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Research

Key factors determining scales of burned areas in state Victoria (Australia) and province Alberta (Canada) during 1980-2019

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Abstract

Regular wildfire supports the balanced development of sclerophyll forests in Victoria (Australia), as well as, boreal forest in Alberta (Canada). Also, they are a major part of local Aboriginal culture in these regions and a means of regulating ecological functions of flammable vegetation communities for improving their productivity. Taking into consideration that burning is used as an effective tool for ecosystem management in Alberta and Victoria, it is relevant to assess the impacts of fire practices on the environment and to find connections between fire spread and key factors determining scales and locations of burned areas. Based on literary materials on fire practices, statistical data on wildfire cases occurring since the 1980s, geospatial data on the distribution of fire-prone plant communities' locations, and results of correlation analysis of fire cases with climatic, environmental, infrastructural, and social factors author reveal the following patterns: fires frequency depends on the landscape features; an increase in the number of fire occurrences correlates with an increase of dry periods duration (number of days); human settlements, where Aboriginal population reaches 50%, are subject to fires more frequent; the risk to the environment and settlements damage on small populated rural areas is higher than on densely populated suburban and urban places. Reduction of out-of-control wildfire risk can be achieved through fire management practices directed to wildlife and biodiversity protection, considering these patterns.

Keywords: Aboriginals, environmental hazards, flammable landscapes management, indigenous peoples, prescribed burning

Introduction

There is ample evidence that regular wildfire supports the balanced development of sclerophyll forests in Victoria, as well as, boreal forests in Alberta (Wood, 1966; Jurskis & Underwood, 2013; Christianson, 2014; Cawson et al., 2018; Francos & Ubeda, 2021). The majority of ecologists claim that coniferous trees in Alberta and arid vegetation communities in Victoria are ecologically adapted to regular wildfire influence (Cheney, 1981; Bradstock et al., 1998). Historically, Australian Aborigines have been burning sclerophyll forests, shrub, old arid and semi-arid grasses, as well as, Native American communities in Canada have been using wildfire for land cleaning to stimulate fire-prone vegetation growth and to allow young grass grows for natural pastures creation. Aborigines' communities in Victoria and in Alberta, have a unique traditional eco-culture of burning, which allows them to support ecosystem health (Abbott, 2003; Jurskis & Underwood, 2013). Also, wildfire is a part of way-of-life for these native peoples and a major element of their culture. They use fire in a spiritual context and to strengthen social relationships within the community (Christianson et al., 2014; Clode & Elgar, 2017).

Both governments of Canada and Australia consider fire activity as an effective mechanism that regulates ecological functions of flammable landscapes (Government of Australia, 1992; Hurditch & Hurditch, 1994; Council of Australian Governments, 2009). Indigenous carry out controlled burning is prescribed by the governments of both countries (Shea et al., 1981; Eriksen & Hankins, 2014). Besides, governments develop policies, programs, and strategies focusing on the ecological balance between humans and ecosystems. At the same time, both governments support the involvement of indigenous fire skills in environmental management (Abbott, 2003; Christianson et al., 2012; Christianson et al., 2014; Nekrich, 2017; Nekrich, 2020). Native Americans in Alberta, for example, are integrated into a fire mitigation program «Peavine FireSmart Projects». This program is directed to controlled fire use by indigenous for environment management and prescribes to burn boreal forest partially to clean places, where deciduous forest and herbal associations can grow. Native Australians participate in environmental programs securing the basis for their livelihoods (Clode & Elgar, 2014). Most members of Aborigines communities regularly take part in the forest monitoring system are carried out by the Victoria Country Fire Authority, in the educational programs, and in training courses, such as «The Operation Fireguard». These actions allow native peoples to prepare for fire seasons. Also, the aboriginal experience on fire practices is studied at Melbourne's Bushfire Cooperative Research Centre for the elaboration of the environmental strategies. Many indigenous are staffed at such centers. Fire practice carried out by indigenous communities is based on environmental principles and allows transferring Aboriginal experience to young native generations and all stakeholders (Jurskis & Underwood, 2013). However, it is not possible to fully control the direction and intensity of the fire. Out-of-control wildfires are the cause of numerous human deaths, wildlife damage, settlements, and environmental destructions (Commonwealth of Australia 2016; National Exposure Information System 2020). Taking into consideration that burning is broadly used as an effective policy for ecosystem management in Alberta and Victoria, it is relevant to assess connections between fire spread and key factors determining scales of burned areas.

The purpose of the research is to reveal the causes and effects occurring during fire management in natural ecosystems are located in state Victoria and Alberta province, to assess the role and impacts of the fire practices on the environment, and also to detect key factors determining scales and location of burned areas. To achieve this goal, it was necessary to solve the following tasks: to study specifics of the fire management practice carried out by native peoples and supported by the governments; to analyze dynamics of fire cases that occurred during the last 40 years in these regions; to highlight the links between fire cases and factors determining scales of affected territories: environmental, infrastructural, and social.

Material and methods

Study areas

Victoria is located in southeastern Australia and covers 227.416 Km², where typical semi-arid mallee communities dominant on the flatlands. In highlands, lying along Victoria's coastline, shrub-steppe and humid sclerophyll forests are well developed. Alberta is a province located mainly in the boreal forests, grasslands, and prairies of the central part of Canada. The province encompasses 661.848 Km². These two regions are both placed on landscapes that are ecologically adapted to wildfire influence (Wood, 1966; Christianson et al., 2014). They may be considered as typical regions where environmental conditions determine the system of land management are carried out by indigenous communities with governmental support. The native peoples are active agents of environmental transformation, they participate in collaborative researches and environmental projects on fire management by securing the basis for their livelihood (Council of Australian Governments 2009; Christianson, 2014).

The research is based on analyzes of the fire management practice implemented by Native American communities in Alberta and Aboriginal groups in Victoria, on geospatial data on distribution and dynamics of fire-prone plant communities' locations, on statistical data on fire cases (wildfire and prescribed burning) occurring since the 1980s in Alberta and Victoria, and on correlation analysis of fire cases with environmental, infrastructural, and social factors. Statistical data were gathered from official reports published by the Canadian Forest Service (https://www.nrcan.gc.ca), Bureau of Meteorology (http://www.bom.gov.au), Australian Bureau of Statistics (http://www.abs.gov.au), Commonwealth of Australia (https://www.pc.gov.au), Australian Academy of Science (https://www.science.org.au), Council of Australian Governments (https://www.coag.org.au), Commonwealth Scientific and Industrial Research Organization (CSIRO) (https://www.csiro.au), Department of Agriculture, Water, and the Environment – Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (https://www.agriculture.org.au), the National Dynamic Land Cover Dataset (https://ecat.ga.gov.au), and Geoscience Australia (www.ga.gov.au).

In the first stage of the research, the natural landscapes of Victoria were mapped and described. The source of information is the landcover database provided by European Space Agency (http://www.esa-landcover-cci.org). All landscapes units were grouped concerning present-day climate, relief features, and associated with arid, semi-arid, sub-humid, and humid conditions according to the classification of vegetation cover elaborated by Wood (1966), Learmonth (1971), Beadle (1981), and Ogureeva (1989). Vegetation cover units are correlated with the major soil groups according to the classification of CSIRO (Taylor, 1966) and the International Soil Classification System (IUSS Working Group WRB 2015). The landscapes analysis allowed the author to reveal the following patterns: vegetation cover is changing not only according to change of zonal climatic and environmental features but also has limits of distribution depending on soils types, rainfall variability, and especially on the rainfall amount. The amount of rainfall gradually diminishes on passing inland (from 1.500 to 250 mm per year). Lack of humidity and high variability of rainfall are the main factors leading to droughts. Special attention is given to the landscapes located in zones of imbalanced synoptic situation, where fire cases occurred during 1980-2019.

In the next stage, the correlations between fire cases and environmental, infrastructural, and social factors were defined. Among the environmental factors is a change of dry period duration (number of days) has been chosen. The major infrastructural factor is changing the density of settlements are located in the most burning landscapes. The main social factor is a change of density Aboriginal population. All calculations were performed for each landscape's unit concerning relief forms and for settlements where the Aboriginal population is dominant.

Results

Although Native peoples in Alberta and Victoria carry out fire management by taking into account ecological functions of plants, regional seasonality, meteorological conditions, and wind direction (Christianson et al., 2014), wildfire and prescribed burning have not only a positive impact on fire-prone plant communities, but enhances the risk of disaster, environmental hazards, and spread of negative processes, such as erosion, deflation, and desertification (Nekrich, 2020). Yearly about 30% of burned areas in Alberta and 40% in Victoria are subject to erosion. To minimize the development of these negative processes, a special system of rules and regulations have to be applied: fire activity is prohibited during the dry seasons; burning has occurred only in the prescribed places; grazing, farming, and recreation are limited during the time of fire spread; to restrict the spread of uncontrolled fire irrigated furrows are built along the perimeter of the burned territory; all dead trees and branches must be removed after fire application to reduce the risk of deadfalls (Commonwealth of Australia 2016). However, these regulations were implemented partly and uncontrolled fire cases appear. To analyze the spatial appearance of fire cases on the landscapes and to set correlations between fire cases occurrence and environmental features the map of the natural landscape of Victoria was created (Fig. 1).

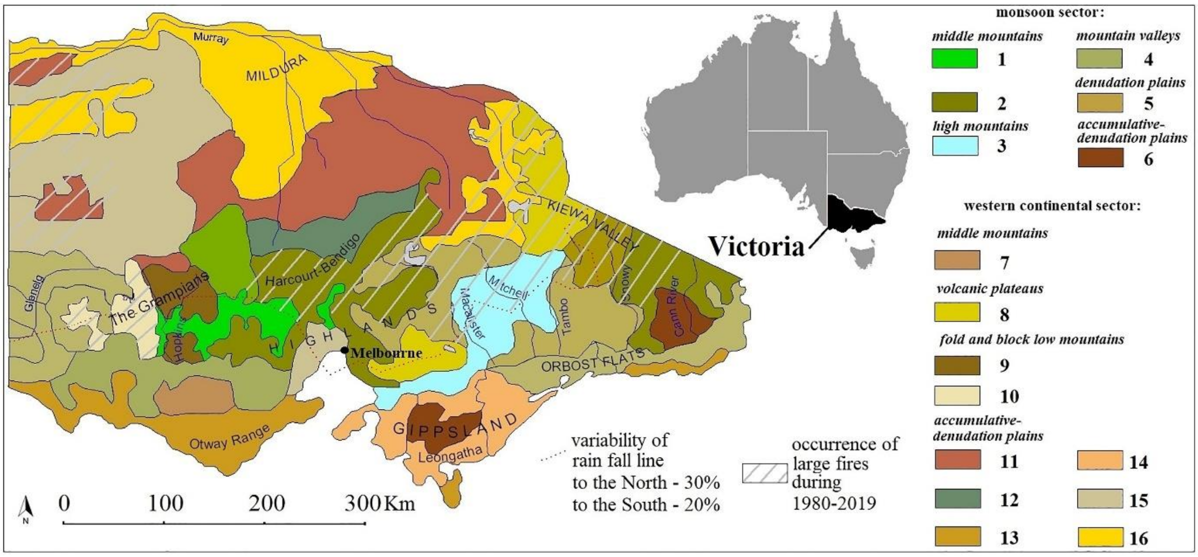

Figure 1. Natural landscapes units of Victoria (Australia)

Landscapes of monsoon sector (the total rainfall amount is 800-1.500 mm per year): 1 – sub-humid eucalyptus communities (*Eucalyptus rubida*) with grassland (*Poa* and *Stipa)* on ferralitic soils, red-brown earth, and yellow soils; 2 – humid tall eucalyptus communities (*Eucalyptus fastigata)* and woodland (*Acacia melanoxylon)* on brown soils; 3 – humid eucalyptus forests (*Eucalyptus delegatensis*), woodland (*Acacia dealbata)*, and Alpine meadows – a community dominated by forbs and perennial herbs (*Celmisia longifolia, Poa caespitosa*) on meadow podzolic soils; 4 – eucalyptus forests (*Eucalyptus vimnalis)* with *Cyathea, Acacia, Banksia,* and *Hakea* woodland with grassland (*Poa, Stipa*, *Themeda*, and *Danthonia*) on yellow and brown soils; 5 – sub-humid eucalyptus forests (*Eucalyptus ovata, E. radiata)* and shrubs on gleysol and alluvial soils; 6 – wet sclerophyll communities including forests *(Eucalyptus delegatensis, E. regnans)* with tussock grassland (*Stipa variables, Poa sieberiana*) on humus podzol, podzolic soils, and podzols. ***Landscapes of continental sector*** (the total rainfall amount is less than 800 mm per year): 7 – forests (*Eucalyptus melliodora, E. albens)* and sub-arid woodland with *Acacia* and *Banksia* on red and yellow ferralitic soils; 8 – humid forests communities on red loams; 9 – woodland (*Eucalyptus melliodora, E. albens)* and sub-arid woodland with *Acacia* and *Banksia* on luvisoils; 10 – woodland *(Eucalyptus melliodora, E. albens)* on solonetz; 11 – mallee shrub with *Eucalyptus socials, E. dumosa, E. oleosa* and cereals (*Poa, Stipa)* on brown and grey soils; 12 – woodland *(Eucalyptus macrorhyncha, E. woollsiana)* and *Acacia* with tussock grassland (*Astrebla, Dichanthium, Stipa,* and *Eragrostis)* on planosols, vertisols, and luvisols; 13 – dry sclerophyll forests (*Eucalyptus baxteri, E. ovata, E. viminalis)* on podzols; 14 – sub-humid sclerophyll forests (*Eucalyptus ovata, E. radiata, E. ribuda)* on podzolic soil; 15 – semi-arid and arid mallee (*Eucalyptus incrassate, E. foecunda)* on solonetz soil; 16 – semi-arid mallee (*Eucalyptus gracilis)* with grassland (*Poa, Stipa)* on solonized brown soils

Fires occur in Victoria. Statistical data derived from the Bureau of Meteorology (Bureau of Meteorology 2020) and Australian Bureau of Statistics (Australian Bureau of Statistics 2016) have been shown that the frequency of occurrence of large fires is the highest on Eastern Highlands, Kiewa Valley, and on the Northwestern low plains of Victoria. The fire-prone plant communities lie on territories, where the variability of rainfall reaches 30% per year: humid tall eucalyptus communities (*Eucalyptus fastigata)* and woodland (*Acacia melanoxylon)* on brown soils in highlands, forests (*Eucalyptus melliodora*, *E. albens)*, and sub-arid woodland with *Acacia* and *Banksia* on red and yellow ferralitic soils, and semi-arid and arid mallee (*Eucalyptus incrassate, E. foecunda)* on solonetz soil on low inner plains. The yearly burning landscapes cover almost half of the territory of Victoria.

Discussion

Aborigines burn out mallee-scrub, tussock grassland, and bushes. Fire is used locally; most forests and scrub are defended from uncontrolled wildfire in order to save refuges for native animals. According to geospatial data on distribution and dynamics of fire-prone plant community's locations in Victoria, burned areas didn't increase during 1980-2019. The broad-scale fire in 1983, 2009, 2019 burned 4.400 Km², 2.200 Km², 1.300 Km², respectively. In 2020 about 7.800 Km² were burnt during a prolonged drought; the scale of these burned areas at this time is comparable with the scale of areas burned during 1980-2019 (The National Dynamic Land Cover Dataset 2020).

Regular seasonal burning is one of the main cleaning factors allowing the creations of productive rangelands (pastures) (Wood, 1966). As geospatial data shows, the principal types of rangelands in Victoria are the following: the moist temperate perennial grass, the winter annual grass, the temperate short grass, and the mixed alpine grass with the moist temperate perennial grass (The National Dynamic Land Cover Dataset 2020). Most of the rangelands are derived by cleaning shrub, dry and wet sclerophyll forests. The moist temperate perennial grasses have little grazing value in their native state (Christian, 1966). When cleared, wet sclerophyll forests commonly give a good grass cover, consisting of *Themeda australis* with tussock species (*Poa caespitosa* and *Danthonia palliada)*. These grasses are a good basis for the cattle and sheep industry of Australia. The winter annual rangelands are characterized by severe summer drought; most of them originally consist of mallee communities with woodland (*Eucalyptus socialis*, *E. Dumosa*, *E. gracilis*, *E. oleosa*). The mallee areas are cleared by fire for wheat-growing. The temperate short grasses (*Themeda australis*) are dominant in Victoria and are subject to regular burning. This area includes a large part of the wheat belt of Victoria. Alpine pastures are subject to winter snow; therefore, they are used during the summer season. Summer burning is commonly practiced here too.

Fires occur in Alberta. Fire practice applying in Alberta creates micro-conditions for conifers *(Pinus radiata*, *P. elliot spp. and Spruce)* growth, clears new locations for deciduous forests growth with birch, poplar, willow, and oak *(Betula alba, Populus tremuloides, Willow spp.)*, and supports evolutionary-created ecosystems in sustainable condition (The Canadian Forest Service 2020). Burning is also used to expand the areas of prairies. It was determined that the optimal ratio of the boreal species, deciduous species, and prairies species should be supported in the proportion of 20%, to 50%, and 30%, respectively. This ratio increases the sustainability of ecosystems to natural hazards and anthropogenic pressure (Nekrich, 2017). However, geospatial data on distribution and dynamics of fire-prone plant community's location show that this ratio was not constant in time slice from 1980 to 2019 (http://www.esa-landcover-cci.org/). It was detected that, since 1980 burned areas have been increasing gradually, excluding 1981, when 9.500 Km² were destroyed by uncontrolled wildfire. In 1995 burned area reached 1.600 Km², after 3 years it occupied 2.350 Km², in 2002 about 3.600 Km² were burned out. In 2009 and 2019 the burned areas included 4.300 Km² and 4.800 Km², respectively. The post-pyrogenic landscapes can be used as recreational territories, hunting sites, and areas for berries and medicinal plant gathering.

In further studies, maps of the natural landscape map of Alberta will be created. It is supposed that this map will allow the author to reveal correlations between the occurrence of fire cases and features of the landscapes.

A correlation analysis has shown the links between fire cases with environmental, infrastructural, and social factors. In Alberta, during 1980-2019 broad-scale fires occurred every 3 years and were connected to the duration of dry periods. In Victoria frequency of fire cases is rising, as well as, the number of days is rising during dry periods within the boundaries of landscape units (r = 0.79 in Victoria) (Fig. 2).

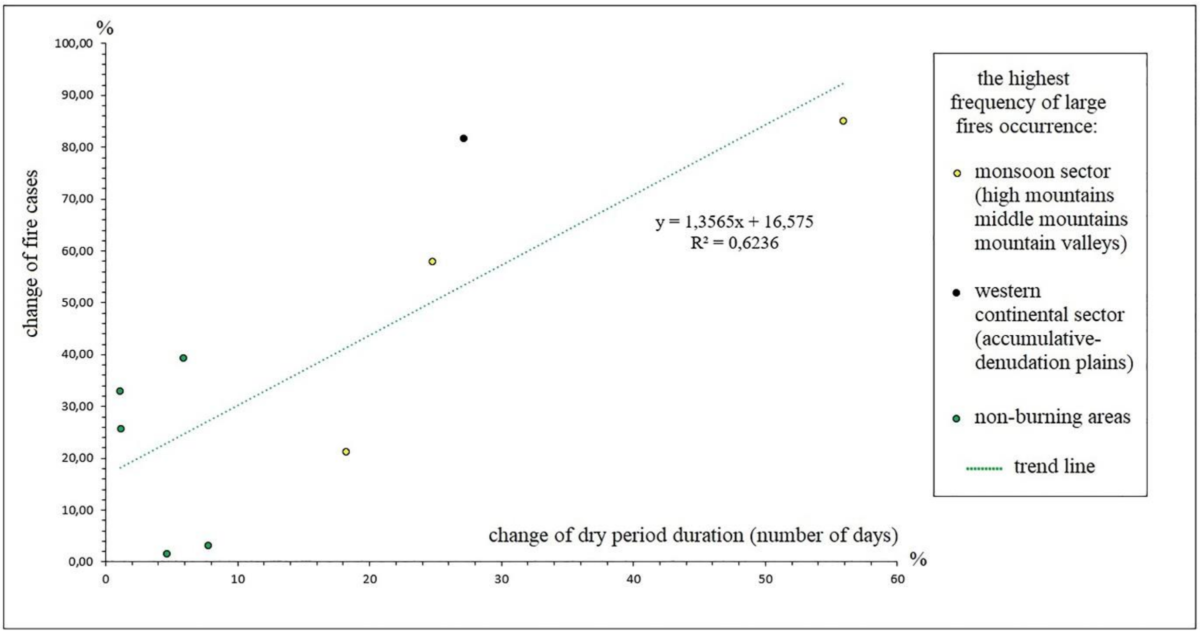

Figure 2. Dependency between change of fire cases and change of dry period duration (number of days) during 1980-2019 in Victoria (Australia)

The findings of this study showed that the dynamic of fire cases in Alberta also is connected to the change of Aboriginal population density in rural settlements. As a rule, the higher density of the aboriginal population, the more frequent fire cases occur (r = 0.66 in Victoria; r = 0.43 in Alberta) (Fig. 3).

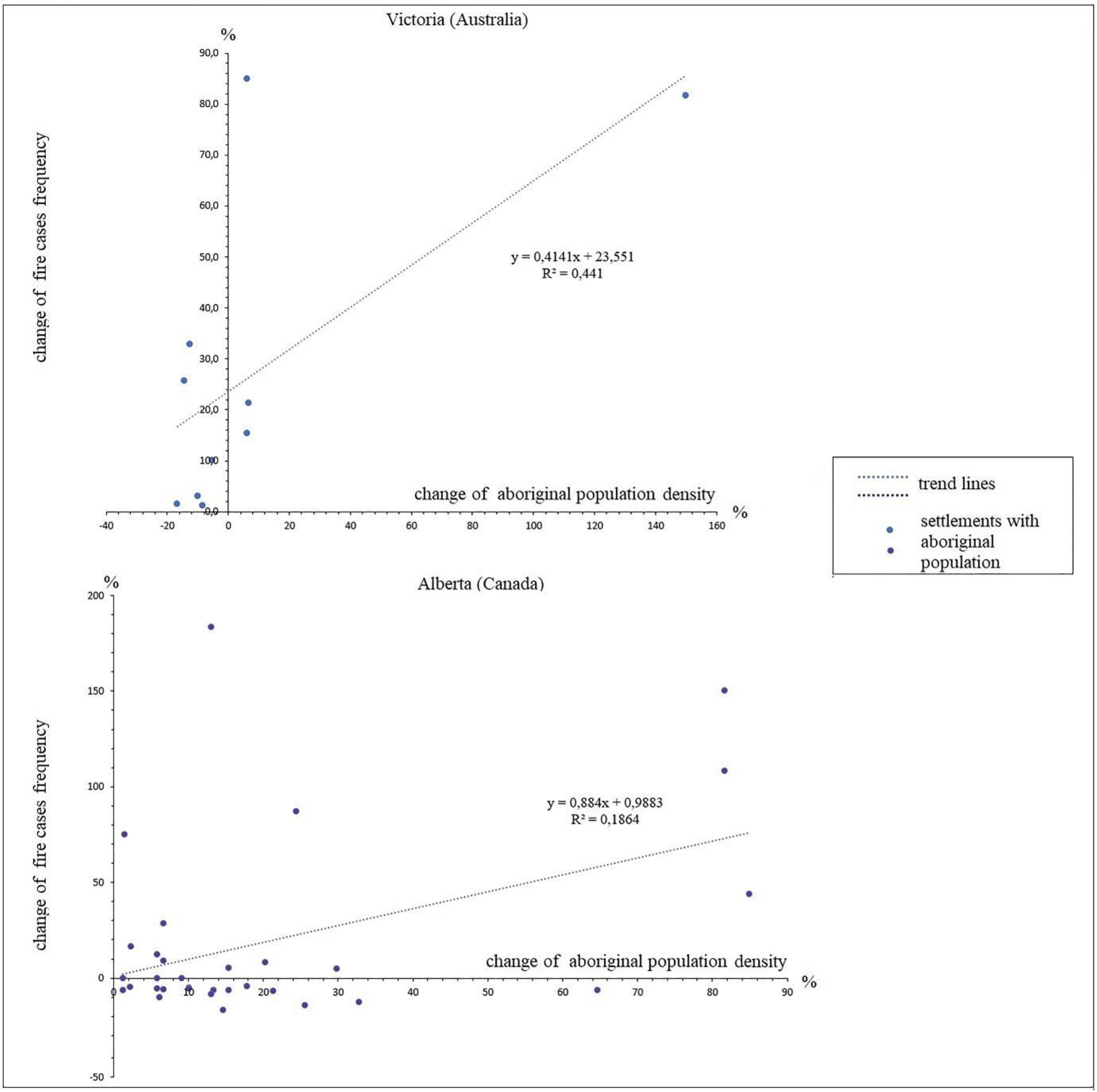

Figure 3. Dependency between the change of fire cases frequency and change of Aboriginal population density during 1980-2019 in Victoria (Australia) and Alberta (Canada)

As a rule, broad-scale fires occur in small arid-vegetated places where the dense population is low, but the Aboriginal population reaches more than 50%. It can be noted that settlement destruction owing to fire on Aboriginal territories and rural areas is higher than on densely populated urbanized places. A similar tendency is observed in Victoria. It is interesting that in Victoria in 1983, during a severe drought, less than 2 rural settlements burned down, while the fire area covered 4.500 m^2. At the same time, more than 8 settlements were affected by the fire on territories occupied 2.000 m^2 (Clode & Elgar, 2014). These facts can be explained by analyzes of settlement density. It was observed that settlements burn more frequently due to the close location of the houses to each other. At the distance of 500-700 m from the fire passage, the frequency of settlements burning raises twice. The higher density of settlements, the fire cases more often occur (r = 0.47 in Victoria; r = 0.50 in Alberta) (Fig. 4).

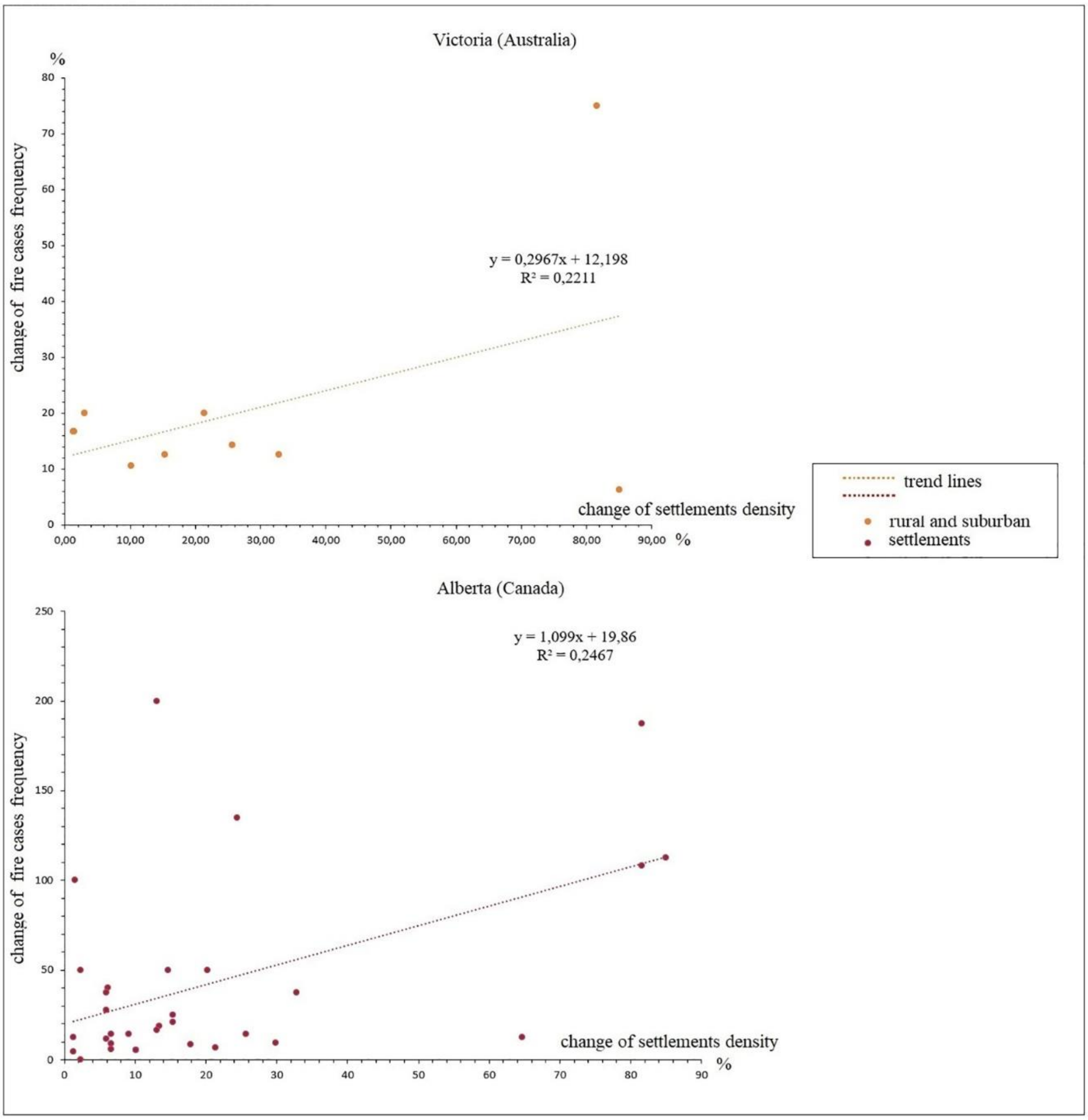

Figure 4. Dependency between a change of fire cases frequency and change of settlements density during 1980-2019 in Victoria (Australia) and Alberta (Canada)

At the distance of 30-50 m from the fire passage, such possibility falls more than 1.5 times. In Alberta, a similar tendency was not observed during the last 40 years.

Conclusion

Data on fire cases that occurred in Alberta and Victoria in the last 40 years and analyses of fire practice implemented by native peoples and controlled by the governments allow the author to come to the following statements: (1) Controlled burning allows supporting flammable landscapes in a productive state. (2) During the last 40 years burned areas in Alberta increased up to 3.5 times. By contrast, in Victoria burned area decreased by 3.4 times at this time. Mallee-shrub and bushes formations were particularly affected. (3) The highest frequency of large fires in Victoria is viewed on the landscapes located in zones where the variability of rainfall reaches 30% per year. The yearly burning landscapes cover almost half of the territory of Victoria. Statistical data on prescribed burning and wildfire cases in Alberta and Victoria have shown, that since the 1980s: fire cases occurrence is strongly correlated with duration (number of days) of dry periods (r = 0.79 in Victoria); the higher density of Aboriginal population, the more frequent fire cases occur (r = 0.66 in Victoria; r = 0.43 in Alberta); the risk of burning settlement on small populated rural areas is higher than on densely populated suburban and urban places; the higher density of settlements, the fire cases more often occur (r = 0.47 in Victoria; r = 0.50 in Alberta). The result of this research emphasizes the need to analyze fire activities as a process determined by environmental, infrastructural, and social factors. According to Wotton et al. (2017), the number of fire cases in two of these regions will likely increase in the future. It is necessary to carry out further research to explore additional aspects of fire impact on the environment, to prevent uncontrolled fire cases, and to support the balanced development of flammable landscapes.

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