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Evaluating Potential Effects of 2019 Australian Bushfires on Animal Species, Protected Land, and Land Cover

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Abstract

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Keywords

GIS, remote sensing, Australia, wildfire, MODIS

Disciplines

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Comments

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The 2019-2020 Australian bushfire event had exceptionally dry, hot conditions as well as high potential impacts on the country's wildlife and natural resources. The purpose of the study was to analyze the potential impacts of the 2019 Australian bushfire event on animal species, protected land, and varied land cover types. The research question of this project is: how does the location of the Australian Bushfires of 2020 potentially impact animal species, protected land and national parks, as well as different land covers? Raster calculator was used to combine and classify layers from the MODIS Burned Area Product of burned (1) and unburned (0) areas from September through December of 2019. The combined burned layer was overlaid upon the Australia - Species of National Environmental Significance Database, Collaborative Australia Protected Areas Database, and MODIS Land Cover Type Yearly Global layer to identify burned animal habitats, protected areas, and land cover types. Many animal species' habits burned in areas like eastern Australian forests, grasslands, and savannas but fire refugia may have provided protection for Blue Mountain Water Skinks and Southern Corroboree Frogs. Indigenous protected land had high burn percentages and were found in larger central regions while national parks burned less in comparison and were dispersed in smaller patches throughout the nation. Evergreen broadleaf forests, woody savannas, and non-woody savannas were the land cover types that burned the most, respectively. Bushfires can cause loss of habitat, decrease in biodiversity, and reduction in resources, however, these fires can be better regulated to help prevent future cases of similar damage in the future.

INTRODUCTION

Fires of 2019-2020

Australia is the driest continent in the world and is the hottest in terms of duration and intensity of heat. The combination of dryness, heat, and certain types of vegetation (e.g. eucalyptus species found in savannas) escalate the frequency and severity of bushfires (Athukorala et al. 2019; Cook et al. 2019). Fire frequencies in Australia have had a dramatic increase of 40% over the past 5 years with grasslands and forests as the leading vegetation types that are most likely to help carry out wildfires (Aryal et al. 2016). This study focused on the Australian Bushfires of 2019-2020 that devastated the country since the wildfire began in early September 2019 through February 15th, 2020 (Australian Government Geoscience Australia 2020; Center for Disaster Philanthropy. 2020; Center for Disaster Philanthropy 2020; Cook et al. 2019). During this event the temperature exceeded 40 °C (104 °F) with peaks of 48/50 °C (118/122 °F) in December 2019 and January 2020 (World Climate Guide 2020). An incredulous, globally unprecedented 21% of Australia's forested area burned during the 2019-2020 fire season alone (Rott 2020)

Climate change exacerbates wildfire intensity, decreased precipitation, increased temperatures, habitat loss, and a lengthened fire season (Clarke 2015; Yeung 2020). The bushfire event demonstrates how the climatic patterns Australia faced deviated from past trends (Fernandez-Carillo et al. 2019; Yeung 2020). As a result of bushfires, Australia's animal species (Adamo et al. 2020; Haywood et al. 2020), Indigenous land (Adamo et al. 2020; Arcese et al. 2019; (Haywood et al. 2020), and human settlements (Agee et al. 2020; Athukorola et al. 2019) were placed at high potential risks and detrimental impacts. In regard to animal species, many animals were exposed and made vulnerable to the bushfire that live within forests, grasslands, rainforests, and shrubland land cover types in Australia. The 2019-2020 Australia bushfire crisis

has led to habitat loss and killings of large numbers of mammals, reptiles, birds and other species with estimates of more than a billion deaths around the country (Cox 2020).

Australia has a long history of devastating wildfire incidents - cycles of fire, rain and recovery are more than common to Australia. Australia is considered a “fire continent” due to the country's frequency of fires (Rott 2020). However, adaptive strategies such as growing epicormic shoots and lignotubers alongside fire resistant and fire-triggered seeds help tree species build resilience to fires (White 1986). Even though many Australian forests are uniquely adapted to fire, climate change is causing more severe fires to occur more often (Rott 2020). One of the most infamous wildfires of Australian history was The Black Friday Bushfire which is remembered as one of the most tragic natural disasters on an international scale (Burt 2013). The fire occurred on January 13th, 1939 and scorched 4.5-5 million acres of land, causing damage of tens of millions of dollars (Chuvieco et al. 2020). The Black Friday Bushfire occurred outside of Australia’s usual fire season and dry season (between April and September) which made it all the more unexpected (Fernandez-Carillo et al.).

Impacts of Bushfires

Bushfires have extremely high heat outputs that can quickly burn forests. These fires can smoulder for days on end and fires in the crown of tree canopies can move at extremely rapid rates, putting countless numbers of plant and animal species in danger (Australian Government Geoscience Australia 2020). However, certain animals are resilient to these fires or are able to hide in refugia like wombats who can burrow within trees, grasslands, and eucalyptus forests during bushfires (British Broadcasting Corporation 2019).

A vast amount of Indigenous land, government-protected traditional areas to promote biodiversity and cultural resource conservation, was found within drier land cover types such as grasslands that are more prone to fires. Traditional Aboriginal Australian practice of cultural burning can oftentimes be used to minimize the risk of larger fires during drier times of the year

through small and controlled burnings to clear potential ignition of debris, undergrowth, and certain grasses (Wegman 2002). Nonetheless, wildfires still cause major complications for the Indigenous communities that live within these protected land regions because they lead to the destruction of homes, loss of resources, and injured community members (National Indigenous Australians Agency 2019; Wegman 2002). National parks and Indigenous land are placed at risk to bushfires because many land cover types have fire-prone qualities such as open land that can promote wind speed, ambient temperature, and sources of vegetation ignition (Australian Government Geoscience Australia 2020). In turn, this can lead to damage and severe destruction of different land covers that range from forests like those found in southeastern Australia to developed, urban areas (Agee et al. 2012).

While there is an understanding of leading causes and impacts of past Australian bushfires, to date no study has evaluated the 2019-2020 Australian bushfire event and its potential effect on animal species, protected land, and land cover types. Knowledge of potential impacts of the 2019-2020 bushfires can help scientists and park rangers prevent future wildfires of the same prolonged length and monstrous potential harm in the future, protecting Australian ecosystems and organisms. The research question of this project is as follows: how does the location of the Australian Bushfires of 2020 potentially impact animal species, Indigenous land and national parks, and different land covers?

METHODS

Identifying Burned Areas

The MODIS Burned Area Product (MCD64AQ v006) and MODIS Land Cover Type Yearly Global 500m (MCD12Q1 v006) (Table 1) are layers that portray burned areas and land use. The MODIS Burned Area Product data layer displays where the 2019 Australian bushfires occurred on a monthly basis from September 1st - December 31st, 2019. 2020 data through the fire's end date of February 15th was excluded from the analysis because it was not yet available

from online resources. The MODIS Burned Area Product and MODIS Land Cover Type Yearly Global 500m were downloaded from Google Earth Engine and selected for the use of this research because the layers exemplify the physical extent of the Australian bushfires as well as different land cover areas that may have potentially been impacted by the fire. Raster calculator was used to combine the monthly burned locations rasters to create a new raster with burned (1) and unburned (0) areas for the entire duration of study that could be used in comparison of animal habits, land cover, as well as Indigenous land and national parks.

Assessing Potential Impact on Endangered Species

The MODIS Burned Area Product was overlaid upon the Australia - Species of National Environmental Significance (SNES) layer (Table 1) in order to see where the bushfires came in contact with various animal habitats. The SNES layer was chosen for this study because it shows the location of Australian animal species. Six animal species were selected to be studied because they were amongst the top ten species that had the largest population declines due to the Australian bushfires (The Guardian 2020; Pys 2020; Rice 2020). These animal species were analyzed using the animal species layer which consisted of the following: koalas, brush-tailed rock-wallabies, glossy black cockatoos, Blue Mountains water skinks, southern corroboree frogs, and western ground parrots. Two species of mammals, birds, and reptiles of vulnerable, endangered, and critically endangered status were selected to represent a wide breadth of animal classifications and to portray areas where they are certain and likely to inhabit. After shapefiles of each species were separately created, raster clip was used to clip the reclassified burned monthly combined layer by each individual animal layer before creating a new layer in order to analyze areas of overlap and thus potential fire impact. The new layers were used to calculate the amount of potentially burned and unburned areas within each species' habitats.

Assessing Potential Impact on Landcover

The Zonal Statistics tool was used on the MODIS Burned Area Product and the MODIS land cover layer (Table 1) to see how land cover types potentially burned from September-December of 2019. The MODIS land cover layer shows the location and area of various land cover types, which is why it was chosen to study the potential effect of bushfires on land cover. Raster clip was then used to clip the reclassified burned monthly combined layer by the MODIS land cover layer to examine the amount of burned land within all 17 types.

Assessing Potential Impact on Indigenous Lands and National Parks

After the Zonal Statistics tool was used on the MODIS Burned Area Product and the protected areas layer, the following area types were selected to be studied from the Collaborative Australia Protected Areas Database (CAPAD) data layer: Indigenous Protected Area and National Park which consisted of three subtypes of parks (Aborginial, Commonwealth, Scientific). Indigenous Protected Area was used in this research because it shows locations where Australian native tribes live. Aboriginal, commonwealth, and scientific national parks were selected to represent national parks because these three categories include a wide breadth of various types of Australian parks suited for different social and environmental interests.

RESULTS

The six researched animal species were mainly found in forest, grassland, and savannas while Blue Mountain Water Skinks experienced the most amount of burned habitat (Table 2; Figure 2; Figure 4). Glossy black cockatoos and southern corroboree frogs had the least percentage of burned habitat, 2.51% (Table 2). This means that glossy black cockatoos had the lowest potential impact of bushfires. In contrast, Blue Mountain water skinks had the highest burned habitat area percentage of 78.81%, meaning that they had the highest potential impact of bushfires. These skinks were found in evergreen broadleaf forests and near woody savannas

(Figure 4). Koalas were found in broadleaf evergreen forests interlaced between shrubland, woody savannas, and cropland (Figure 4). Brush tailed rock wallaby habitats were in evergreen broadleaf/needleleaf forests, closed shrubland, and woody savannas (Figure 4). Western ground parrots were found to live in grasslands, woody savannas, and primarily closed shrubland (Figure 4). Glossy black-cockatoos mainly reside in non-woody savannas, deciduous broadleaf forests, evergreen needleleaf forests, closed savannas, and grasslands (Figure 4). Southern corroboree frogs were found to live in evergreen needleleaf forests, closed shrublands, and grasslands (Figure 4).

Indigenous protected areas burned far more than any of the individual subtypes of national parks and most Indigenous protected land burned heavily in open shrubland (Table 3; Figure 1, Figure 3; Figure 4). Indigenous protected areas had the highest percentage of burned areas, 26.89%, indicating high potential fire impacts. Scientific national parks had the least amount of burned area, 3.47%, indicating low potential fire impacts (Table 3). Evergreen broadleaf forests had 10.15% burned area impact which was the greatest percentage of all studied land cover types. Evergreen forests and natural vegetation mosaics had 0% burned areas which shows low amounts of fire impact. Developed areas had low potential fire impact of 0.06% burned areas which was the smallest non-zero percentage of burned area (Table 4).

Open shrubland and grasslands were the most abundant land cover types that were also within the top 5 studied land cover types that burned the most (Table 4; Figure 1; Figure 4). Many northern and eastern coastal areas in Australia tended to burn in close patches within evergreen broadleaf forests, savannas, and grasslands (Figure 1; Figure 2). There were also many slightly more separated areas within the middle part of the continent that burned where wooden shrubland and grasslands exist. These areas tended to overlap with Indigenous protected land (Figure 1; Figure 2; Figure 3). Burned koala habitats were found near the eastern and southeastern parts of Australia while brush-tailed rock-wallabies had burned habitats near the coastal regions of these same areas. The other species of Blue Mountains water skinks,

western ground parrots, southern corroboree frogs, and glossy black cockatoos had comparatively smaller amounts of burned habitat areas that were scattered along the western, southern, and eastern parts of the continent (Figure 2). Burned Indigenous protected land was mainly focused in connected areas near the center of Australia and smaller isolated areas near the northern coast. Meanwhile, national parks had smaller, more isolated sections of burned land that were dispersed mainly along central regions of Australia in addition to the east, southeast, and northern coasts (Figure 2). Australia is primarily composed of open shrubland areas with expansive regions of grasslands near the northern and southeastern regions closer to the coast (Table 4; Figure 3). Deciduous broadleaf forests had the most amount of burned area (10.15%) while there were land cover types like evergreen needleleaf forests, natural vegetation mosaics, and water bodies with an average 0.00% of burned area (Table 4).

DISCUSSION

Potential Fire Impact on Endangered Species

Australian wildfires have high potential impacts on the researched species of koalas, brush-tailed rock-wallabies, Blue Mountains water skinks, southern corroboree frogs, glossy black-cockatoos, and southern ground parrots. Potential adverse impacts of the wildfires on wildlife include loss of habitat, decreased biodiversity, and reduced resources. However, reptiles and birds like Blue Mountains water skinks, southern corroboree frogs, glossy black-cockatoos, and southern ground parrots may have heightened chances of survival from these events due to their ability to hide in fire-safe burrows as well as cooler, moist environmental conditions (British Broadcasting Corporation 2019; Gorissen et al. 2018).

Blue Mountains water skinks had the most amount of burned habitat area which led to more isolated habitat fragments and less burrowing areas. However, both skinks and their swamp habitats can rebound under an appropriate time frame and under moderate fire conditions of intensity and frequency (Table 2; Table 4; Figure 4; Cox 2020). Blue Mountains

water skinks had 78.8% of burned habitat because the majority of their habitat was found within the same areas as eucalyptus trees habitats that burned (Table 2; Table 4; Figure 1; Figure 4). Intense fires put the Blue Mountains water skinks population in peril because they are restricted to isolated, heavily vegetated and waterlogged peat swamps in montaine southeastern Australia (Figure 2). Because skink habitat burned, these habitats may have lost plants and understory that skinks are dependent upon for survival. Skinks themselves can persist in burnt swamps by hiding beneath logs and in burrows, although they are put in a state of stress during the average 1 year fire-recovery period the swamp needs to regenerate itself (Cox 2020; Gorissen et al. 2018).

Koalas had the second largest area of burned habitat to Blue Mountains water skinks which consequently lead to decreased habitats of eucalyptus forests, decreased food source, and decreased population (Table 2; Table 4; Figure 1; Figure 4; Arcese et al. 2019). It is logical that a very high percentage, 50%, of koala habitat was burned because these habitats are plentiful in eucalyptus trees found in deciduous broadleaf forests where koalas live (Table 2; Table 4; Figure 1; Figure 4). Eucalyptus leaves produce a volatile combustible oil that makes the trees highly flammable and therefore makes it likely that a forest fire would easily burn through the crowns of the tall eucalypt forests in the eastern forests of Australia (Arcese et al. 2019). A study by Fernandez-Carillo et al. 2019 analyzed fire impacts and post-fire tree survival in eucalyptus forests and found that these forests tend to have drier conditions that are more prone to bushfires (Fernandez-Carillo et al. 2019). Eucalyptus trees are also covered with vast amounts of litter with high amounts of phenolics, chemical compounds that prevent fungi from breaking down detritus. The forests within koala habitats were full of wood fuel like dry vegetation that helps to provoke fires which aided in the burn (Figure 4). This in combination to Australia's standard dryness and heat create highly suitable conditions for the bushfire to take place, decreasing the number of eucalyptus trees which serve as koalas' habitats and primary food source (Arcese et al .2019; Athukorola et al. 2019; Cox 2020).

The bushfire event led to an abundant amount of potentially lost habitat for brush tailed rock wallabies which lead to a decreased population size, shelter, and food resources Table 2; Table 4; Figure 1; Figure 4; Athukorola et al. 2019). Brush-tailed rock-wallabies faced a higher percentage of 14.33% burned habitat (Table 2; Table 4; Figure 4). The species faced the percentage of burned and lost habitat because they have a larger area of habitat which raises the probability of being within bushfire zones, particularly because brush tailed rock wallabies live near flammable eucalypt forests (Figure 4; Arcese et al. 2019; Athukorola et al. 2019).

The moist and cooler environment of western ground parrots helped to protect the species and make the habitat more resistant to the bushfire event than other drier areas (Table 4; Figure 1; Figure 4; Rice 2020). The western ground parrot also has extremely limited habitat and can only be found in three isolated patches of land (Table 4; Figure 4; Rice 2020). Although wildfires are a major threat to the western ground parrot, their coastal floodplain habitats provide refugia and drought prevention due to the cooler conditions and more mesic microclimates than adjacent areas - this is why 3.83% of the species' habitat burned (Table 2; Figure 4; Clark et al. 2015). These more moist environments help keep the western ground parrot habitats from burning although the fires still cause scales of imminent danger and loss of resources for the parrots (Aide et al. 2015; Clark et al. 2015). Another study by Edwards et al. 2013 also found that coastal areas of Australia are far less prone to fires due to the high moisture content in the atmosphere (Edwards et al. 2013).

Even though glossy black-cockatoos primarily live in areas with dense vegetation, these areas are mainly developed and therefore did not burn very much (Table 2, Table 4; Figure 1; Figure 4; The Guardian 2020. Glossy black-cockatoos' main threat is habitat lost from deforestation of casuarina trees in woodland areas and the loss of mature eucalyptus for nest hallows. However, in the event of fire the cockatoos are able to fly away from the danger in a relatively short amount of time. (Rice 2020). Even though the glossy black-cockatoo's habitat near the southeastern coast of Australia came in contact with the bushfire, only 2.51% of the

habitat was burned because the majority of the land had already been disturbed by deforestation (Table 2; Rice 2020).

Southern Corroboree frogs had a smaller amount of burned land and similar habitat loss scenarios as the Blue Mountains water skins, although wildfires are not the species' greatest concern (Table 4; Figure 2; Figure 1; Figure 4; Parliament of Australia 2019). Southern corroboree frogs are also put in a state of biological stress although not quite as much. Similar to skinks also have a limited distribution - the frogs are restricted to southeastern sub-alpine areas which heightens the degree of impact from wildfires if the frog habitats are disturbed (Figure 2). Even though southern corroboree frogs live in similar habitats to skinks, most of the frogs' loss of habitat derives from erosion and pollution of waterways of swampy forest and grassland areas that they live in (Table 4; Figure 2; Figure 4; Parliament of Australia 2019) This is why a smaller amount 2.51% of habitat burned for the frog species (Table 2). The added loss and disturbance of habitat from bushfires leads to delayed breeding season and increased risk to the Chytrid fungus due to increasingly restrained habitats (Pys. 2020).

Potential Impact on Indigenous Lands and National Parks

Over a fourth of Indigenous land in arid locations potentially burned, although this percentage could have been significantly higher without regular fire regulation (Table 4; Figure 1; Figure 3; Figure 4. Wegman 2002). The majority of Indigenous protected land tended to be in remote, desert locations like open shrubland, grasslands, and non-woody savannas (Table 4; Figure 3; Figure 4). These regions are very dry and arid which is why they provided ideal conditions for bushfires to have burned through 26.89% of the land (Table 3; Arcese et al. 2019). However, the percentage of burned Indigenous protected area would even higher if Indigenous cultural burning was not regularly practiced in those areas because there would be more flagrant vegetation and debris that would further escalate a wildfire (Wegman 2002).

Collectively, the studied types of national parks (scientific, Aboriginal, commonwealth) burned more than Indigenous protected areas and led to decreased animal habitat (Table 2; Table 3; Figure 1; Bleicher et al. 2020). Unlike Indigenous protected land, national park areas are smaller and more evenly dispersed within Australia. In total, 56.49% of all studied national parks (scientific, Aboriginal, and Commonwealth) burned which is greater than the percentage of Indigenous land because national parks cover a greater amount of territory (Table 3; Figure 1; Figure 3). National parks can be found in a plethora of different land cover types such as evergreen broadleaf forests, open shrubland, barren land, savannas, and grasslands which provide highly flammable eucalyptus trees and undergrowth to promote bushfires (Table 4; Figure 3, Figure 4; Adamo et al. 2013). The burning of national parks results in animal species that are put at increased risk from other factors like predatory exposure that would put the population in jeopardy. This was seen in a study by Bleicher et al. 2020 in which fire disturbances drove mammals like brush-tailed rock-wallabies out of hiding as they attempted to escape bushfires and became exposed to their natural predator, the red foxes. This led to a decrease in the population of brush-tailed wallabies (Adamo et al. 2013; Bleicher et al. 2020).

Assessing Potential Impact on Landcover

Dense forests and dry, arid savannas and grasslands tended to burn the most, leading to less habitats for the studied animal species (Table 4; Figure 1; Figure 3; Figure 5). Deciduous broadleaf forests had 10.15% burned area which is noticeably more any other land cover type (Table 4; Figure 4). Savannas and grasslands are dry and arid areas which is why it is easy for them to burn (Figure 5). Natural vegetation mosaics, small-scale cultivation primarily composed of natural tree, shrub, and herbaceous vegetation that did not burn on average because there are less heavily dense forests that would provide highly flammable sources that would lead to intense bushfires (Edwards et al. 2013). Developed areas also had a very low percentage of burned area, 0.06%, because most developed areas in Australia are cities with many impervious

surfaces made from materials like concrete, asphalt, brick, and stone instead of natural vegetation that is far more likely to burn (Athukorola et al. 2019).

Limitations

Limitations to this study include the fact that 4 months of data from 2019 (September through December) were used out of the total approximate 5.5 months that the bushfire lasted (which includes about 1.5 months from January through February 15th, 2020) (Australian Government Geoscience Australia 2020). This was due to a lack of available data at the time the research was initially conducted in September of 2019. Another limitation was that each 500 m^2 pixel was classified as (un)burned based on an algorithm that analyzed rapid changes in daily surface reflectance dynamics to approximate the existence and spatial extent of fires (NASA Goddard Space Flight Center 2020). However, utilizing boolean logic leaves room for error because not every part of that identified pixel may have burned even if it was categorized as so. Aside from that, it is not absolutely known whether the burned habitat suffered negative consequences like loss of habitat that caused the distress of animal species. This study focused on the potential impacts of the Australian bushfire event, although the impacts are not confirmed to have occurred with full certainty.

Based on the results of this research, it would be interesting to examine the conditions and behavior of tree species such as the eucalyptus tree that heavily burned in high potentially impacted areas like in southeastern Australian broadleaf forests. This analysis could be used to determine if the trees have responded to the intense bushfire through new adaptive behaviors much like they have in the past. Another potential future study would be to see how intense wildfires have become specifically in Indigenous protected areas over the course of the past 50 years. This event could be studied in order to see how climate change may have impacted the severity of fires in one of Australia's driest and arid areas.

CONCLUSION

The Australian bushfires that began in 2019 led to a plethora of potential effects on animal species, Indigenous land and national parks, as well as various land cover types. Plausible adverse impacts of the wildfires include loss of habitat, decrease in biodiversity, and reduction in resources. However, specialized animal characteristics and the ability for certain land covers to recover over time can help mitigate the damage of wildfires. Wildfires can also pose major risks to Australian animal species like koalas alongside varied land cover types, especially arid grassland Indigenous areas. However, it is also very possible that certain areas and species in Australia were able to recover relatively quickly in response to the wildfires due to fire refugia. Although certain Australian regions like the southeastern broadleaf forests are susceptible to bushfires, the humidity of coastal areas like those within the habitat of western ground parrots can help combat the potential negative impact of bushfires. It is important to draw attention to conservation efforts and forest restoration programs in order to help regulate and prevent future bushfires of similar scale as the 2019-2020 Australian wildfires.

Table 1. Data sources

Name	Who Created	Time Valid For	Description	Link
MODIS Burned Area Product (MCD64AQ v006)	NASA	2019	Monthly, global gridded 500 meter product with per-pixel burned-area and quality information. Includes: Burn Fate, Burn Data Uncertainty, Quality Assurance, and First Day and Last Day of reliable change detection.	https://lpdaac.usgs.gov/products/mcd64a1v006/
MODIS Land Cover Type Yearly Global 500m (MCD12Q1 v006)	NASA	2018	Stage 2 data - global land cover types at yearly intervals (2001-2019) derived from six different classification schemes: Layers for Land Cover Type 1-5, Land Cover Property 1-3, Land Cover Property Assessment 1-3, Land Cover Quality Control (QC), and a Land Water Mask. Includes data of developed areas.	https://lpdaac.usgs.gov/products/mcd12q1v006/ (info) https://catalog.data.gov/dataset/modis-terraaqua-land-cover-type-yearly-l3-global-500m-sin-grid-v006/resource/75a1012a-7c8c-4d04-8645-87ab69725920?inner_span=True (updated 2019)
Collaborative Australia Protected Areas Database (CAPAD)	Australian Government Department of Agriculture, Water and the Environment	018	Spatial and textual information about government, Indigenous and privately protected areas for Australia, in both the marine and terrestrial environments	https://www.environment.gov.au/land/nrs/science/capad
Australia - Species of National Environmental Significance (SNES) Database	Australian Government Department of Agriculture, Water and the Environment	2019	Database of animal and plant Species of National Environmental Significance stores maps and point distribution information about Species of National Environmental Significance as listed in the Environment Protection and Biodiversity Conservation (EPBC) Act 1999	http://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B337B05B6-254E-47AD-A701-C55D9A0435EA%7D

Table 2. Burned area of animal species habitats

Animal Species	Burned Area (km^2)	Total Area (km^2)	Burned Area (%)
Blue Mountain Water Skink	109.875	139.43	78.81
Koalas	4,291.7	8,583.4	50.00
Brush-Tailed Rock-Wallaby	3,039.43	21,209.98	14.33
Western Ground Parrot	28.43	742.03	3.83
Glossy Black Cockatoo	17.85	710.3	2.51
Southern Corroboree Frog	2.15	85.83	2.51

Table 3. Burned area of Indigenous land and national parks

Area Type	Burned Area (km^2)	Total Area (km^2)	Burned Area (%)
Indigenous Protected Area	1,804.78	67,108.53	26.89
National Park (Commonwealth)	257.65	2,061.88	12.5
National Park (Aboriginal)	146.98	2,136.28	6.87
National Park	2,051.73	30,357.6	6.76
National Park (Scientific)	0.2	52.85	3.47

Table 4. Land cover burned area

Land Cover	Value	Burned Area (km^2)	Total Area (km^2)	Burned Area (%)
Evergreen broadleaf forest	2	2627.53	25,879.83	10.15
Woody savannas	8	899.75	13,712.83	6.56
Non-woody savannas	9	3,223.73	52,982.95	6.08
Evergreen needleleaf forest	1	208.55	5,158.6	4.04
Grasslands	10	7,713.68	197,731.63	3.90
Mixed forest	5	16.13	683.98	2.36
Deciduous broadleaf forest	4	2.15	103.5	2.08
Closed shrubland	6	555.88	29,789.3	1.87
Permanent wetlands	11	20.18	1,990.88	1.01
Open shrubland	7	3,824.35	415,127.13	0.92
Croplands	12	15.95	26,850.6	0.59
Developed	13	0.73	1,126.63	0.06
Barren	16	3.45	17,514	0.02
Natural vegetation mosaics	14	0	69.03	0.00

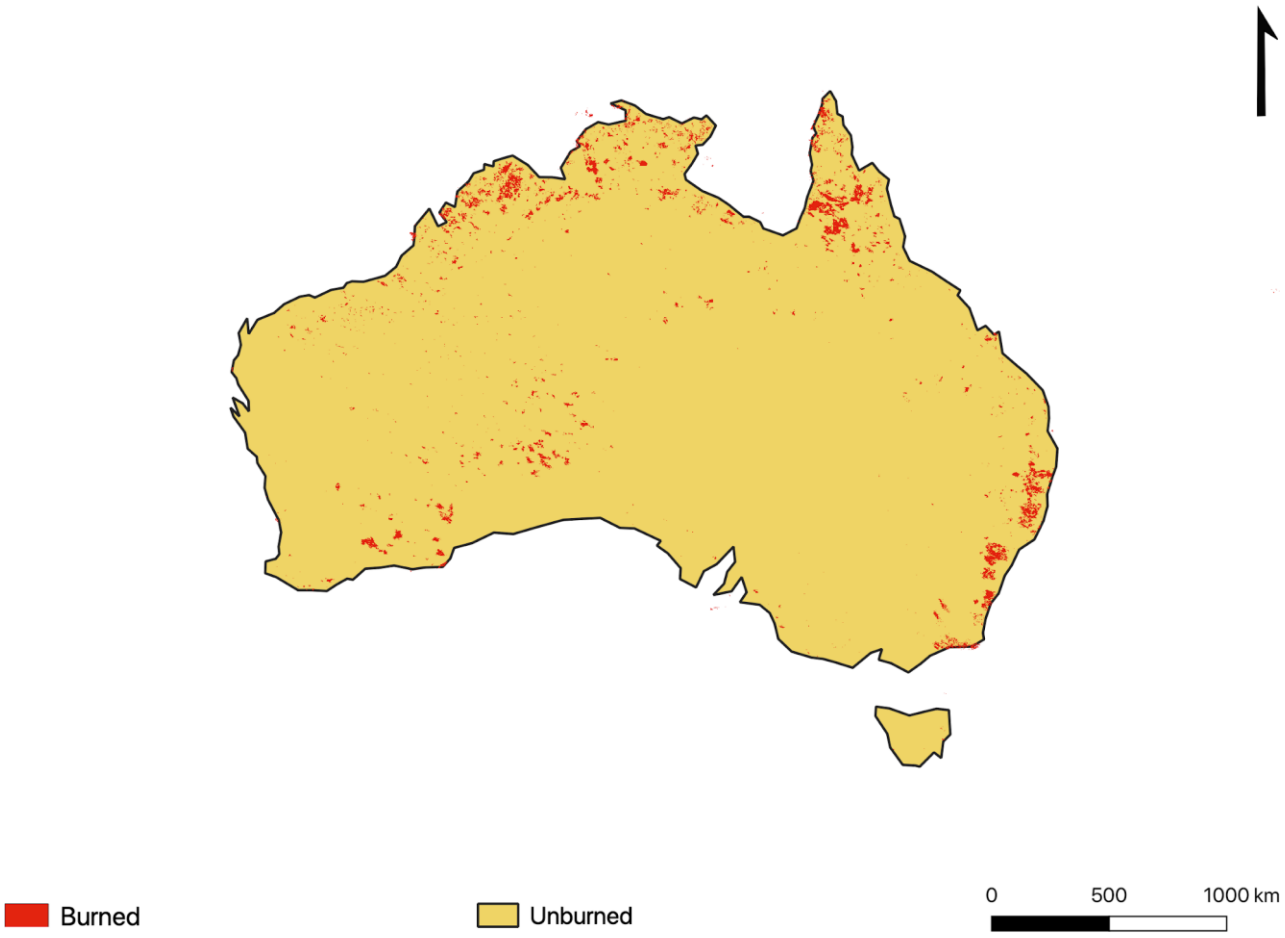

Figure 1. Combined burned areas in Australia from September through December of 2019.

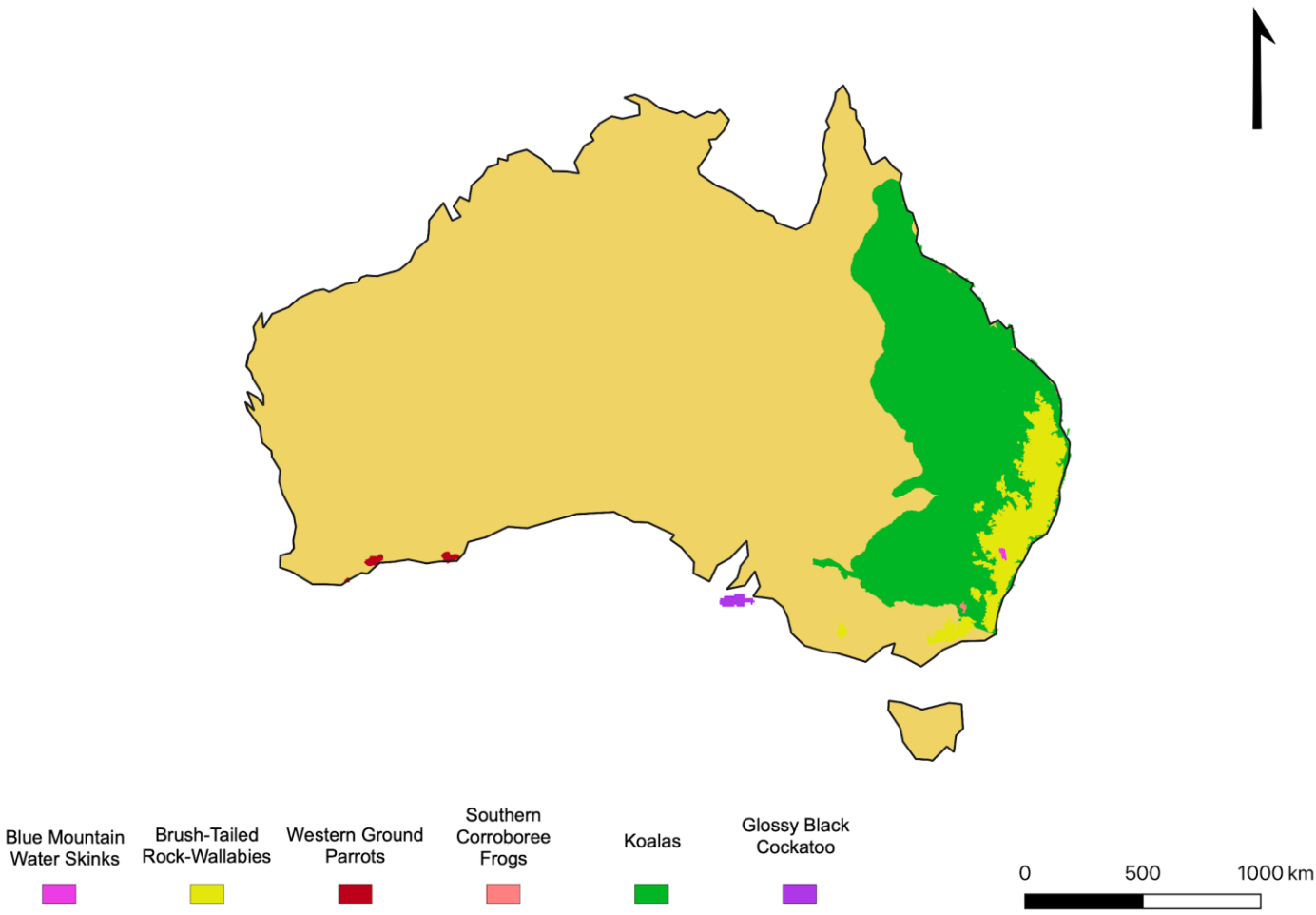

Figure 2. Habitats of animal species in Australia

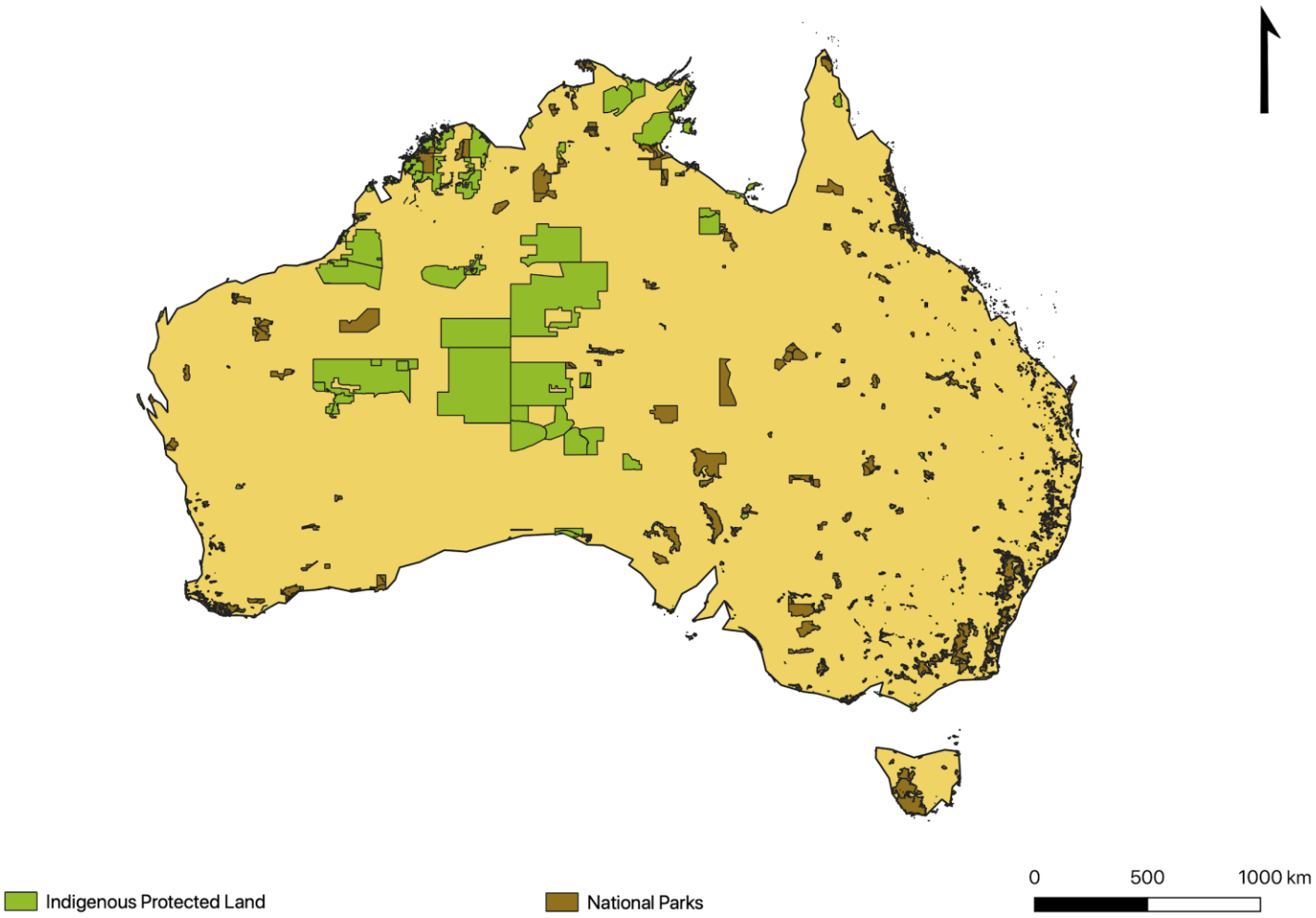

Figure 3. Indigenous protected land and national parks in Australia

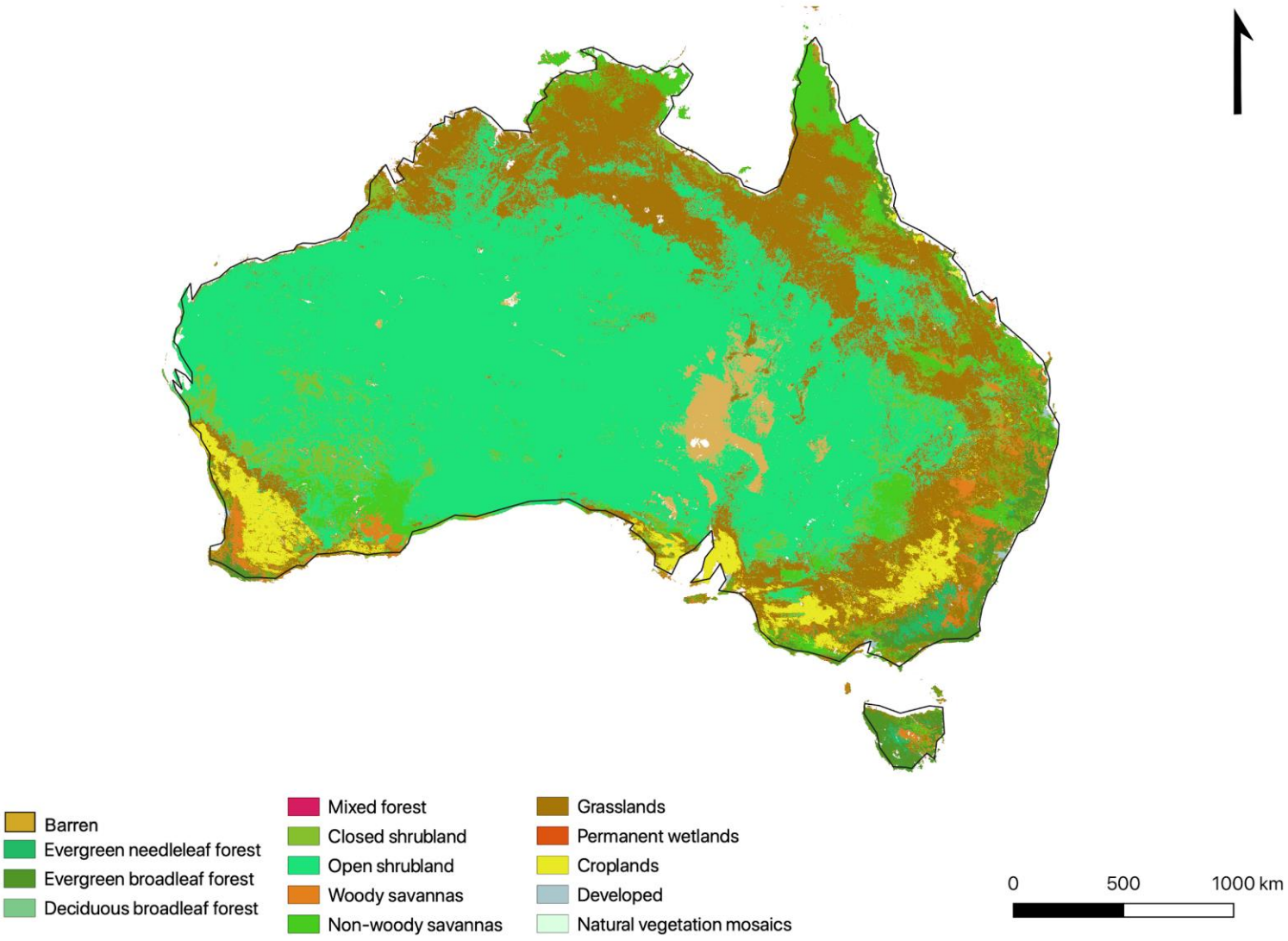

Figure 4. Australian land cover types

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