suffer from the lack of management practices as other actors cannot influence what happens there due to their protected status (Thackway, 2018). On the other hand, the national government committed to providing increased funding for managers of indigenous protected areas (IPAs) who can use traditional knowledge to successfully deal with the wildfires on their lands (Australian Conservation Foundation, 2017).

State government has also included wildfire into land use change associated legislation such as those mentioned above. The State Environmental Planning policy 2019 (NSW), for example, has authorized for future development only to take place if bush fire management has been considered, amongst several other requirements. This builds on older legislation such as the 1979 Environmental Planning and Assessment Act (NSW) that also states that consent must be given in order for certain land development projects to take place when 'bush fire prone' lands are involved. However, certain developments are excluded from this which raises the question on the effectiveness as the act states:

> "*development consent cannot be granted for the carrying out of development for any purpose (other than a subdivision of land that could lawfully be used for residential or rural residential purposes or development for a special fire protection purpose)*"
>
> Source: Environmental Planning and Assessment Act 1979 (NSW)

Lastly, the Rural Fire Service plays an important part in aiding legislative decisions as this is the organization that determines the previously mentioned 'bush fire prone' areas in the state to which legislation applies.

2.3 Prescribed burning

Land management is an important way that humans can influence certain natural events occurring or not such as wildfires. Conducting prescribed burns as a way to manage land is a tactic that has been used in many parts of the world such as the USA (Fernandes, Delogu, Leone, & Ascoli, 2020), Brazil (Fanin & van der Werf, 2015), the Mediterranean region (Levin et al., 2016) and of course Australia (Clode & Elgar, 2014). The use of prescribed burning is one that is often debated in the scientific community as it has the potential to protect lives and livelihoods but the extent to which this is successful without having too much of a negative impact on wildlife and ecological communities is not agreed upon (Altangerel & Kull, 2013; Andersen et al., 2005; Clode

& Elgar, 2014). Furthermore, in Australia in particular, it has the potential of bridging the gap between governmental agencies and indigenous communities as the latter have been utilizing this tactic for a lot longer and therefore have extensive knowledge on its use (Birch, 2016).

2.3.1 History of prescribed burning

Prescribed burning has been part of land management under different names for many years already, in the USA, for example starting with native Americans (Tulbure, Wimberly, Roy, & Henebry, 2011) and with continued use by European settlers in the late 19th century under the term 'fire suppression' (Leone & Tedim, 2020) and developing into 'fire exclusion policies' in modern-day USA (Fernandes et al., 2020). In Australia, indigenous communities have been using fire in their land management practices long before European settlement which was later coined "Igniculture" or "fire-stick farming" (Birch, 2016; Fache & Moizo, 2015). For indigenous communities, using fire was an important part of their lives for a multitude of reasons. First of all, fire was used in order to make the collection of food and other resources easier as modern-day infrastructure was of course not in place (Sharples et al., 2016; Vigilante, Bowman, Fisher, Russell-Smith, & Yates, 2004). Besides practical uses, it has been found that fire played a much more important role in their culture than it does in present-day Australian life as they use it for e.g. religious purposes (Fache & Moizo, 2015). The many years of practicing forms of prescribed burning has led to a huge amount of knowledge to remain within these communities as it has been passed down through generations (Bardsley, Prowse, & Siegfriedt, 2019; Birch, 2016; Fache & Moizo, 2015). This knowledge has caught the attention of current 'Euro-Australian' land managers who have started to acknowledge their value and have become more and more interested over the years to involve indigenous practices in contemporary land management activities (Bardsley et al., 2019; H. T. Lewis, 1989). Additionally, having lived on the continent for thousands of years (H.

T. Lewis, 1989), the unique understanding of its climate could prove essential in present-day issues that come up regarding climate change (Birch, 2016). Unfortunately, since European settlement, this vast amount of knowledge was not valued properly and through settlement many indigenous communities were displaced (Bardsley et al., 2019). Despite the history between traditional and non-traditional inhabitants of the country, policies and practices have been set into place where all stakeholders are involved in the management process (Fache & Moizo, 2015).

2.3.2 Prescribed burning in Australian national and state legislation

The Australian government has national legislation in place that regulates and protects the environment and activities that could have an impact on that. The Environment Protection and Biodiversity Conservation Act, more commonly known by its abbreviated name the EPBC Act, from 1999 (CTH) is the main rule of law regarding this. However, as was previously mentioned, state governments have the authority over their respective lands which includes the management of prescribed burning activities. There are exceptions to this rule, for example when threatened species and/or their habitat is involved in which case approval must be given by the national government. New South Wales has its own state legislation which includes prescribed burning through the Rural Fires Act 1997 (NSW). In this act, the first objective is as follows:

> *"(a) for the prevention, mitigation and suppression of bush and other fires in local government areas …"*
>
> Source: Rural Fires Act 1997 (NSW)

By this Act, hazard reduction by an authorized person may take place everywhere within the state's jurisdiction, including on private lands. Furthermore, the act includes measures to avoid prescribed burning activities near homes utilizing the '10/50 Vegetation Clearing Scheme' which allows the clearing of certain types of vegetation within a fixed distance from one's home. Clearing can be more favorable in some circumstances such as when in close vicinity to homes but sometimes more reasons are found that oppose of prescribed burning.

2.3.3 The pros and cons of prescribed burning

The question of whether or not to use prescribed burning as a tool for land management has been asked a lot in recent history and especially with the expected transformations wildfire regimes will undergo due to climate change (Gralewicz, Nelson, & Wulder, 2012). It has been argued by many that prescribed burning can reduce the severity of future wildfires in close vicinity to where the prescribed burn took place as the amount of fuel available will have decreased (Boer, Sadler, Wittkuhn, McCaw, & Grierson, 2009; Fernandes, 2015; Furlaud, Williamson, & Bowman, 2018; Kobziar, Godwin, Taylor, & Watts, 2015; Tolhurst & McCarthy, 2016; Vilén & Fernandes, 2011). However, more extreme fire weather conditions can undermine the success of the prescribed burn (Fernandes et al., 2020; Leone & Tedim, 2020). Previous research has shown that beyond a certain threshold of fire intensity, the occurrence of prescribed burning to reduce the amount of fuel available becomes less influential on the severity of the fire (Furlaud et al., 2018; Leone & Tedim, 2020).

Furthermore, the effect of prescribed burning activities on the surrounding ecosystems has also been noted as a potential issue for its widespread use (Furlaud et al., 2018). This is a critical consideration in Australia especially as it has unique flora and fauna that are already enduring pressures from other sources such as habitat fragmentation (Andersen et al., 2005; Bardsley et al., 2019; Clode & Elgar, 2014). Another consideration is the effect prescribed burning has on human health as the smoke it produces can create health issues for those living in close vicinity to the burning area (Altangerel & Kull, 2013; Clode & Elgar, 2014; Furlaud et al., 2018; Kobziar et al., 2015). If the activities are successful and future wildfires are avoided or the effects are minimized this negative side effect of prescribed burning can be canceled out in the end. Additionally, as prescribed burns are planned, (vulnerable) people can be removed from an area to avoid health complications from breathing in smoke. Lastly, the effectiveness of prescribed burning relies heavily on the continuation of the practice as frequent burns have the most positive impact on reducing future fires as Bardsley et al. (2019) mentioned. This does demand a commitment of resources from agencies involved which can be viewed as an issue with e.g. changes in political leadership with different views on the use of prescribed burning.

Fortunately, research has also found considerable benefits from prescribed burning aside from the reduction of future fire intensities making it a more widely appreciated practice. First of all, there is the potential for prescribed burning to benefit greenhouse gas concentrations reductions through reducing emissions from wildfires that otherwise would have been more severe (Vilén & Fernandes, 2011). Additionally, despite the negative side effects possible for certain species, prescribed burning activities can aid in the process of nutrient recycling which is very beneficial for plant growth post-fire and could make regeneration easier (Fanin & van der Werf, 2015). Lastly, a side effect of reducing the severity of future fires lessens the potential damage made to properties and threat to human lives, an essential aspect in the politics of fire management strategies (Altangerel & Kull, 2013; Clode & Elgar, 2014). Overall, prescribed burning has both benefits and drawbacks to it that need to be considered when implementing it. However, with the goal of reducing fuel to reduce fire severity it is usually considered successful given the fire weather conditions are not too irregular.

3 Methodology

3.1 Case Study Area

New South Wales has the highest population number of Australia's six states with over 8 million inhabitants (ABS, 2020) and holds many important sights of Australia such as Sydney and conservation areas like the Blue Mountains National Park in the hinterlands of the iconic Australian east coast. Furthermore, a large part of the state is also used for agricultural purposes. With New South Wales having an area of 80 million ha (SEED, 2011), the climate in the state can vary per region but due to the great dividing range, the west side of the mountain range is known to be very dry while the coasts enjoy more precipitation. In this dry area the vegetation is characterized by eucalypt forests that cover 77% of forest areas in Australia (ABARES, 2019). These iconic trees are able to survive in dry conditions and withstand and even thrive in bushfires which is why this area is an interesting case study for wildfire research. However, they also provide fuel for fires through their leaf and bark litter and, with certain subspecies of eucalypts, have more flammable bark than other species (Bond & Wilgen, 1996). Figure 1 below shows the land use in New South Wales in 2017.

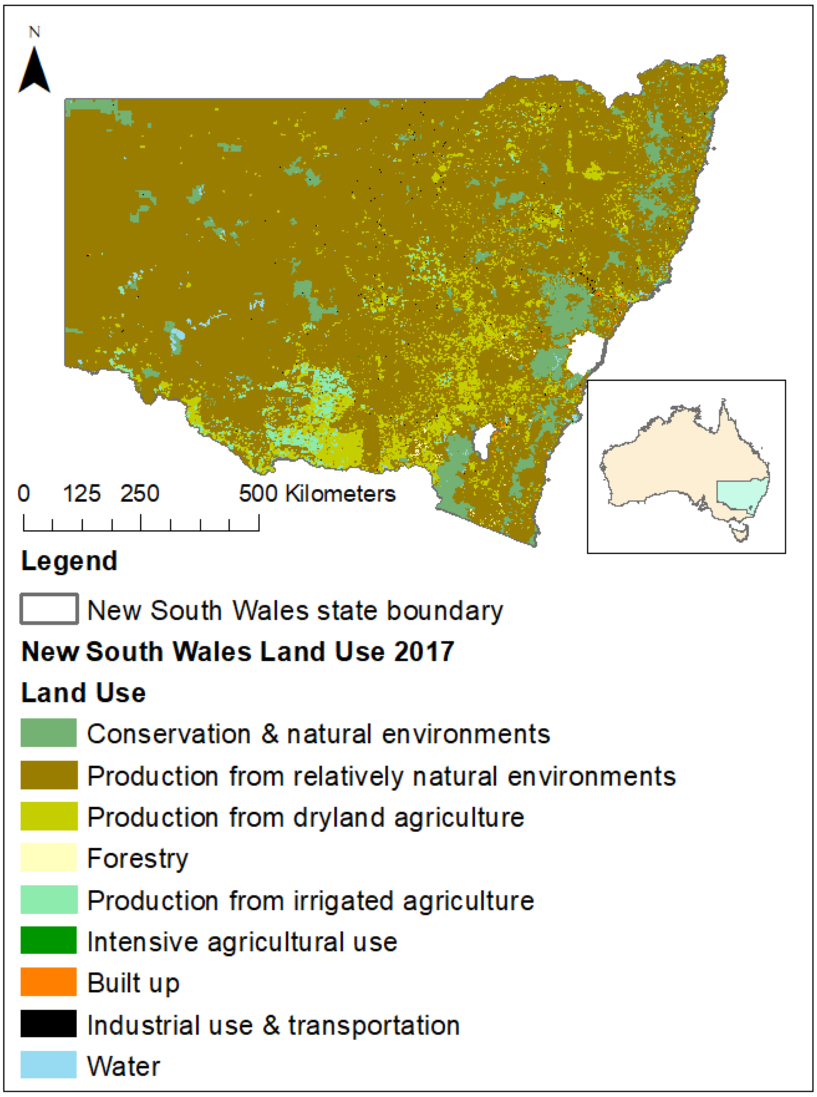

Figure 1. New South Wales Land Use 2017

Table 1 below shows the division of each land use class in the state. All the land use types have been divided into nine main classes: Conservation and natural environments, which for example includes wilderness areas and national parks, Production from relatively natural environments such as land used for grazing from native vegetation, Production from dryland agriculture, Production from irrigated agriculture, Production from forests, Intensive agricultural use, Industrial use and transportation, Built up and Water. Within these classes, there are more subdivisions of categories. These subdivisions can be seen in appendix 1.

	AREA IN HA	% OF TOTAL
(1) CONSERVATION AND NATURAL ENVIRONMENTS	10328766 Ha	16.32%
(2) PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS	45834227	72.42%
(3) PRODUCTION FROM DRYLAND AGRICULTURE	1819680	2.88%
(4) PRODUCTION FROM IRRIGATED AGRICULTURE	2098557	3.32%
(5) PRODUCTION FROM FORESTS	211886	0.33%
(6) INTENSIVE AGRICULTURAL USE	33209	0.05%
(7) INDUSTRIAL USE & TRANSPORTATION	372147	0.59%
(8) BUILT UP	778483	1.32%
(9) WATER	1814952	2.87%

Table 1. Division of land use in 2017

3.2 Data sources

For the case study, four main spatial datasets are used that were created by the Department of Planning, Industry and Environment of New South Wales using a combination of methods relying on Landsat and/or SPOT imagery and aerial photos. The first is the NSW Land use between 2000 and 2007 dataset which was created because of legislative and regulatory requirements to class land use practices and is at a scale of 1:50.000 (SEED, 2011a). The data was collected between 1999 and 2006 and last updated in 2011. According to the Data Quality Statement (DQS; SEED, 2011b), the accuracy of the data is ‘good’ and the overall quality was ranked between ‘fair’ and ‘good’. Secondly, the NSW land use of 2013 dataset which was created in accordance with the Local Land Services Act (SEED, 2017a). The reliability scale of this dataset is 1:10.000 or 1:25.000 depending on the original source from which the dataset was created. The DQS used five categories to rate the quality of the dataset (SEED, 2017b). First of all, the institutional environment, coherence and interpretability were ranked ‘Very good’, the accuracy was ‘excellent’ and the accessibility as ‘poor’. Thirdly, the NSW Land use 2017 dataset which was also created because of legislative and regulatory requirements and used to e.g. identify impacts on biodiversity (SEED, 2019a). This dataset has a reliability scale of 1:10.000. The DQS ranked the accuracy of the data as ‘excellent’ and the overall quality between ‘very good’ and ‘excellent’ (SEED, 2019b). Lastly, the NSW Fire history dataset which was created to e.g. estimate fire severity and is at a scale of 1:25.000 (SEED, 2020a). The DQS for this dataset ranked the accuracy of the data to be ‘fair’ and the quality is said to be between ‘fair’ and ‘good’ (SEED, 2020b). Figures 2 and 3 below show the wildfires that occurred in 2019/20 (fig. 2) and the prescribed burning activities between 2011 and 2020 (fig. 3). When analyzing both maps, it can be noted that many prescribed burning activities occur in the same region as where the wildfires happened.

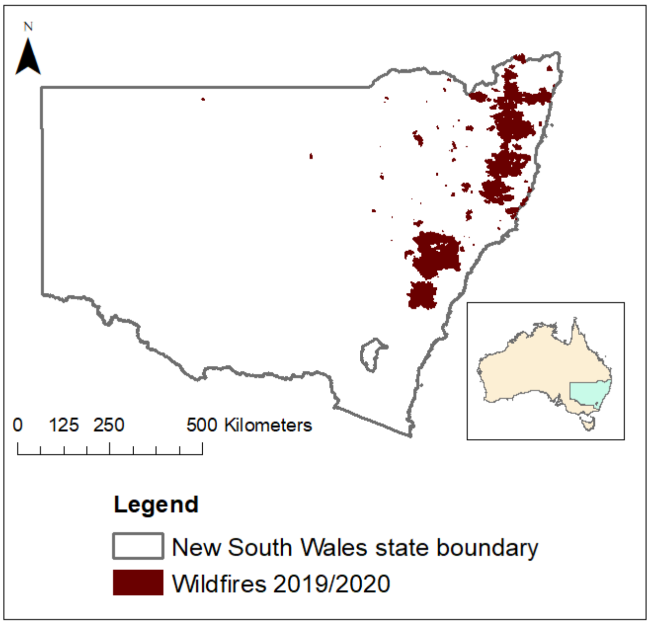

Figure 2. Wildfires in 2019/20 in New South Wales

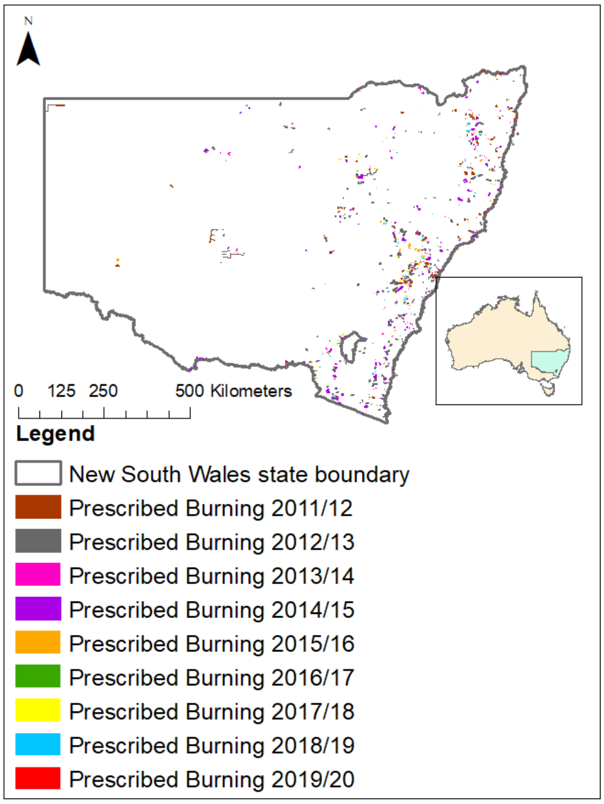

Figure 3. Prescribed burning between 2011 and 2020 in New South Wales

3.3 Spatial analysis

Each of the datasets were transformed to be in the 'GDA 1994' geographic coordinate system. In order to determine changes in land use between 2007 and 2017, the original vector files were reclassified into raster files based on the Australian land use and management classification. A slight alteration was made in the classification separating the intensive land uses into three individual categories: Intensive agriculture, Industrial & transport and Built up (see appendix 1 for the full reclassification). This alteration was made in order to better analyze influences of these specific types of land uses on wildfire occurrence as these are where people are most present and land is intensively used but in vastly different contexts.

In order to analyze the datasets together, a desktop GIS (ArcMap 10.6) was used. First of all, land use change was found following the model as shown in Figure 4. The final step in this model was the application of the raster calculator tool where the formula shown below (equation 1) was applied based on the theory used by Peña et al. (2007). With this formula a transition matrix was created using spreadsheet software. This matrix shows how land use changed between different years in New South Wales.

Equation 1: $Raster\ Calculator\ Land\ Use\ (LU)\ output = (10 * \ LU07) + (1 * LU13)$

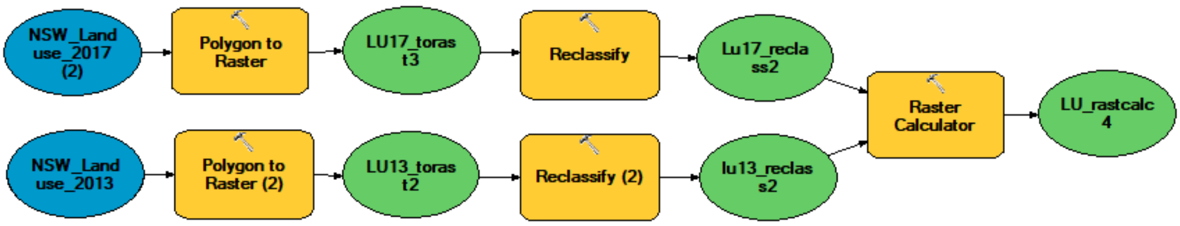

Figure 4. Methodological approach explaining steps taken in ArcMap to analyze land use change

The bushfire and prescribed burn dataset was used to create layers of the wildfires that occurred in the 2019-2020 bushfire season. Furthermore, the prescribed burns of the year and nine years preceding said bushfire seasons were made into separate layers for further analysis. Additionally, the 2017 land use types were also separated into single files. On each of these layers, the Euclidean distance tool was applied and alterations were made to the classification (see appendix 2). On each different land use, prescribed burns, and 2019/2020 bushfires layer the Sample tool was applied in order to further analyze the data. An example model of these actions can be seen in figure 5 below.

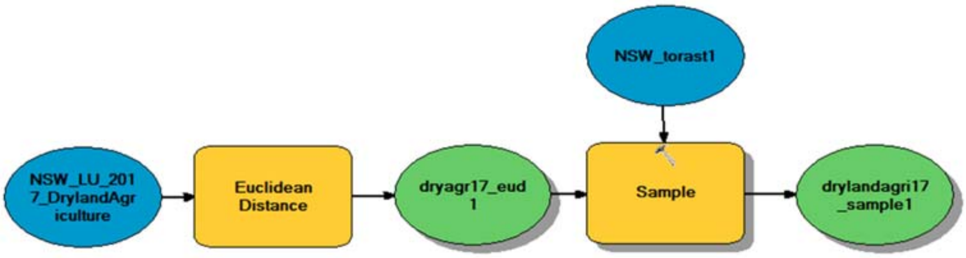

Figure 5. Methodological approach explaining steps taken in ArcMap to create datasets for further analysis

3.4 Statistical analysis

Using the findings from the review of existing literature on the influence of land use on wildfires, a statistical analysis was performed to determine the influences of e.g. the distance of built up areas to bushfires as argued by Levin, Tessler, Smith, & McAlpine (2016) on the occurrence of prescribed burnings in the years leading up to the researched bushfires season (Andersen et al., 2005). The analysis set up as a binary logistic regression analysis in which wildfire occurrence is specified as dependent variable. The prescribed burning and wildfire data is measured as nominal variables meaning if a fire (prescribed or not) occurred it is assigned 1, and when there was no fire it is assigned 0. The land use data is measured through continuous variables. The dependent variable in the analysis was the wildfires that occurred in 2019/2020.

The logistic regression was performed but excluded 30 outliers that were found based on a standard deviation of >2.5. Additionally, the final logistics regression used the forward LR stepwise method to select the independent variables. In this analysis, the initial model that is run does not contain any variables and each following new model contains a new variable. The final model contains all variables that provide the most statistically significant improvements.

4 Results

4.1 Descriptive statistics

Table 2 below show the descriptive statistics. This includes the minimum, maximum, mean and standard deviation of all variables in the analysis.

	MIN.	MAX.	MEAN	STD. DEVIATION
WILDFIRE 19/20	0	1	.19	.395
PRESCRIBED BURN 11/12	0	1	.00	.044
PRESCRIBED BURN 12/13	0	1	.00	.048
PRESCRIBED BURN 13/14	0	1	.00	.062
PRESCRIBED BURN 14/15	0	1	.00	.050
PRESCRIBED BURN 15/16	0	1	.00	.068
PRESCRIBED BURN 16/17	0	1	.00	.039
PRESCRIBED BURN 17/18	0	1	.00	.052
PRESCRIBED BURN 18/19	0	1	.00	.062
PRESCRIBED BURN 19/20	0	1	.00	.030
(1) CONSERVATION AND NATURAL ENVIRONMENTS	.00	.337	.037	.051
(2) PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS	.00	.404	.015	.041
(3) PRODUCTION FROM DRYLAND AGRICULTURE	.00	.531	.035	.059
(4) PRODUCTION FROM IRRIGATED AGRICULTURE	.00	1.071	.343	.254

(5) PRODUCTION FROM FORESTS	.00	.820	.220	.157
(6) INTENSIVE AGRICULTURAL USE	.00	.786	.269	.175
(7) INDUSTRIAL USE & TRANSPORTATION	.00	.418	.081	.072
(8) BUILT UP	.00	39117.035	8485.278	6969.678
(9) WATER	.00	.374	.048	.054

Table 2. Descriptive statistics

4.2 Regression outcomes

The logistics regression using the forward LR method was performed in 13 steps. In these steps, certain variables were included and others excluded. The variables that were excluded are: Prescribed burns in 2012/13, prescribed burns in 2014/15, prescribed burns in 2018/19, prescribed burns in 2019/20 and industrial use & transportation land use in 2017. The model explained .307 (Cox & Snell R square) and .490 (Nagelkerke R square) of the variants. Furthermore, the overall percentage of the final model in the regression analysis was 86.1%. The results of the logistics regression excluded the previously mentioned variables can be seen in table 3 below. There were three variables with a negative coefficient: the most influential variable Conservation & natural environments' as land use with a coefficient of -43.743, 'Production from relatively natural environments' with a coefficient of -5.061 and 'Production from forests' with a coefficient of -1.371. The remainder of the variables have positive coefficient. The most influential with positive scores are: 'Production from dryland agriculture' with a coefficient of 14.733, 'Water' with a coefficient of 7.624 and 'Intensive agricultural use' with a coefficient of 4.082. The variables that use prescribed burning to explain wildfire occurrence in 2019/20 do not have very influential coefficients compared to those of the land use variables as can be seen in table 3 below.

Independent variables	*B*	*Significance*
Prescribed burning 2011/12	1.976	.003
Prescribed burning 2013/14	1.197	.008
Prescribed burning 2015/16	1.730	.000
Prescribed burning 2016/17	1.958	.037
Prescribed burning 2017/18	1.236	.035
(1) Conservation & natural environments	-43.743	.000
(2) Production from relatively natural environments	-5.061	.008
(3) Production from dryland agriculture	14.733	.000
(4) Production from irrigated agriculture	1.219	.000
(5) Production from forests	-1.371	.000
(6) Intensive agricultural use	4.082	.000
(8) Built up	.000	.000
(9) Water	7.624	.000

Table 3. Logistics regression results

4.3 Land Use change results

The results for the land use change analysis are displayed in the matrices below for changes from 2007 to 2013 and 2013 to 2017 (see tables 4 and 5), the land use that is associated with each number can be seen in appendix 1. These were separated due to the long timespan between the initial land use dataset and the following two as the 2007 land use contains data collected from 1999 onwards. The results between 2007 and 2013 are very diverse with some land use classes staying mostly the same, such as ‘Production from relatively natural environments’ (2) and ‘Conservation and natural environments’ (1), while others underwent major changes such as ‘Industrial use and transportation’ and ‘Intensive agricultural use’. This can be due to a wide variety of reasons with a strong consideration for the huge time gap between the mapping of both datasets.

2007/2013	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1 (CONSERVATION & NATURAL ENVIRONMENTS)	76.57%	14.80%	4.41%	0.32%	2.16%	0.02%	0.43%	0.55%	0.74%
2 (PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS)	1.85%	94.34%	2.35%	0.37%	0.31%	0.00%	0.28%	0.06%	0.44%
3 (PRODUCTION FROM DRYLAND AGRICULTURE)	5.20%	36.18%	52.03%	2.74%	0.91%	0.08%	0.47%	1.13%	1.26%
4 (PRODUCTION FROM IRRIGATED AGRICULTURE)	0.70%	14.93%	17.71%	63.28%	0.20%	0.20%	0.10%	1.09%	1.79%
5 (PRODUCTION FROM FORESTS)	24.04%	5.58%	4.87%	0.24%	64.51%	0.00%	0.09%	0.43%	0.24%
6 (INTENSIVE AGRICULTURAL USE)	20.00%	20.00%	20.00%	13.33%	6.67%	6.67%	6.67%	6.67%	0.00%
7 (INDUSTRIAL USE AND TRANSPORTATION)	8.77%	37.26%	32.60%	4.11%	2.47%	0.55%	6.30%	6.03%	1.92%
8 (BUILT UP)	12.54%	22.26%	14.58%	6.27%	0.63%	0.47%	2.51%	36.68%	4.08%
9 (WATER)	12.14%	33.42%	20.89%	5.61%	0.78%	0.26%	0.65%	3.26%	22.98%

Table 4. Land use change matrix 2007-2013.

The changes between 2013 and 2017 are more subtle compared to those from 2007-2013. The exception here is found with class 5 or Production from forests which can be explained through the restructuring of general land use classes (see appendix 1). This class was originally divided over other forms of agricultural practices but for this study set as a separate class due to the difference in fuel availability from a forest compared to e.g. a cropping field or deforested grazed pasture. Of the remainder of the categories, the most substantial changes can be seen in 'Intensive agricultural use' (6), where changes to 'Production from dryland agriculture' (3) were seen, 'Conservation and natural environments' (1), where land was changed to 'Production from relatively natural environments' (2) and 'Built up' (8) where the most significant number of changes were to 'Production from relatively natural environments' (2).

2013/2017	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1 (CONSERVATION & NATURAL ENVIRONMENTS)	82.25%	15.83%	0.08%	0.01%	0.02%	0.00%	0.03%	0.08%	1.70%
2 (PRODUCTION FROM RELATIVELY NATURAL ENVIRONMENTS)	0.19%	96.18%	1.53%	0.04%	0.01%	0.00%	0.08%	0.17%	1.79%
3 (PRODUCTION FROM DRYLAND AGRICULTURE)	0.02%	1.14%	97.78%	0.75%	0.04%	0.02%	0.05%	0.17%	0.03%
4 (PRODUCTION FROM IRRIGATED AGRICULTURE)	0.00%	0.07%	1.05%	98.10%	0.00%	0.07%	0.00%	0.07%	0.63%
5 (PRODUCTION FROM FORESTS)	0.11%	90.47%	0.05%	0.00%	8.93%	0.00%	0.11%	0.00%	0.33%
6 (INTENSIVE AGRICULTURAL USE)	0.00%	0.00%	12.00%	4.00%	0.00%	80.00%	0.00%	4.00%	0.00%
7 (INDUSTRIAL USE AND TRANSPORTATION)	0.00%	8.26%	0.87%	0.00%	0.00%	0.00%	88.70%	0.87%	1.30%
8 (BUILT UP)	2.15%	8.01%	3.71%	0.00%	0.00%	0.20%	2.15%	83.59%	0.20%
9 (WATER)	0.31%	7.51%	1.25%	0.00%	0.00%	0.00%	0.16%	0.31%	90.45%

Table 5. Land use change matrix 2013-2017

5 Discussion

Spatial and statistical analyses were used to determine the influence of land-use practices on wildfire occurrence in the study area New South Wales. First of all, the prescribed burning in five years was found to be significant and therefore included in the analysis. These are the prescribed burning activities in 2011/12, 2013/14, 2015/16, 2016/17 and 2017/18. The beta coefficients for all of these independent variables are positive which means that with these prescribed burns taking place, there is a higher chance that wildfires would occur. As was mentioned in section 3.3.3, previous research has argued that prescribed burning has the potential to reduce the severity of future wildfires due to the reduction of fuel available as a result of the prescribed burn (Boer et al., 2009; Fernandes, 2015; Furlaud et al., 2018; Kobziar et al., 2015; Tolhurst & McCarthy, 2016; Vilén & Fernandes, 2011). The findings of this research cannot conclude much about reducing the severity as they only look at whether or not they are or are not more likely to occur. The findings can only comment on the likelihood of the wildfires occurring and as the coefficients are positive, this research found that wildfires are more likely to be 1, meaning they occurred. However, the coefficients are not as high as that of other independent variables making these not as influential in the whole process of wildfire occurrence. Furthermore, it must be acknowledged that prescribed burning activities are carried out in places where authorities have higher expectations of wildfire occurrence. Therefore, a positive coefficient is not unheard of. Overall, although the results seem to conflict with the general scientific consensus that prescribed burning should reduce the occurrence and severity of future fires, it has also been noted on multiple occasions that extreme wildfires can undermine this (Fernandes et al., 2020; Furlaud et al., 2018; Leone & Tedim, 2020). The 2019/20 wildfire season in Australia was considered to be very extreme with a huge amount of land burning and under very extreme conditions making the fires hard to manage. Furthermore, NSW was one of the worst affected states. This can explain the results of prescribed burning activities on the likelihood of wildfires occurring in 2019/20 but does not lead to an overall conclusion on the effectiveness of prescribed burning activities under ordinary circumstances. Moreover, the additional benefits of prescribed burning such as benefitting the nutrient cycling process (Fanin & van der Werf, 2015) are not considered in this analysis. Lastly, it is important to note that of the variables excluded from the final model, four out of five are prescribed burning variables from different years which can make one question the overall use of these variables in the analysis.

Secondly, the influence of land use on the occurrence of wildfires in 2019/20. The most influential land use is (1) Conservation & natural environments. It was found that the closer land is to conservation & natural environments, the higher the likelihood of wildfire occurrence becomes. This can be explained by the amount of fuel available in areas classified as conservation & natural environments as they are covered with vegetation and the accompanying litter. The higher likelihood of wildfire occurrence in conservation & natural environments opposes previous research as these are areas where people are usually scarce and many human pressures are removed from the equation while these were factors that were often found to be causes of wildfire ignition (Levin et al., 2016).

In addition to conservation & natural lands, production from relatively natural environments (2) had a similar influence on wildfire occurrence with a negative beta coefficient meaning the likelihood of wildfire occurrence increases when closer to this type of land. The lower score can be attributed to the slight decrease in available vegetation and litter when compared to conservation & natural environments as these lands are often used for cattle grazing (ABARES, 2016). Additionally, similar to the abovementioned land use (conservation & natural environments), there are usually little human pressures surrounding this type of land use which goes against existing literature that often state human presence to be a major cause of wildfire ignition leading to wildfires. Lastly, it is important to consider the type of vegetation present in both of these environments. In Australia, this means human presence can be considered to be less essential for wildfire ignition as certain species can contain very flammable oils (Levin et al., 2016) and bark (Bond & Wilgen, 1996) that make it so that ignition can occur more naturally.

Lastly, Production from forests also had a negative coefficient meaning that wildfire occurrence is more likely the closer one gets to this type of land, just like those above. This land use does not cover a large area of the state according to the 2017 Land Use data (SEED, 2020) and only accounts for a very small percentage of the total land coverage (see table 1 in section 3.1). Therefore, it is not the main focus of this research but overall similar reasoning can be found for the results regarding this land use as for the two previous land uses as these are non-intensive forms of production with significant amounts of vegetation.

The other forms of production were found to have the opposite effect on wildfire occurrence meaning that wildfire occurrence is less likely to happen when one is on or closer to these land use types. First of all, production from dryland agriculture (3) has, according to ACLUMP, mostly been cleared of native vegetation in order to make space for primary production such as cropping or horticulture without the use of irrigation (ABARES, 2016). Despite the lack of irrigation infrastructure in place which would arguably make the vegetation very dry, wildfires are less likely to occur on or closer to this land use type. However, these results are in line with the findings from Nunes et al. (2005) who said that cropped land will sometimes be avoided by wildfires as they favor more of the native vegetation. A similar reasoning can be used to explain the results found for production from irrigated agriculture (4) as this use also has a positive coefficient. However, the lower value of the coefficient shows a weaker correlation between this land use and wildfire occurrence.

Thirdly come land uses that are more intensive for example with regards to the amount of human interaction with the surrounding environment. First of all, in an area where land is used for intensive agricultural purposes (7) it was found that wildfires are more likely to occur the further away you get from this type of land use. This land use class has two main subdivisions; intensive animal agriculture and intensive cropping and while for the latter the same explanation can be used for the lower likelihood of wildfire occurrence as with production from dryland and irrigated agriculture (that wildfires do not favor crops as fuel), intensive animal agriculture has both vegetation and human presence which would arguably make it more prone for wildfires. However, as the case study area is incredibly large, and intensive agricultural use is the least prevalent in the area covering circa 0.05% of the state (see table 1 in section 3.1) these results cannot be considered as conclusive evidence on the influence of intensive agricultural use on wildfire occurrence.

Previous research does not go into great detail about wildfires on many different types of agricultural practices in the general division made in this analysis, however, the fragmentation caused by many different types of agricultural practices and spread of rural communities who tend to the lands can have a significant impact. This is therefore a topic that requires further research to draw more definitive conclusions as these lands are essential for maintaining the way of living currently upheld in Australia and many other countries in the world.

A second land use that is more human intensive is the built up area which has a neutral beta coefficient (.00). Although previous research has found that wildfires tend to ignite close to built up areas, the lack of vegetation and other fuels can explain the results found in this research. In addition to this, New South Wales is not very densely populated and has highly concentrated built up areas making this a difficult category to analyze the way it was done in this study. Further research is needed where, for example, specific areas are isolated within a state.

Finally the results for water are very much in line with the general understanding of wildfires and water presence as the relatively high valued beta coefficient shows that the further you get from a body of water, the higher the likelihood of wildfire occurrence becomes. However, as the land use data was collected a number of years ago, it is possible that certain bodies of water are not of similar proportions anymore especially considering the climatic variabilities that have struck Australia recently as 2019 saw one of the strongest positive IOD events ever recorded resulting in a severely drought struck New South Wales (Bureau of Meteorology, 2019; Bureau of Meteorology, 2020). Therefore changes within these results are still possible if more recent data had been available. Further research and new land use maps are needed in order to find the influences of reduced sizes of otherwise significant bodies of water on wildfire occurrence.

When looking at the land use changes that occurred between 2007 and 2013, some changes can be considered to have influenced the increased number of wildfires that occurred in the 2019/20 crisis such as the changes from a variety of land uses to either conservation & natural environments and/or production from relatively natural environments. These increased changes can be linked to the establishment of the Environmental Protection and Biodiversity Conservation Act of 1999 which lead to more land uses gaining a conservation status in Australia (AWE, 2020). Comparably, changes that occurred between 2013 and 2017 show the most noteworthy changes from a variety of land uses to production from relatively natural environments. Once again a use that is associated with higher wildfire occurrence. These changes together can be one of several explanations for the increase in wildfire occurrence in the 2019/20 wildfire season. The increase of conservation lands is of course important for the protection of endangered species, however, with the increased risk of wildfire occurrence additional measures must be taken in order to find a balance between species and fire protection beyond the current policies in existence such as the Environmental Planning and Assessment Act 1979 (NSW).

5.1 Limitations

There are several notable limitations concerning this study aside from those shortly mentioned above. First of all, several climatic variabilities were not incorporated in this research but have considerable effects on wildfire occurrence. Examples of these are El Niño Southern Oscillation (ENSO) which influences temperature and precipitation patterns in Australia with a focus on the south-eastern region (Lewis, Karoly, King, Perkins, & Donat, 2017) or the Indian Ocean Dipole (IOD) which in turn also can have a significant effect on precipitation patterns (Alexandra, 2012). This can not only influence wildfire occurrence through increased droughts but also by reducing the amount of prescribed burning activities that can be carried out due to the risk of fire spreading further than the dedicated area. Secondly, other landscape variables have not been included in this analysis such as soil type which can influence moisture content of the land or elevation which can influence precipitation patterns. Lastly, as has been suggested, the 2019/20 wildfire season was one of many extremes. It is important to acknowledge that results found for this season cannot be generalized for future seasons without further research into certain climatic effects. With that, more can be said about the possibility of extreme events like those seen in 2019/20 becoming more normalized.

6 Conclusion

Land use practices are one of the main considerations when attempting to determine the influence of wildfire occurrence. There are many uncertainties when it comes to the causes of wildfire occurrence throughout a landscape due to the complications added by climate variabilities but the landscape factor must be understood before these others can be further explored. This study looks at land use practices in New South Wales, such as the application of prescribed burning techniques and land cover such as type of agricultural use, to find the influence these components have on wildfire occurrence in the state. Existing literature found that prescribed burning can reduce the impacts of future wildfires and has a number of additional benefits. However, the ability to reduce the occurrence of wildfire is lessened when conditions are considered extreme and therefore no conclusive results were found based on the analysis of the 2019/20 wildfire season. The type of land that was found to be influential on wildfire occurrence according to the results of this study is that which is classed as or in close vicinity to native vegetation rich environments. Most notable were the influence of natural and semi natural environments such as ‘Conservation from natural environments’ and ‘Production from relatively natural environments’. This counters results from existing literature that argue for human presence as an important influencing factor in wildfire occurrence but as a built up lands are not very common in the case study area the lack of conclusive evidence was not unpredictable.

Future studies on the effect of land use practices on wildfire occurrence should focus on smaller research areas in order to avoid irregularities and incorporate climate variabilities and other additional variables such as soil type into their analysis based off of the framework created in this study. This will create a more comprehensive overview of the factors influencing wildfires to be more prepared for future disasters.

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9 Appendix

9.1 Appendix 1

table with reclassified land use classes for the GIS analysis

VALUE	2007 CLASSES	2013/2017 CLASSES
1	Conservation & natural environments • Nature conservation • Managed resource protection • Other minimal use	Conservation & natural environments • Nature conservation • Managed resource protection • Other minimal use
2	Production from relatively natural environments • Grazing native vegetation	Production from relatively natural environments • Grazing native vegetation • Production native forests
3	Production from dryland agriculture • Grazing modified pastures • Cropping • Perennial horticulture • Seasonal horticulture • Land in transition	Production from dryland agriculture • Grazing modified pastures • Cropping • Perennial horticulture • Seasonal horticulture • Land in transition
4	Production from irrigated agriculture • Grazing irrigated modified pastures • Irrigated cropping • Irrigated perennial horticulture • Irrigated seasonal horticulture	Production from irrigated agriculture • Grazing irrigated modified pastures • Irrigated cropping • Irrigated perennial horticulture • Irrigated seasonal horticulture • Irrigated land in transition
5	Production from forests • Plantation forests • Irrigated plantation forests • Production forestry	Production from forests • Plantation forests • Irrigated plantation forests
6	Intensive agricultural use • Intensive horticulture • Intensive animal husbandry	Intensive agricultural use • Intensive horticulture • Intensive animal production
7	Industrial use & transportation • Manufacturing and industrial • Utilities • Transport & communication • Mining • Waste treatment and disposal	Industrial use & transportation • Manufacturing and industrial • Utilities • Transport & communication • Mining • Waste treatment and disposal
8	Built up • Residential and farm infrastructure • Services	Built up • Residential and farm infrastructure • Services
9	Water • Lake	Water • Lake

	• reservoir/dam • River • Channel/Aqueduct • Marsh/Wetland • Estuary/Coastal water	• reservoir/dam • River • Channel/Aqueduct • Marsh/Wetland • Estuary/Coastal water

9.2 Appendix 2

Classification break percentages of land use datasets with Euclidean distance

Land use class	Break values (8 classes)
Conservation & natural environments – 2017	1% - 2.5% - 5% - 10% - 20% - 35% - 60% - 100%
Production from relatively natural environments – 2017	1% - 2.5% - 5% - 10% - 20% - 35% - 60% - 100%
Production from dryland agriculture – 2017	1% - 2.5% - 5% - 10% - 20% - 35% - 60% - 100%
Production from irrigated agriculture – 2017	1% - 2.5% - 5% - 10% - 20% - 35% - 60% - 100%
Forestry – 2017	1% - 2.5% - 5% - 10% - 20% - 35% - 60% - 100%
Intensive agricultural use – 2017	2.5% - 5% - 10% - 20% - 35% - 55% - 75% - 100%
Industrial use & transportation – 2017	1% - 2.5% - 5% - 10% - 20% - 35% - 60% - 100%
Built up – 2017	1% - 2.5% - 5% - 10% - 20% - 35% - 60% - 100%
Water – 2017	1% - 2.5% - 5% - 10% - 20% - 35% - 60% - 100%

9.3 Appendix 3

List of abbreviations

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ACLUMP	Australian Collaborative Land Use and Management Program
BOM	Bureau of Meteorology
EPBC	Environmental Protection and Biodiversity Conservation

CTH	Commonwealth
DQS	Data Quality Statement
ENSO	El Niño Southern Oscillation
GDA	Geocentric Datum of Australia
GIS	Geographic Information Systems
IOD	Indian Ocean Dipole
IPA	Indigenous Protected Area
NRS	National Reserve System
NSW	New South Wales
SEED	Sharing and Enabling Environmental Data
SPOT	Satellite Pour l'Observation de la Terre (translation)
	Satellite for Observation of Earth (translation)