LLOYD'S

WILDFIRE:
A BURNING ISSUE FOR INSURERS?

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CONTENTS

1 EXECUTIVE SUMMARY

WILDFIRES ARE AN ECOLOGICALLY IMPORTANT PHENOMENON ACROSS MUCH OF THE GLOBE AND HAVE OCCURRED NATURALLY OVER MILLIONS OF YEARS. Lightning is the most common cause in remote regions whereas human ignitions (accidental or arson) are a major cause of wildfire starts in more densely populated areas.

IN POPULATED REGIONS, WILDFIRES POSE A RISK TO LIVES AND INFRASTRUCTURE AND SIGNIFICANT LOSSES CAN OCCUR. Losses are particularly severe where fires affect large areas and are of high severity. These fires are typically associated with dense live vegetation and dead vegetation, prolonged dry conditions prior to the fire, high temperatures and strong winds.

CLIMATE AND WEATHER ARE KEY DRIVERS FOR WILDFIRE, WITH DROUGHTS AND HEATWAVES INCREASING WILDFIRE RISK. Recent changes in climate have already led to a lengthening of the fire season in some regions, such as parts of western North America. However, this trend has not been witnessed everywhere and, on average, the global area burned by wildfires has not increased over the last 15 years.

SOCIO-ECONOMIC AND LAND USE CHANGES ALSO AFFECT WILDFIRES. Population growth at the fringe of urban and wildland areas in North America has raised the likelihood of wildfire ignitions, whereas rural depopulation and abandonment of traditional agriculture in Mediterranean Europe has led to vegetation build-up, increasing the risk of severe fires. Wildfire suppression has led to an unnatural build-up of vegetation in some regions, which in turn has contributed to an increase in fire severity and size.

FUTURE CLIMATE CHANGE IS EXPECTED TO INCREASE AVERAGE GLOBAL TEMPERATURES AND, IN SOME REGIONS, DROUGHT FREQUENCY AND SEVERITY WILL INCREASE. THIS COULD LEAD TO SUBSTANTIAL INCREASES IN FIRE PROBABILITY AND POTENTIALLY AREA BURNED. The greatest increases are expected for parts of western and southern US, south-west Canada, parts of the Mediterranean basin, eastern Siberia, south-central Australia, western South America and much of the drier regions in Asia. There may, however, be surprises due to our limited understanding of the interactions between climate, vegetation response and human activity.

SEVERAL OF THE REGIONS AT INCREASED WILDFIRE RISK, AND NORTH AMERICA AND AUSTRALIA IN PARTICULAR, HAVE SIGNIFICANT LEVELS OF INSURANCE PENETRATION. Therefore, the potential increases in fire activity can be expected to have some implications for the insurance industry, especially for property and, to some extent, liability lines.

EARLY WARNING SYSTEMS EXIST TO PREDICT HIGH FIRE RISK; ALTHOUGH, LARGE AND SEVERE FIRES CANNOT NORMALLY BE PREVENTED. Preventing naturally-recurring fires can result in a build-up of vegetation, which leads to delayed, but more severe and therefore damaging fires. Controlled prescribed fires can help in reducing dead vegetation and in some cases the severity of subsequent wildfires.

THERE ARE EFFECTIVE RISK MITIGATION STRATEGIES TO REDUCE HUMAN AND ECONOMIC LOSSES. Many of these strategies require action at the community and homeowner level. The insurance industry could play a key role in reducing the risk of losses through direct engagement with legislators, communities and individuals.

2 INTRODUCTION

A wildfire is an uncontrolled fire, consuming vegetation in the countryside or a wilderness area, such as forest, woodlands, bushland, scrubland, grassland or peatland. Prescribed fires used by humans in a controlled fashion for land management purpose, also known as management burns, are not considered wildfires unless they get out of control. Wildfires and prescribed fires in wildland areas are termed wildland fires irrespective of their size or rate of spread. Where wildfires are very large and have very high human, economic or environmental consequences, they are sometimes described as mega-fires, although a precise definition is lacking[1].

Wildfires have been a natural process for over 400 million years since plants began to cover the land[2]. Many forests, shrub and grassland ecosystems are well adapted to burning and, for these, naturally recurring fire is an important agent maintaining ecosystem health. The primary natural ignition source is lightning. However, humans are another common ignition source, either by accident, arson or where management fires get out of control[3] (Fig. 1). However, it is important to recognise that overall the availability of flammable fuel is the limiting factor for wildfire.

In many areas, wildfire risk is seen as an increasing threat with wide ramifications for society, businesses and the environment. This report will show how land management, socio-economic factors and climate influence economic damage and insured losses caused by wildfires. The report will also discuss the nature of wildfires, their global distribution, the role of management, socio-economic and climatic drivers in changing wildfire patterns, as well as the implications of wildfires for the insurance industry and wider society.

Figure 1: Lightning-caused wildfire scars in an uninhabited region of boreal Canada (August 2010). Such natural fires maintain forest age diversity, maintain biodiversity and forest resilience to disease (Source: Doerr).

3 THE NATURE OF WILDFIRES

Vegetation can burn and flames spread when there is a source of ignition, fuel (ie live and dead biomass) which is sufficiently dense and dry enough to burn, and enough oxygen to sustain burning.

The most common natural source of ignition is lightning in the northern latitudes. Although lightning is often accompanied by rainfall and very few strikes cause a spreading fire, there are sufficient lightning strikes to be the leading cause of wildfire in many remote regions. In Alaska, for example, 94% of the area burned since 2001 has been due to lightning-caused wildfires[4]. In more densely populated areas, humans are responsible for many of the ignitions. In the lower 48 states of the US, human ignitions were responsible for nearly half of the annual burned area since 2001[5]. In Europe, with its high population density, over 95% of fires are caused by humans[6].

Humans have used fire for millennia to clear forests for agriculture and maintain grasslands for grazing and hunting. There is a risk with management fires that if they get out of control, they could become wildfires. Other accidental ignitions from campfires, downed power lines or discarded cigarettes, as well as arson, are also important causes of wildfire[7]. Sources of ignitions are not always clear and in large fires different sources of ignition may lead to a major complex fire. For example, the 2009 Black Saturday fires in Australia, which covered around 4000 km^2 and killed 173 people, were caused by separate ignitions including lightning, a downed power line and suspected arson[8].

Vegetation is at its most flammable when it is dry and fine. For example, dry tall grass is particularly flammable, whereas large pieces of dry wood (eg large branches or tree trunks), will normally not sustain burning on their own. In a typical forest fire, little standing timber is actually consumed (although the fire may kill the trees), with litter, small branches and leaves providing most of the fuel. Where leaves contain significant amounts of waxes or oils (eg eucalyptus and conifer trees or gorse bushes) they can be very flammable when green. Even the most flammable vegetation needs to be heated before burning occurs therefore, the probability of ignition and sustained burning increases with high temperatures[9].

Figure 2: Fire spreading through a boreal conifer forest in western Canada. Much of the fuel driving the fire is provided by the ground vegetation, litter and dead wood. Small branches and leaves on trees are a minor fuel component, whereas tree trunks contribute very little except in very severe fires. Temperatures in the flaming zone can exceed 1000°C (Source: Doerr).

Finally, oxygen availability is also a critical factor. Whereas the supply of fresh air and therefore oxygen may be limited in building fires, the availability of atmospheric oxygen is not normally a major limitation in wildfires. The presence of high wind and of steep slopes increases oxygen flow to the flaming zone and wildfires do not only travel faster, but also burn more vigorously. Wind also increases spotting, when light pieces of burning vegetation (i.e. embers composed of bark and leaves) are carried by winds ahead of the flaming front, igniting new areas that may be hundreds or more metres away from the fire. Spotting is therefore a primary cause of ignition for buildings lying outside of a vegetated zone[10].

Wildfire risk is particularly high in areas with contiguous zones of flammable vegetation, and on hot windy days that follow a prolonged dry period, as was the case for the 2003 Canberra wildfires, which involved several deaths, over 490 injured, and over 500 damaged or destroyed houses. The effects of weather and climate on wildfires, together with key terms for distinguishing fires (area burned, fire occurrence and fire severity), are introduced in section 5.

4 WILDFIRES ON A GLOBAL SCALE

Currently wildland fires affect three to four million km^2 of the global land surface every year[11], which equates to over 3% of the Earth's vegetated land surface. They impact a wide range of land including boreal, temperate and tropical forests, and peatlands, as well as shrub and grasslands. Fire seasons vary by hemisphere and region with, for example, fire activity in Africa switching between its northern and southern hemisphere dry seasons (Fig. 3).

In some ecosystems, such as savannah grasslands, fires may recur every few years, whereas in forests, fire recurrence may vary from several decades to centuries. Some regions, such as large parts of Europe, have few areas with natural vegetation (eg pristine forest) remaining and a natural fire recurrence regime does not exist anymore. Figure 4 provides an overview of average annual fire activity over a 40-year period, illustrating the global distribution of wildfire and management burns.

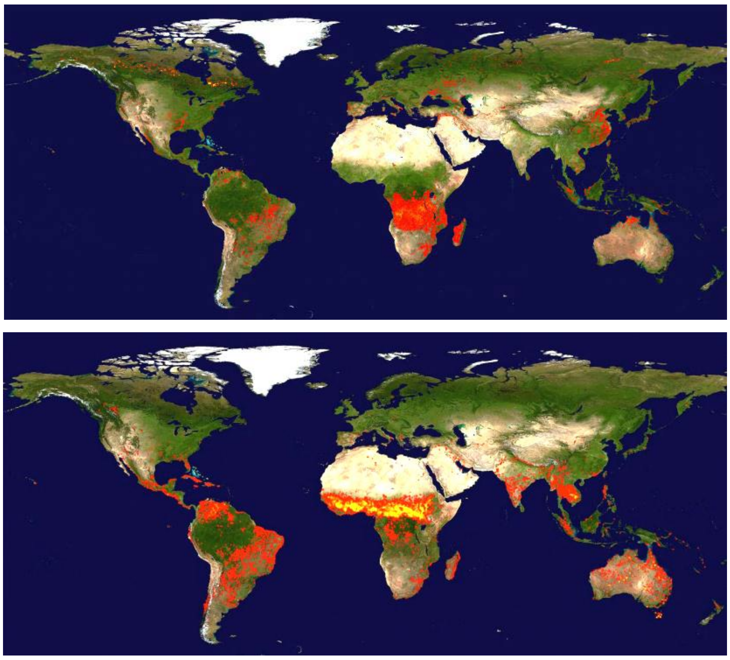


Figure 3: Recent fire activity over a 10 day period for 1-10 January (top) and 30 June–9 July 2013 (bottom). Each coloured dot indicates at least one fire during the period. Red indicates a low and yellow a high fire count. NASA makes 10-day composites available for download at http://lance-modis.eosdis.nasa.gov/cgi-bin/imagery/firemaps.cgi

Over 80% of the global area burned occurs in grassland and savannahs, primarily in Africa and Australia, but also in South Asia and South America, while the remainder occurs largely in forest and shrub-dominated regions of the world[12]. Most fires in grassland-dominated ecosystems have a low impact in terms of human or economic losses despite their high frequency. The less frequent fires in forest and shrublands in more densely populated regions have a much greater impact on lives and infrastructures. These regions include the mid- and south-western US, south-western Canada, Mediterranean Europe (ie Portugal, Spain, southern France, Italy and Greece), eastern China, and south-eastern Australia. Particularly high-risk areas in terms of losses are the coastal parts of southern California with their steep slopes, highly flammable shrub vegetation and increasing population, and south-eastern Australia where the forests are dominated by extremely flammable eucalypt species.

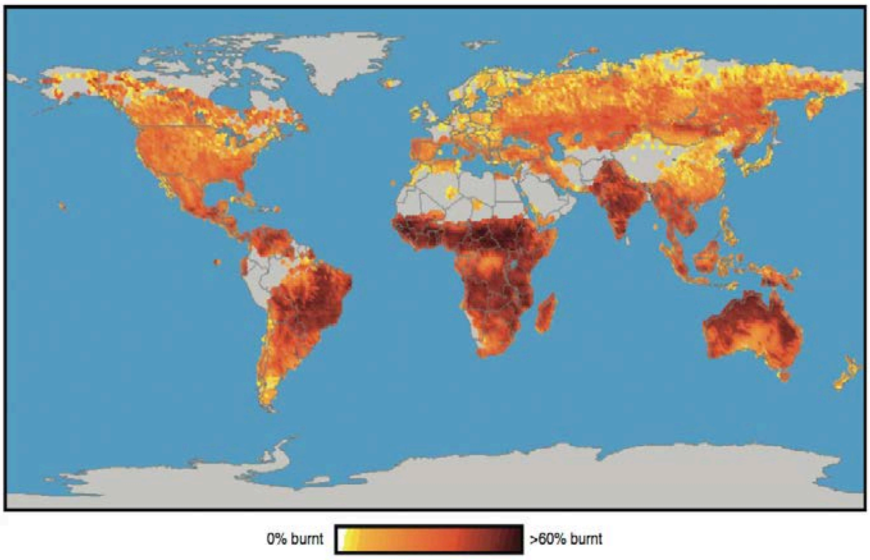


Figure 4: Average annual area burned between1960-2000. (Source: Flannigan et al. 2009).

5 WILDFIRES IN A CHANGING WORLD

Human activity and climate are the main factors affecting wildfire activity. **Area burned** is perhaps the most robust parameter for examining trends and also of major relevance with regards to insurance losses. It can be derived with reasonable accuracy from satellite observations. **Wildfire occurrence** (ie number of fires) quantifies the presence or absence of a fire and is distinct from area burned. From an impact perspective, however, they are linked. When many fires occur over a short time period, fire fighting capabilities may be overwhelmed and unable to tackle new ignitions. Under those circumstances, fires have the highest probability of escaping, burning large areas and causing significant damage[13]. Trends in occurrence are less reliable as recording methods vary and, for example, an increase in the number of fires may not necessarily increase the area burned and damage caused. This is illustrated for fires in Mediterranean Europe in Figure 5. The number of fires more than doubled from the early 1980s to the mid-1990s, but this did not translate into an increase in the area burned.

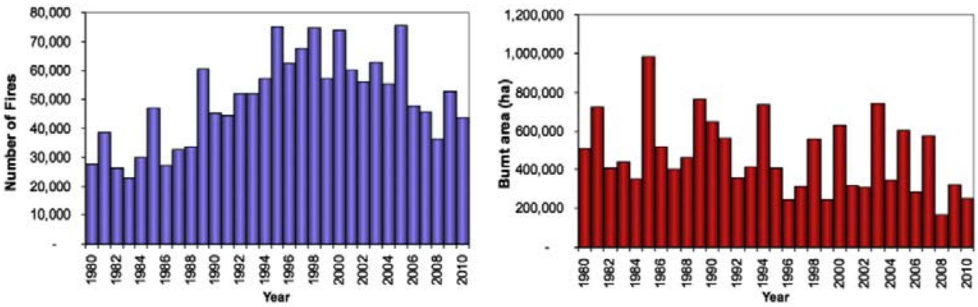


Figure 5: Wildfire occurrence (left) and corresponding area burnt (right) in the European Mediterranean region. (Source: San-Miguel-Ayanz et al. 2013).

Fire severity is also an important parameter, which can refer to the amount of vegetation destroyed, or other ecological and infrastructure damage. It varies in definition and use, and general trends are therefore difficult to quantify. Overall, drier, warmer and windier conditions lead to greater fire severity in terms of vegetation destruction and also increase the probability of loss of lives and damage to properties. **Fire intensity** is a more defined parameter, reflecting the amount of energy released per unit length of the flame front. It is often, but not always related to fire severity[14].

5.1 THE ROLE OF LAND USE AND MANAGEMENT CHANGE

Human activity influences wildfire trends as humans affect ignitions and fuel availability in many regions across the globe. The ability to suppress fires (ie contain or even extinguish fires) has seen dramatic improvements particularly over the last three decades, thanks to technological development. These advances, together with the desire in some regions to keep fire entirely out of wildland areas, can lead to a reduction in fire incidence for decades, resulting in an unnatural build-up of fuel, which in turn can cause an increase in fire severity and size, as experienced in the US (see section 5.3). This trend has now been recognised and efforts are being made to re-introduce fire by letting fires burn or by carrying out prescribed fires to reduce fuel loads.

Increases in fuel load have also occurred in many parts of Mediterranean Europe, where the recent reduction in rural population has led to the encroachment of shrubs and trees into former agricultural areas and to the introduction of forest plantations with often very flammable species. This has resulted in a more flammable landscape in areas where the change from wildland to agriculture over millennia had initially led to a reduction in wildland fire. Finally the presence of humans can lead to a greater incidence of accidental and intentional ignition events. Population growth in the Wildland Urban Interface[i], increases ignitions, as well as wildfire risk to lives and infrastructure[15].

5.2 THE ROLE OF CLIMATE, WEATHER AND CLIMATE CHANGE

Fuel availability, ignition and weather are drivers of fire that are sensitive to changes in climatic conditions, with weather (ie temperature, precipitation, relative humidity and wind) in particular being linked to existing and anticipated future trends in climate[16].

Temperature is a very important climate and weather variable, affecting wildfire. Warmer temperatures and more frequent heatwaves, which are predicted for many regions under global climate change scenarios[17], are expected to increase wildfire activity[18]. Three factors link temperature and wildfire activity: higher temperatures increase evapotranspiration, and therefore decrease fuel moisture, unless offset by increased rainfall; warmer temperatures generally increase lightning activity and therefore, potential ignitions[19]; and increased temperatures can lengthen the fire season[20]. Decreases in precipitation and particularly increased frequency of droughts predicted for some regions[21] would be expected to result in lower fuel moisture contents and therefore increased wildfire probability. Over longer timescales however, reduced precipitation can limit vegetation growth and fuel load, and associated wildfire risk. Data for the 1977–2003 period for the western US showed that a few climate variables explain over half of the variations in an area burned by wildfire. The mechanism behind the fire–climate relationship is climatic preconditioning before a fire, either via drying of existing fuels, or by providing good conditions for vegetation growth followed by drought[22].

Recurring climatic patterns have been identified around the world, most notably the El Niño–Southern Oscillation (ENSO)[ii], which causes systematic variations in temperature, precipitation, air pressure, humidity, wind and lightning occurrence over large areas[23]. Links between fire frequency, seasonality, area burned and ENSO have been detected[24]. For example, in the North American Pacific, warm and dry conditions are associated with El Niño[25], causing earlier spring snowmelt and therefore an extended fire season. Conversely, in the American south-west, warm and wet conditions related to El Niño increase vegetation growth. This new growth represents potential fuel during a drought. Therefore when El Niño is followed by a La Niña drought, widespread and severe fires can occur[26]. In Australia, an increased wildfire occurrence during El Niño phases is well established[27].

5.3 PAST AND RECENT TRENDS

Under one scenario, the global average area burned reportedly decreased slightly by about 7% during the first half of the 20th century[28]. The authors of this study attributed this to human factors, such as increased fire prevention, detection and fire fighting efficiency, abandonment of slash-and-burn cultivation in some areas, and permanent agricultural practice in others. During the second half of the 20th century, this trend reportedly reversed with a 10% increase in global area burned under that scenario. However, this trend is not reflected everywhere and there are regional variations and substantial uncertainties[29]. Overall this increase in the latter half of the last century has been attributed to land management changes, including increases in deforestation fires in the tropics[30], but it may also reflect a 'return' to a more ‘natural’ fire regime in areas where fire had been suppressed.

[i] The area where houses meet or intermingle with undeveloped wildland vegetation.

[ii] El Niño refers to the irregular warming in the sea surface temperatures from the coasts of Peru and Ecuador to the equatorial central Pacific. This disrupts the ocean-atmosphere system in the tropical Pacific with important consequences for global weather. This phenomenon occurs, on average, once every four years.

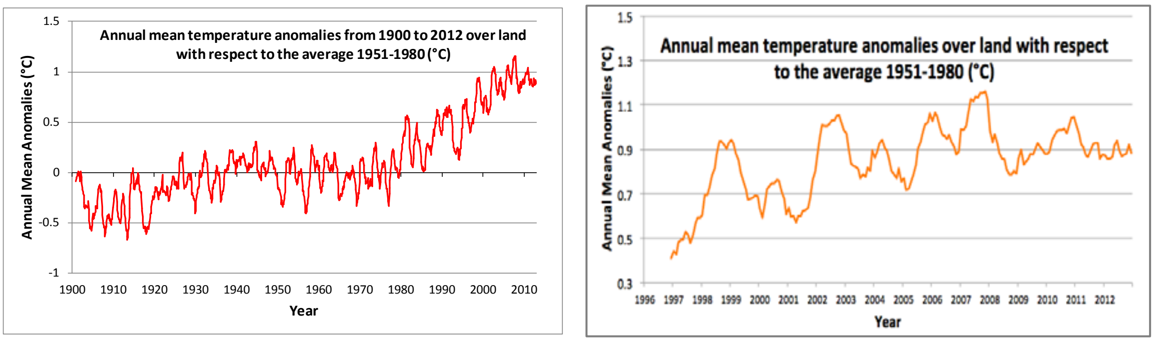


Figure 6: Average annual global land surface temperature deviation from the 1951-1980 average for the periods 1900-2012 and 1996-2012. (Data source: Columbia University 2013)

In addition, the increase in average global temperature observed between the 1980s and 2000 may have also contributed to this trend (Fig. 6). When considering the 20th century trends reported in the literature, it is important to recognise that they are marred by substantial uncertainty. The availability of satellite data allows a more robust and standardised evaluation of area burned, both globally and by region for the more recent past. Data and accompanying trends from 1996-2012 are summarised in Appendix 1, although it must be stressed that this period is too short to reliably identify long-term trends[31].

Trends by region

The boreal forest (Taiga) is the largest vegetation community on Earth, including 33% of the Earth's forested area. Its area burned increased slightly in North America, due to extended fire seasons in some areas, linked to an overall increase in temperature in this region[32].

Forests in the western US show an overall slight increase in area burned in the last decades largely due to unnaturally high fuel loads associated with decades of fire prevention[33] and climate change. A lengthening of wildfire seasons has arisen from increased spring and summer temperatures and earlier spring snowmelt[34].Considering area burned and the number of fires for the entire US during the last four decades (Fig. 7), an overall increase in area burned has been evident since 2000. Numbers of fires have seen an overall decrease, reflecting the occurrence of fewer, but larger fires.

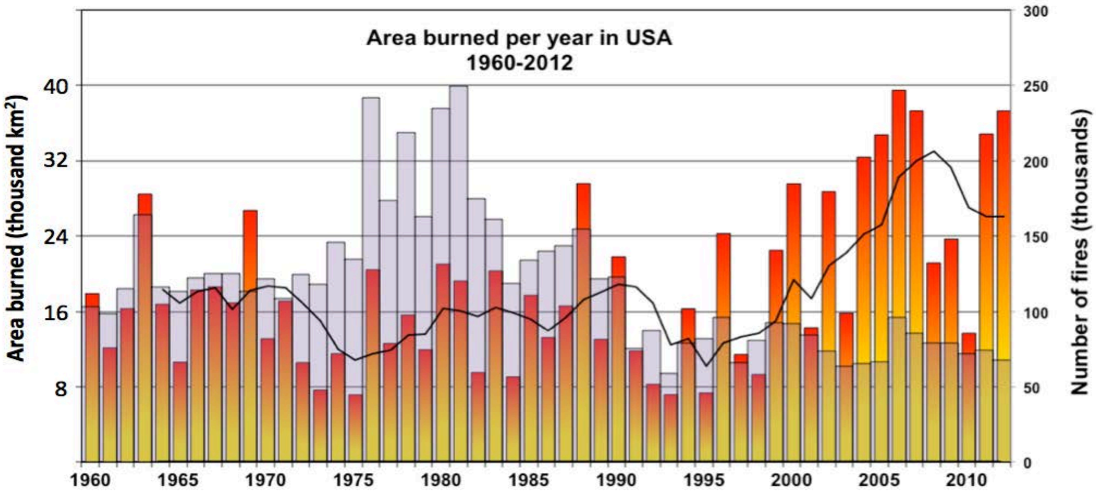


Figure 7: Average annual area burned (red-yellow bars) and number of fires (grey). The black line is the 5-year moving average for area burned. (Source: National Interagency Fire Centre; July 2013)

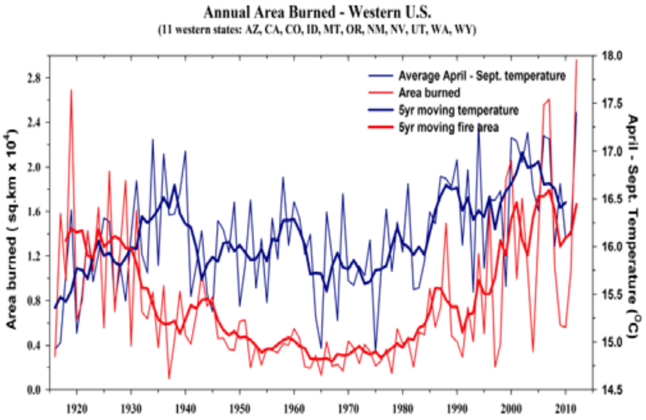


Figure 8: Area burned and average summer temperature from 1915 to 2012. (Source: J.S. Littell updated from Littell et al. 2009)

When looking at longer-term data, these trends are perhaps less dramatic (Fig. 8). For 11 western states in the US, data going back to 1915 reveals that the recent increase in area burned in this region is comparable to the area burned before aggressive fire suppression policies were adopted in the US. The 1950s to 1980s were a phase of unusually little area burned. This could be due to fire prevention and suppression measures, and also to climate as this was a period of relatively stable temperatures. These measures led to the accumulation of fuels in many forests and the recent increase could be seen, at least in part, as a return to a more typical scenario. The recent increase in temperature for the western US (Fig. 8) may have also been a contributing factor.

In the temperate regions of Europe, fire is now strongly influenced by human population and land use patterns, prescribed fire and fire prevention policy, and there are no clear general trends. However, in Mediterranean Europe, fire occurrence increased in the 1980s and 1990s as a result of changes in agricultural policy, causing rural exodus and establishment of forest and shrubland on abandoned land[35]. This increase in fire occurrence, however, did not translate into an increase in area burned (Fig. 5), indicating that fire size, in general, has been decreasing. A breakdown of area burned and number of fires for EU Mediterranean countries between 1998 and 2010 is provided in Figure 9. Portugal remains the most fire-affected country given its relatively small size. Extensive and highly flammable eucalypt tree plantations, combined with relatively moist winters followed by dry summers are likely to be contributing factors. The regional variability across Mediterranean Europe is also well illustrated here. Whereas Portugal had its greatest area burned in 2003, Greece and Italy were less affected. In contrast, the extensive fires in Greece and Italy in 2007 corresponded to only modest areas burned in Portugal and Spain. When considering Europe as a whole, the last 15 years show a high inter-annual variability with an overall slightly decreasing trend in area burned (Fig. 5).

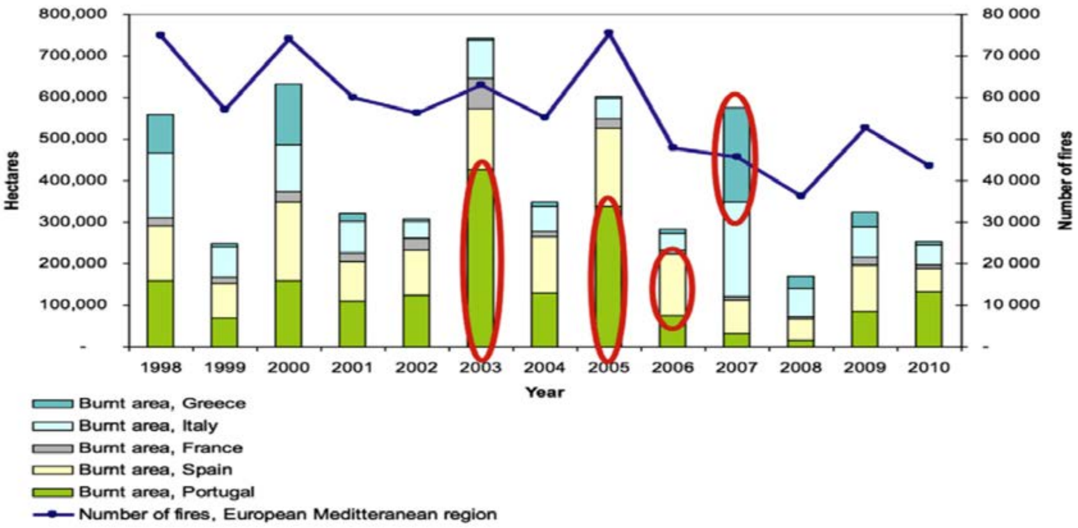


Figure 9: Area burned and number of fires for EU Mediterranean countries between 1998 and 2010. Fires highlighted in red are classed as 'Megafires' based on their large size and associated economic losses. (Source: San-Miguel-Ayanz et al. 2013).

Australia continues to be the ‘fire continent’, affected by ENSO-driven multi-year variability. During the last few decades, area burned in eucalypt-dominated forests and savannahs has remained constant or slightly decreased[36] with a particularly notable decrease (–10.7%/year) from 2001 through to 2009, which may reflect natural variability. This was followed by a major increase in 2011, in which the annual area burned exceeded the previous 14 years (Appendix 1).

Overall, global fire activity in terms of area burned appears to have increased over much of the second half of the 20th century followed by a minor (1.2%) overall decline in the last 15 years, albeit with regional increases in, for example, southern Africa and Asia (Appendix 1). This coincides with a levelling off of the observed overall global increase in average atmospheric temperature from the late 1990s associated with global climate change (Fig. 6). Although temperature is a key driver for wildfire activity, it is not clear whether recent trends in global temperature and therefore climate change have had a substantial effect on global area burned. As is evident from the examples, large regional and annual variations occur and the reasons for these differ between regions. It is clear that climatic effects, such as ENSO events, played a major role in driving trends in area burned although human activity has also been important. Perhaps the clearest trend in the effect of climate has been the lengthening of wildfire seasons in parts of western North America due to increased spring and summer temperatures and earlier spring snowmelt[37].

5.4 ANTICIPATED FUTURE TRENDS

Many studies show that the world will experience a future increase in wildfire activity[38,39,40,41], although this is still a much debated topic[42]; how much and where specifically the increase will occur is less clear. What is certain is that both land management and climatic changes need to be considered although most studies tend to focus on the latter.

Land management and socioeconomic trends will continue to affect wildfire occurrence irrespective of any future changes in climate. Socioeconomic changes continue to drive rural depopulation in some regions (although the current financial crisis may be slowing this trend in Mediterranean Europe), leading to increase in fuel loads and its continuity across the landscape. In regions, such as the western US, the Wildland Urban Interface continues to expand, leading to increased population, greater ignition probability and, most importantly an increase in values at risk.

In addition to these factors will be the effects of climate change. Global warming, resulting from an increase in greenhouse gases in the atmosphere, is expected to accelerate in the future[43]. Warming is expected to lead to a general increase in wildfire activity due to greater flammability (fuel dryness) and more lightning strikes[44]. This overall trend is complicated by regional variability in precipitation (notably the severity and duration of droughts), atmospheric moisture, wind, and cloudiness[45,46]. Vegetation patterns, and therefore fuels, will be altered to both direct effects of climate change and indirectly as a result of changing fire patterns[47]. Therefore, the projected magnitude of change and whether wildfire frequency, severity and area burned in a specific region will increase or decrease is hotly debated[48]. Existing studies predicting future fire activity have used various greenhouse gas emissions, and associated temperature and precipitation scenarios, based on global climate models (GCM) outputs. The potential impacts of these climate driven trends on wildfire activity is examined further below.

According to some studies, global area burned is expected to rise due to the increased temperatures predicted for many regions[49,50]. Most published estimates focus on North America. For Canada, an increase of 74–118% by the end of this century has been suggested[51]. For Alaska, increases of 14–34% for 2025–99 relative to 1922–96 are predicted[52]. In California, where a high population density in the Wildland Urban Interface puts lives and property at a particularly high risk, estimated future changes in area burned range from a 41% increase for the San Francisco Bay area and the Sierra Nevada to an 8% decrease for the north coast of California part[53].

One set of projections shows that wildfire occurrence in general is expected to show "substantial and rapid shifts across vast portions of the globe"[54]. Predicted fire probabilities based on this recent study for the periods 2010-2039 and 2070-2099, considering both future climate and its influence of on vegetation growth, are given in Figure 10. According to this study, for the first period, increases are most probable in fire-prone areas that already experience a warm climate, such as Mediterranean regions, mountainous and desert grass and shrub lands, and temperate coniferous forests, although different models do not agree on whether fire occurrence will decrease or increase for over 50% of terrestrial land. Towards the end of the century, the magnitude of change and the level of agreement between models increased. Over 60% of the increase in global fire probability occurs in the mid- to high-latitudes (boreal forest and tundra, temperate forests, mountainous grass and shrub lands), while most tropical vegetation types are predicted to see a 20% decrease in fire probability. In parts of the circum-Atlantic region, a slight decrease is also expected due to a wetter climate.

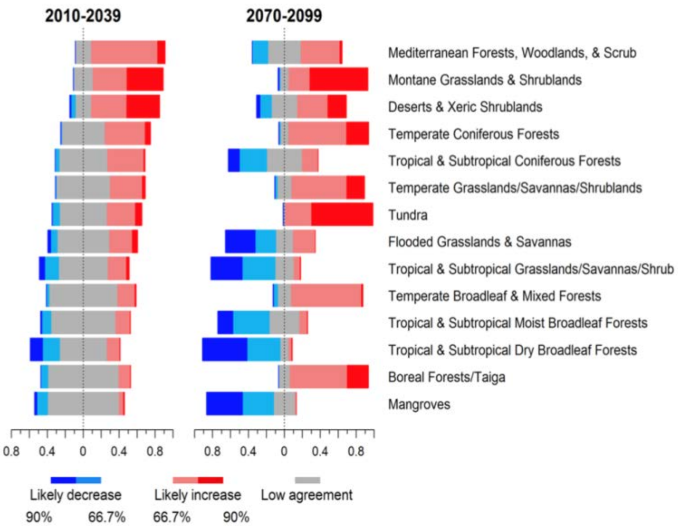
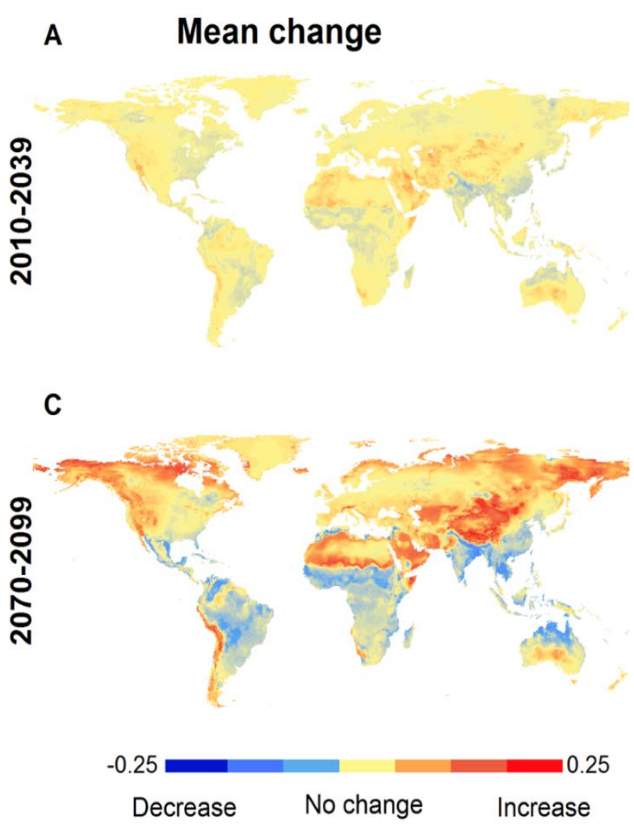


Figure 10: The proportion of global ecosystems by decreasing or increasing fire probability class for 2010–2039 and 2070– 2099 time periods based on predictions using 16 Global Climate Models. Light and dark colours refer to different % levels of agreement between models. (Source: Moritz et al. 2012)

Figure 11: Average change in modelled fire probability based on 16 GCMs. (Source: Moritz et al. 2012)



Therefore, the projections shows that in the nearer term (2010-2039), regions, such as the western US, south-west Canada, parts of the Mediterranean basin, eastern Siberia, south-central Australia, western South America, and much of the drier regions of Africa and Asia could potentially experience greater fire occurrence associated with anticipated climate change (Figure 11-A). In the longer term (2070-2099) this overall trend is predicted to become, and remain, much more pronounced (Fig. 11-C).

Wildfire severity and intensity would also be expected to rise with increasing temperatures, particularly where increased severity of droughts leads to very dry fuel conditions. For boreal Canada and Russia, severity and intensity are predicted to rise[55]. For other regions, however, few predictions exist and future changes are likely to vary by region. Fire severity is strongly influenced by fuel load, but given that climate change is likely to influence vegetation growth, composition and decomposition rates, the net impact of future climate on fuel load remains unknown[56]. In more populated areas, where risks to lives and property are greatest, human activity is likely to continue to be an equally important factor determining fuel loads.

In summary, area burned and fire occurrence are potentially predicted to increase, based on a range of climate change scenarios, but some regions will experience decreases or little change. The length of the fire season in some of the temperate and boreal regions of the world already shows an increasing trend, which is expected to continue. In some areas of the tropics, future climate may be less conducive to burning; however, this could be offset by increased human-caused fire activity. Future fire severity and intensity are more problematic to predict. Regional increases in drought and temperature are likely to lead to increases in both fire severity and intensity and associated risk of losses. Surprises could be expected in the future due to our limited understanding of the complex interactions between weather–climate, vegetation response and human activity[57].

6 WILDFIRE LOSSES

6.1 HUMAN LOSSES

Direct casualties

It is estimated that a total of 1933 people have been killed worldwide in 303 catastrophic wildfire events in the last 30 years (between 1984 and 2013), with the deadliest events having occurred in Indonesia (240 deaths, 1994), China (191 deaths, 1987) and Australia (173 deaths, 2009). The total number of people affected by wildfires is estimated at 5.9 million[58], which translates to an overall probability of death of 0.03% within the wildfire-affected population (Table 1). This is an order of magnitude greater than the risk of death from flooding (0.006%), whereas the risk of death from seismic activity (earthquakes and associated tsunamis) is much greater than that from wildfire (0.57%).

Firefighters have a much greater exposure to wildfire risk than the general population and, despite major advances in techniques, equipment and the prediction of fire behaviour, deaths continue to occur. For example, the recent Yarnell Hill Fire in Arizona in 2013 resulted in 19 deaths[59].

Indirect casualties

Exposure to fire smoke can be a serious health threat, as was the case for the extensive fires around Moscow in 2010 and in South East Asia in 2013. Short-term effects include respiratory infections, asthma, conjunctivitis, rhinitis, and also increases in mortality related to accidents and aggravating of chronic conditions, such as respiratory and cardiovascular diseases[60]. These effects are greater among children, the elderly and people with pre-existing respiratory problems. Other longer-term effects, for example, can occur through exposure to carcinogenic components of smoke.

The first global estimate of premature deaths linked with landscape fire smoke over a ten year period (1997–2006) is 339,000 people per year[61]. By comparison, urban air pollution kills an estimated 800,000 people per year worldwide. Most fire smoke deaths occur in low-income areas (46% in sub-Saharan Africa and 32% in Southeast Asia), where large numbers of intentional burns for agriculture and land-use change take place. Strong El Niño conditions (see section 5.2) appear to contribute to more deaths, with an estimated 532,000 deaths during the 1997–1998 El Niño cycle, which was associated with increased fire activity (compared with 262,000 deaths during the 1999–2000 La Niña cycle).

Table 1: Comparison of human and economic losses derived from wildfire, seismic activity (earthquake and tsunamis) and flood disasters from 1984 to 2013. (Source: EM-DAT 2013)

	Wildfires	Seismic activity	Floods
No. of Events	303	758	3,432
People Killed	1,940	849,609	197,202
Total People Affected	5,808,986	148,522,190	3,119,638,798
Risk of death (%)*	0.033	0.572	0.006
Total costs ($)	52,301,080,000	697,831,942,000	554,015,614,000
Cost per event ($)	172,610,825	920,622,615	161,426,461
Cost per person affected ($)	9,003	4,699	178

*No. of fatalities per No. people affected (%)

6.2 ECONOMIC LOSSES

The economic losses associated with wildfire vary considerably between events, ranging from negligible to several million US dollars. Direct economic loss is mainly associated with wildfire impacts on property, other infrastructures and, where applicable, forestry resources. However, indirect impacts can also cause substantial losses. Examples of these indirect costs include atmospheric pollution by smoke and ash affecting human health and traffic, carbon dioxide and other greenhouse gas emissions (relevant in terms of carbon accounting), and post-fire effects, such as contamination of water supply reservoirs and fish stocks by accelerated soil erosion, or increases in destructive flood events and debris flows[62,63].

Global estimates of losses are typically based on limited data and caution is advised when using these, but the 303 worldwide wildfire disasters[iii] that are listed by the International Disaster Database (EM-DAT) in the last 30 years (1984-2013) are estimated to have caused $52,300m in economic losses (Table 2). Over half of these are in the Americas, which account for over one third of the global events listed. In contrast just over one fifth of all estimated losses are in Asia, which has over half of the total global population affected by fire. This is likely to reflect overall differences in development, and perhaps also a bias in data availability towards North America. National or sub-national estimates tend to be more detailed and can indicate overall higher economic losses. Therefore, for the US alone, catastrophic[iv] wildfires from 1980 to 2011 are estimated to account for more than $28,500m in losses[64]. Between 2002 and 2011, wildfires accounted for $13.7 bn in total economic losses, a spike from the previous decade, which saw $6.8 bn in economic losses[65].

Table 2: Summary of wildfires caused human and economic losses by global region from 1984 to 2013. (Source: EM-DAT 2013)

	N. of events	People killed	Total people affected	Economic costs ($)
Africa	25	272	21,672	440,000,000
America	118	234	1,229,175	25,228,900,000
Asia	50	748	3,188,257	11,892,500,000
Europe	89	462	1,295,562	12,618,811,000
Oceania	21	224	74,320	2,120,869,000
Total	**303**	**1940**	**5808986**	**52,301,080,000**

No direct relationship between human losses or number of people affected by wildfires and the economic losses associated to them has been identified (Table 2). Wildfires in densely populated areas may affect more people, but this does not necessarily imply high economic costs, especially in developing countries. For example, comparing the Top ten wildfire disasters' years by country in terms of total people affected and economic costs (Appendix 2), seven of the ten most important in terms of people affected occurred in developing countries[v] whereas only two of the ten most economically costly occurred there, with the remaining eight located in developed countries[vi].

A list of the 20 countries most affected by wildfire disasters in terms of economic damage since the beginning of the last century is given in Table 3. The US is the country with the highest economic losses, followed by Indonesia and Canada.

[iii] For a disaster to be included at least one of the following criteria has to be fulfilled: ten or more people killed; 100 people affected; a call for international assistance; declaration of a state of emergency. Thus, many wildfires that led to economic losses are excluded.

[iv] ISO's Property Claim Services unit (PCS, January 1, 1997) defines catastrophes as events that cause more than $25m in insured property damage and that affect a significant number of insured and insurers.

[v] Defined according to the International Monetary Fund's World Economic Outlook Report, April 2012.

[vi] Amongst the 35 developed countries listed by the International Monetary Fund's World Economic Outlook Report, October 2012.

Table 3: The 20 countries most affected, in terms of economic damage, by wildfire disasters for the period 1900 to 2013 (Source: EM-DAT, 2013).

Country	N. Events	Damage (millions $)
United States	64	17,787
Indonesia	9	9,329
Canada	20	6,463
Portugal	8	3,475
Spain	14	2,754
Australia	30	2,645
Greece	13	2,425
Russia	22	2,183
Mongolia	3	1,823
Italy	7	1,700
Chile	9	880
South Africa	9	440
Israel	3	315
Malaysia	4	302
Yugoslavia	2	200
China	6	110
Argentina	5	100
Mexico	3	91
Nicaragua	3	80
Croatia	5	38

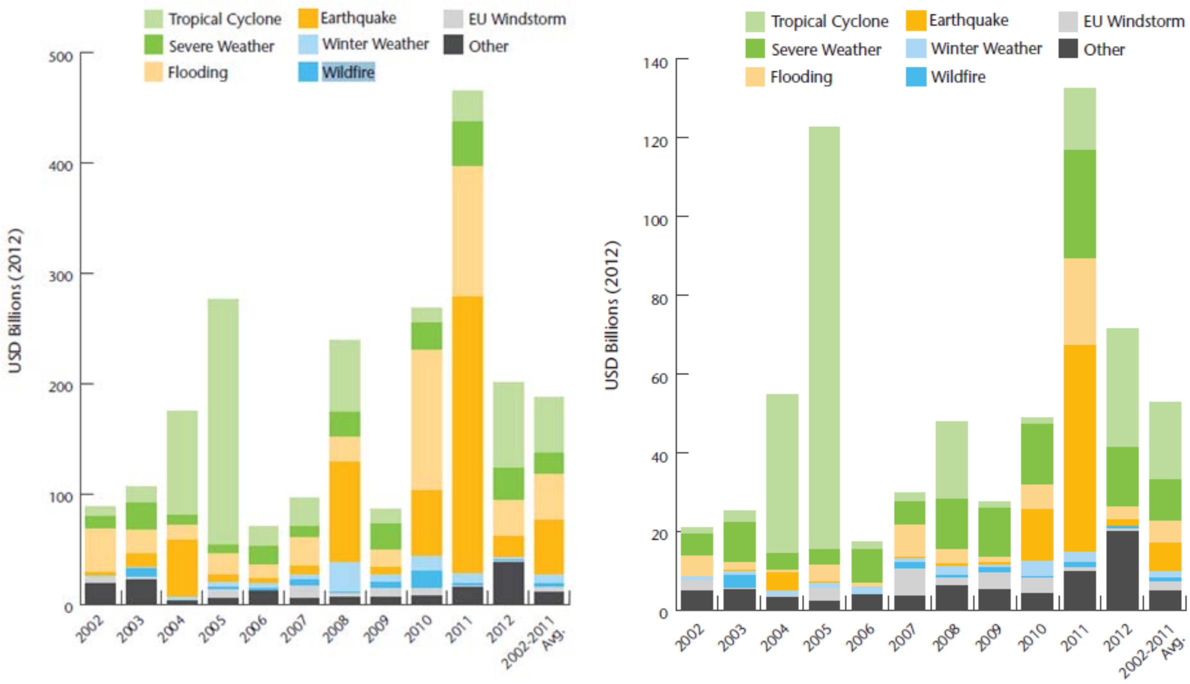
Regarding future trends in losses, the combination of predicted increase in global temperature and extreme climatic conditions, coupled with a growing world population and land use changes is expected potentially to lead, overall, to increased fire occurrence, area burned and probably also more severe and therefore damaging wildfires. An overall increase in losses might therefore be expected. In addition to this, in many countries fire-prone landscapes have seen increasing urbanisation in recent decades. For instance, in the US the Wildland Urban Interface grew in area by 19% during the 1990s, and in 2000 it represented 38% of all housing units for the lower 48 US states[66]. The expansion of the Wildland Urban Interface increases the number of people and expensive infrastructures at risk of wildfire. This alone would be expected to lead to an increasing trend in losses. In addition, the anticipated increase in fire activity in many regions of the mid-latitudes affects much of the population living in the Wildland Urban Interface. Furthermore, other extreme-weather related catastrophic events such as severe droughts and electric storms, which are predicted to increase in some regions[67], are likely to enhance wildfire risk. However, the actual trend in losses will depend not only on these 'external' fire variables, but also on the mitigation and post-fire rehabilitation strategies applied.

7 TRANSFERRING WILDFIRE RISK

The evolution of insurance was partly led by major catastrophic fire events in Europe, highlighting the significance of fire as a peril for insurers throughout history. Fire insurance dates back to the 17th century as it developed following the 1666 Great Fire of London which destroyed over 13,000 structures. Fire insurance evolved in urban centres, where there was a high concentration of wooden structures, and only later widened to properties in non-urban environments. While the risk of fire in cities has significantly decreased as brick and concrete structures have replaced wood, the risk of damage, especially to property in the Wildland Urban Interface, from wildfires is on the increase. The majority of wildfire insured losses have resulted from property damage in the Wildland Urban Interface and property exposure in this area will most probably increase. As economic losses are potentially set to rise due to population growth, increased property value and a growing desire to live in the Wildland Urban Interface, insured losses are likely to experience the same trend as economic losses. Therefore, insurers need to be aware of their exposure to wildfires and the implications of wildfires across their books of business.

7.1 INSURED LOSSES

The graphs below compare economic and insured losses from major perils between 2002 and 2012. Wildfire disasters are present every year, although their magnitude varies and their relative importance in terms of insured loss is relatively small compared to other natural catastrophes, such as earthquakes, floods or tropical cyclones.



Global Economic Losses by Peril

Global Insured Losses by Peril

Figure 13: Global economic and insured losses from major catastrophic events over the period 2002-2012. (Source: Aon Benfield, 2012)

Insured losses for wildfires should not be underestimated; wildfires have accounted for billions of dollars of insurance losses in California and in Australia alone over the past quarter-century[68]. Although comparatively, tornadoes cost the insurance industry over $25bn in 2011 alone as highlighted by a Lloyd's report on tornadoes[69,70].

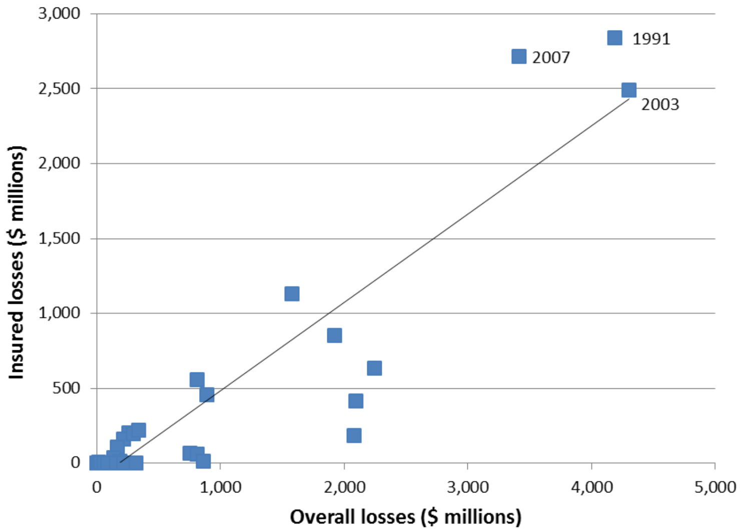


Figure 14: Relationship between overall and insured economic losses ($ millions) from catastrophic wildfires in the US over the period 1980-2011 (coefficient of determination R2: 0.83). Each point represents the total losses for each year. The three years with highest overall and insured losses are labelled in the graph (Data from III, 2013).

In the US, catastrophic wildfires caused $595m of insured losses in 2012 alone[71]. Between 1980 and 2011 wildfires are estimated to have accounted for more than $28,500m in economic losses. An average of 47% of these losses was insured[72]. Between 2002 and 2011, wildfires accounted for $7.9bn in insured losses in the US, an increase from the previous decade when insured losses from wildfires were estimated at $1.7bn[73]. If anticipated predictions of increasing wildfire and therefore associated economic losses become reality and the current trend continues, an increase of insured expenses derived from wildfire catastrophes should be expected.

In California wildfires have resulted in $8.5bn in insured losses since 1990[74]. In July 2013, the insured losses of the June 2013 Black Forest Fire in Colorado had already been estimated at $292.8m[75]. It is the second costliest wildfire in Colorado in terms of insured losses after the Waldo Canyon Fire (Box 1), although the Black Forest Fire is considered the most destructive in terms of number of properties destroyed[76].

Box 1: 2012 Waldo Canyon Fire

The 2012 Waldo Canyon Fire in Colorado's springs burned approximately 7400 hectares over 18 days. The ignition was apparently human-caused although no one knows whether it was intentional or accidental. It is reported to have destroyed 346 homes[77] and led to the evacuation of 32,000 people. It was ranked as one of the 20 most costly insurance losses in 2012[78].

It is estimated to be the costliest wildfire in Colorado with insurance costs totalling $453.7m from about 6,648 claims[79]. As highlighted above, the Black Forest Fire destroyed more properties but did not top Waldo Canyon Fire's insured losses because Black Forest residents filed fewer homeowner and automotive claims. The difference in insured losses may lie in the types of properties and neighbourhoods which were devastated. The Waldo Canyon Fire was located in a more densely populated urban neighbourhood which led to an increased number of claims[80].

In Australia, wildfires have accounted for 10% of insured losses from all natural disasters with average annual insured losses estimated at AU$120m based on Crompton and McAneney's analysis[81,82]. The costliest bushfire for the insurance industry dates back to 1983. The 1983 bushfires in Victoria, more commonly known as Ash Wednesday bushfires, took place on 16 February and lasted twelve hours. Years of drought associated with extreme weather resulted in more than 180 fires blown by winds of up to 110 km/h which amounted to AU$1.3bn in insured losses[83]. This event led to changes in the event definition in catastrophe contracts; since then, the standard Australian provision for bushfires has treated all fires in Australia within a set period (usually specified as 168 hours or 7 days) as constituting a single event, even if the fires are as far apart as Tasmania and Western Australia.

Box 2: 2009 Black Saturday

A decade of drought combined with high wind speeds of 95km/h and a month free of rainfall resulted in six major fires breaking out on 7 February 2009 in Australia's Victoria state. The 2009 Black Saturday Fires burned through over 4,000 km2 and destroyed more than 2,000 homes and 3500 structures. The 2009 Victorian Fire caused AU$1.3bn in insured losses[84], which included buildings and contents claims as well as motor claims. It was the deadliest bushfire in Australia in over a century, killing 173 people[85]. The ignition is thought to have been the result of different sources, including lightning and a downed power line. Based on these findings a number of class actions were started against energy provider SPI Electricity, Utility Services Corporation Limited, as well as the Department of Sustainability and Environment (DSE) amongst others. A class action against SP AusNet and the Victorian Department of Sustainability and Environment over the Black Saturday fires at Beechworth was settled out of court for $32.8m with SP AusNet's share being $19.71m. Insurers paid for SP AusNet, although the overall size of its cover is unknown[86].

The township of Marysville after the 2009 Black Saturday fires (Source: Doerr)

Canada is another country which has suffered devastating wildfires, leading to large insurance claims. The 2011 Slave Lake wildfire burned 48.6km^2 in two days and destroyed one third of Slave Lake Town. Claims were filed for damage to homes, cars and businesses triggering $0.7bn in insured losses, making it Canada's second costliest insured catastrophe at the time[87].

These figures show us that although wildfires represent a relatively small proportion of total insured losses compared to flooding or tropical cyclones, the cost of wildfires to the insurance industry should certainly not be overlooked. This is especially relevant for regions such as North America and Australia where insurance penetration is high and properties at risk are of high value.

7.2 MODELLING WILDFIRE LOSSES

Predicting wildfire insured losses is difficult as changes in building practices and developing urbanisation of wildfire risk prone areas limit the effectiveness of relying on historical losses. However, despite the limitations of historical data, businesses continue to rely on them to estimate future wildfire losses. Companies, such as RMS, AIR and Eqecat, have developed catastrophe models for potential high exposure regions, such as California and Australia. These models incorporate additional factors to historical data, such as weather data, post-disaster damage survey, elevation and related slope and aspect, susceptibility of a structure and accessibility of locations for initial fire suppression efforts.

7.3 INSURANCE IMPLICATIONS

Property is the most exposed line of business to wildfires, as the majority of loss results from destroyed or partially burned property structures and their contents. Losses also include claims from smoke damage, additional living expenses due to the mandatory evacuation, and home cleaning[88]. The flammability of a structure's exterior surface, especially the roofing and wall-siding materials, are a critical factor in defining its vulnerability to fire. For example, wood shingles is much more vulnerable to fire than aluminium.

The risk of wildfire to property, and the related insured losses, has increased partially as a growing number of people choose to live in the Wildland Urban Interface, an area where property value tends to be higher. For example, in California more than five million homes are based in high risk areas which is more than twice as many as in any other states; in western United States, nearly 40% of new home development is in the Wildland Urban Interface[89].

An additional area affected by wildfires is agriculture. Multi-peril crop insurance (MPCI) covers agricultural losses caused by severe hazards including wildfire. In the summer of 2010 in Russia, agriculture was severely disrupted due to drought and wildfires[90], leading to insured losses. Although crops are vulnerable to wildfires, droughts will normally drive the loss. In comparison to other perils, such as hail, wildfire is not considered a major peril for crop insurance. However, forestry has been regarded as more vulnerable to wildfires. According to Forest Re, a single catastrophe event can typically be in the order of $35m for forestry[91]. Many insurers suffered major losses on their forest portfolios in 2003 due to fires in Australia and Chile. Regions exposed to such perils include Chile, Indonesia, South Africa and the US. Forestry is also covered in many crop insurance covers in China, exposing insurers and reinsurers to losses not experienced in the past with respect to agriculture insurance covers.

Following a wildfire, business interruption may also occur, with those sectors at risk including forestry and agriculture. In Virginia, forests are the source of $27.5bn income every year, with 144,000 people employed in forestry. Wildfire threatens 16m acres of forest and the livelihoods of the population of Virginia[92]. In South Africa, the forestry sub-sector contributes significantly to the national and provincial economies and employment; forestry directly employs 66,500 people and there is approximately 1.8m people whose livelihood is dependent on forestry[93]. Business interruption cover will include interruption prior to the event due to evacuation, during and after the event depending on the damage. Commercial property policies with business interruption coverage vary widely with regard to coverage of business income loss due to order of civil authorities. Some policies require direct physical damage to the property before business interruption coverage is triggered. Generally, under these types of policies, where the order of civil authority (and not physical damage) causes the business interruption loss, coverage is not triggered. Other polices require a direct link between the civil authority order and the suspension of the insured's business[94].

Historically, only about 5% or less of total insurance losses in wildfires have been commercial, as most properties at risk are concentrated in residential areas and during a wildfire event business interruption does not play a large role in commercial losses[95]. Nevertheless, given that wildfire is a threat both to property structure and to business continuity, the peril should be carefully considered.

Liability insurance is also another line of business which may be affected by wildfires as unintentional ignition could lead to large claims under a liability cover as demonstrated by Sempra's case in 2007 (see box 3) or the 2009 Black Saturday case (see box 2). Wildfires are one of the few potential man-made natural catastrophes, which can affect liability insurers. If there is evidence that a fire was the result of human action and liability is established, the claims will be transferred from property to liability insurers. The Ash Wednesday bushfires was another case when much of the insurance burden was transferred from the property to the liability area although it took several years to establish liability and for recoveries to be made by the property insurers. One of the main causes was due to inadequately maintained power lines belonging to the electricity authorities of South Australia and Victoria. The total amount recovered was $135m although this included uninsured recoveries as well[96].

Motor is another line of business which can be affected by wildfires. Following a wildfire event, there may also be repercussions on health insurance because of secondary health problems caused by smoke, smog, burns or even water contamination from the fire.

Box 3: Sempra and 2007 Californian wildfires

In 2007 a series of wildfires, fuelled by a drought, hot weather and unusually strong winds began burning across Southern California. The wildfires lasted 19 days and led to the death of two people and the destruction of 1200 homes.

Actions against Sempra Energy's San Diego Gas & Electric Co. (SDG&E) were taken on the basis of two reports stating that two of the fires were caused by SDG&E power lines and that a third fire was sparked when a Cox Communications fibre optic cable came into contact with a SDG&E power line. They were also accused of not having properly designed and maintained their power lines as required by commission rules. More than 100 lawsuits were filed over damage caused by the fires[97], claiming close to $1bn[98].

Although the defence attempted to claim the wildfires resulted from an "Act of God", insurers had to pay out the claims under Sempra's liability coverage. Sempra reached a $686 million settlement with several homeowners' insurance companies which was met by its liability insurance coverage[99].

8 MITIGATING WILDFIRE RISK

8.1 EARLY WARNING SYSTEMS

Early warning systems identify critical time periods of extreme fire danger to facilitate fire prevention, detection and suppression. The Global Early Warning System for Wildland Fire provides a one to seven day forecast that identifies the expected future fire danger trend by means of an index that ranges from low (0-5) to extreme (>30) (GWFEWS 2013). It provides a means of comparing relative fire danger conditions between countries, continents, and biomes. Updated maps can be downloaded from http://www.fire.uni-freiburg.de/gwfews/forecast_ews.html.

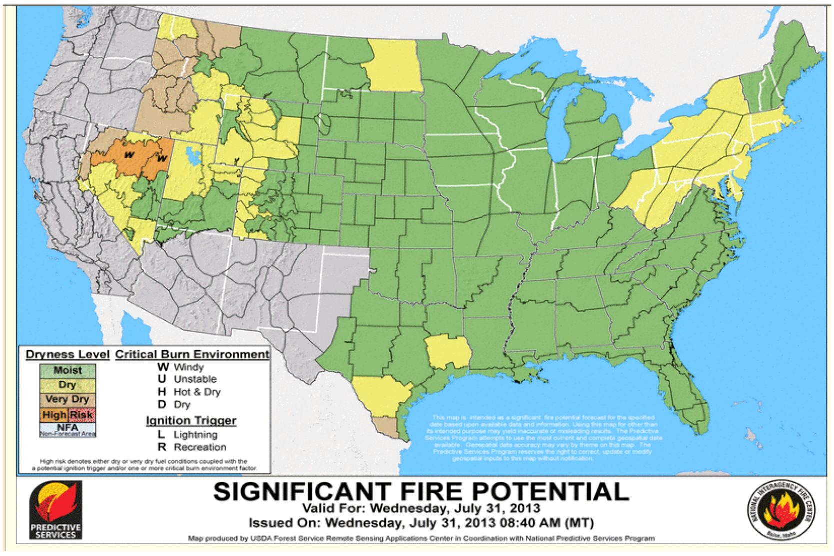


Figure 16: Significant Fire Potential forecast for 31 July 2013. (Source: NICC www.predictiveservices.nifc.gov/outlooks/outlooks.htm).

At a more detailed spatial scale, for example, the US National Interagency Coordination Center provides seven day fire weather, fire danger, and fire potential reports based on fuel conditions, weather and resource availability (Fig. 16). It provides daily probability of a new large fire and/or the daily potential for significant new growth of existing fires.

8.2 FIRE PREVENTION

Wildfire policies over the last century have focused on eliminating fire from the landscape[100,101]. However, wildfire is part of the natural cycle of many ecosystems and human intervention can typically only delay but not stop its occurrence. Critically, reduced occurrence can lead to unnaturally high fuel loads, which, in combination with extreme weather, can eventually lead to mega-fires. Although they represent only a small proportion of the total numbers of wildfires, they account for a high percentage of total suppression cost, private property losses, damage of natural resources and fatalities. Mega-fire incidence shows that prevention/suppression-centric wildfire protection programmes are not effective although this is not yet fully acknowledged within the fire management community or the general public[102]. Other wildfire risk mitigation strategies are discussed in the next section.

8.3 MITIGATING WILDFIRE RISK

An effective wildfire mitigation strategy needs not only to minimise the effect of wildfire on lives and property, but also to avoid conditions that may lead to particularly damaging fires. This means not only protecting properties and other infrastructures against fires, but also managing the landscape in a way that minimises the risk of severe wildfires.

Efforts to move away from a suppression focused policy require the re-introduction of natural fire occurrence and risk mitigation efforts to protect Wildland Urban Interface communities. Florida and Western Australia have recently developed prescribed fire programmes to complement suppression capabilities and they have largely avoided high impact mega-fires[103].

Wildfire public policies often differ between countries or regions. In the US, fuel reduction projects on public lands are part of the National Fire Plan[104] and Healthy Forest Restoration Act of 2003[105]. Many south-eastern states recognise the application of prescribed fire for fuel reduction, whereas Washington and California prohibit it except under special circumstances[106]. In Colorado, the use of prescribed fire is currently limited due to associated implications for air quality. In Australia, prescribed burning is one of the main tools for fire management on public land, and following the catastrophic 2009 Black Saturday fires, legislation in Victoria now requires that at least 5% of the public land is subjected to prescribed burning each year. In the European Union a common fire management policy does not exist. The regulation of fire (prescribed fire and suppression fire practices) is only considered in the legal framework in France, Portugal and Spain. In non-Mediterranean Europe wildfire policy is usually limited to suppression[107]. Introducing zoning regulation that by law limit or even prevent building in areas with high wildfire risk would be a major step forward in wildfire risk mitigation.

Wildfire risk mitigation by governments alone is arguably insufficient and it has been suggested that risk mitigation strategies need to be a joint effort between public agencies and private owners. Different public policies can increase the commitment of private landowners, such as subsidising private spending on fuel treatments, enacting legislation that marries insurance availability and premiums to risk mitigation behaviour and providing education about wildfire risk and mitigation. For instance, laws exist in some US states that require fuel treatments on private land.

Increasing private wildfire risk mitigation can greatly reduce the risk of loss, but gaining the commitment of homeowners is challenging. First, homeowners in the Wildland Urban Interface generally prefer the natural aesthetics offered by dense forest environments, which are incompatible with reducing wildfire hazards[108]. Second, wildfire risk needs to be addressed from a communal rather than an individualist approach, as decisions taken by neighbours will affect the overall risk. For example, a single property with substantial amounts of flammable vegetation can undermine the effectiveness of mitigation for neighbouring properties. Third, government and insurance programs can influence homeowners' risk management decisions but not necessarily in the 'correct' way. For example, private landowners in the Wildland Urban Interface may perform too little fuel treatment as they already benefit from public fuel treatment[109]. Also, some people may view fire suppression assistance and insurance coverage as substitutes for property risk mitigation[110].

A number of different approaches have been suggested to stimulate private action to mitigate wildfire risk:

- Create awareness across different social contexts to change aesthetic priorities ('safety first') and involve private landowners in wildfire risk mitigation[111].

- Effective mitigation needs to focus at the community level. Conditions on adjacent properties are an important consideration and the spending on private mitigation efforts increase when information about other private individual expenditures is available[112].

- Public incentives can be made conditional upon a threshold level of private mitigation effort being achieved, which ensures private commitment[113]. Regarding insurance coverage, mitigation information can be used to set premiums. However, insurers may have difficulty in verifying mitigation by policyholders, and they would also need similar information for adjacent properties. Where communities issue certificates, they ensure the whole community satisfy the criteria (eg www.firewise.org)[114]. Even among lower-income residents, premiums could prove effective where savings offered by discounted policies cover the costs of mitigation. Additionally, cost-sharing programs that make mitigation affordable for low-income homeowners can promote action.

- Private property specific measures include: reducing fuel loads; creating strategic breaks in fuel sources and avoiding continuity between different fuel sources; maintaining an effective defensible space and regularly removing debris from areas on and near the home; ensuring a safe distance between houses to avoid home-to-home fire spread; using flame resistant building materials, and applying flame retardants[115].

9 CONCLUSIONS

Wildfires are an ecologically important phenomenon in many forests, shrubs and grassland regions across the globe, and have occurred naturally over many millions of years. Lightning causes most natural ignitions, but human ignitions are also a common cause of wildfire starts. The most destructive fires, sometimes called mega-fires, are typically associated with high fuel loads, prolonged dry conditions prior to the fire, high temperatures and strong winds.

In populated regions, wildfires pose a risk to lives and infrastructures and significant losses occur particularly where fires affect a large area and are of high severity. Early warning systems exist to predict when the risk of fire is particularly high; however, the occurrence of such fires can normally not be prevented. In contrast, attempts to exclude fire from the landscape can cause the build-up of fuel, which ultimately leads to more severe fires. Controlled management burns can go some way to reducing fuel loads and subsequently the severity and damage caused by future fires. However, they are arguably unlikely to be sufficient to prevent large fires in the future.

Socio-economic and associated land-use changes also affect wildfires. For example, population increases in the Wildland Urban Interface in North America have raised ignition risk and values at risk, whereas rural depopulation in much of the European Mediterranean has led to fuel build-up, increasing the risk of severe fires.

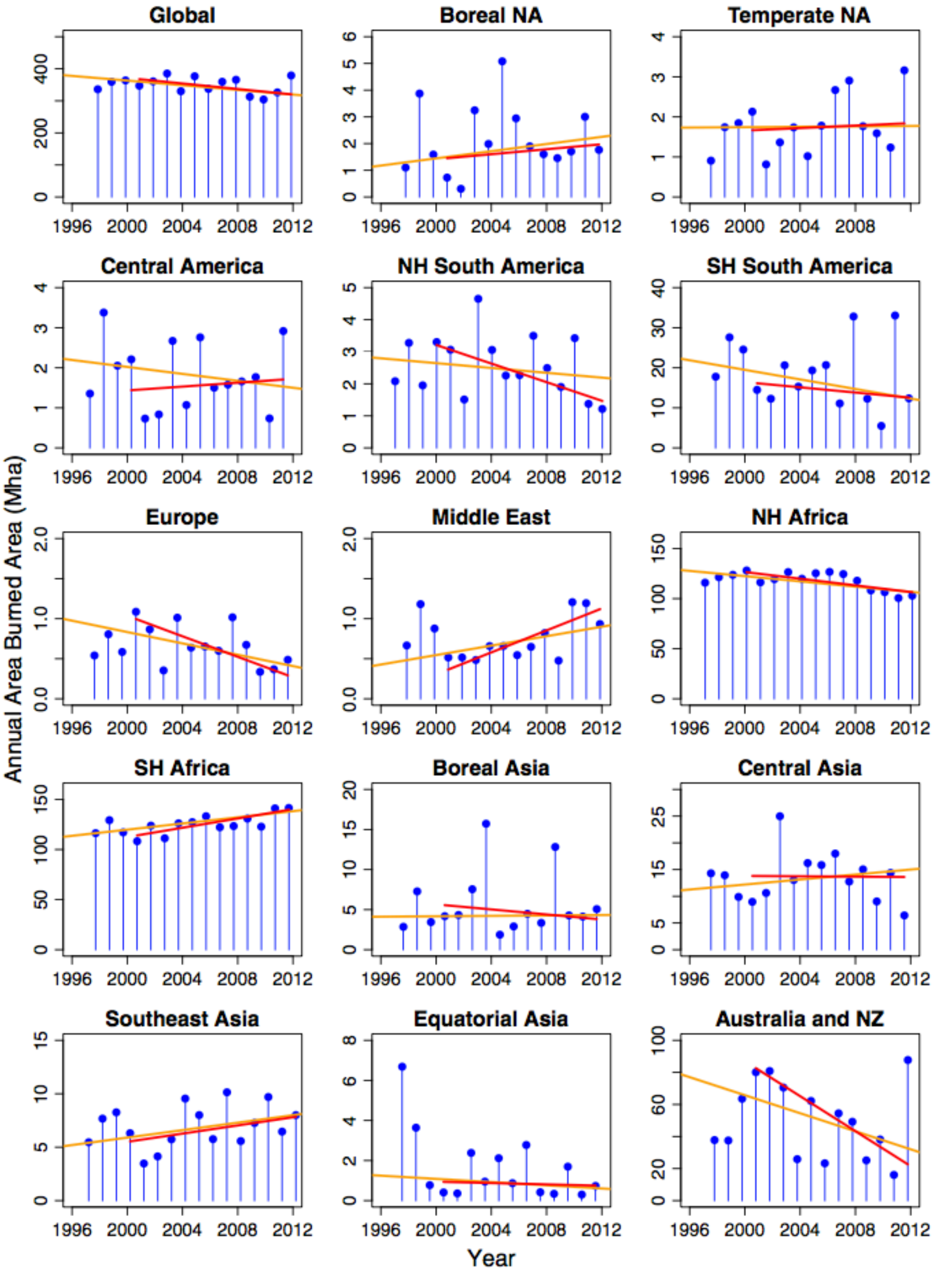
Climate also affects wildfire occurrence, with droughts and heatwaves increasing wildfire risk. Recent changes in climate have already led to a lengthening of the fire season and increases in area burned in some of the temperate and boreal regions of the world. These increases are not followed everywhere and when averaged across the globe, area burned has changed little over the last 15 years, which coincides with the levelling off of the marked increase in average atmospheric global temperatures since the late 1990s, while global warming has been flowing into the world's oceans.

The further increase in temperature and, for some regions, greater drought frequency and severity, predicted under future climate change scenarios, could lead to substantial increases in fire probability and therefore likely area burned during the 21st century for many parts of the world. A recent global analysis suggests that the greatest increases can be expected for the western US, south-west Canada, parts of the Mediterranean basin, eastern Siberia, south-central Australia, western South America, and much of the drier regions in Asia. However, there may be surprises due to our limited understanding of the complex interactions between weather and climate, vegetation response and human activity.

Nearly all of the most costly wildfires (total and insured economic losses) have occurred in the regions listed above (most notably the US) and therefore the expected increases in fire activity in the future can be expected to have some implications for the insurance industry, namely in the form of increased losses.

While extensive and severe wildfires cannot be prevented, effective risk mitigation strategies exist that have the potential to lead to significant reduction in human and economic losses from wildfire. Much of these require action at the community and homeowner level. Also the implementation of zoning, i.e. regulating building in areas with high wildfire risk, could represent a major step forward in wildfire risk mitigation. These are areas where the insurance industry could play a key role through working together with legislators, communities and individuals.

10 APPENDIX 1



Average global and regional annual area burned (1996-2012) based on global satellite observations. Orange and red trend lines are fitted to the full period and a subset based on MODIS data, respectively. NA: North America, NH: Northern Hemisphere, SH: Southern Hemisphere. Fires smaller than 0.4 km^2 are not included (Source: Giglio et al. 2013)

11 APPENDIX 2

Table 1. Top ten wildfire disasters' years by country for the period 1984 to 2013 in order of number of people affected (Source: EM-DAT, 2013).

Country	Year	N. Events	Total People Affected
Indonesia	1994	1	3,000,000
F.R.Y. Macedonia	2007	1	1,000,000
United States	2007	3	650,991
Argentina	1987	1	152,752
Portugal	2003	1	150,000
Paraguay	2007	1	125,000
Russia	1998	1	100,683
China	1987	1	56,313
United States	2008	2	55,320
Nepal	1992	1	50,000

Table 2. Top ten wildfire disasters' years by country for the period 1984 to 2013 in order of economic damage costs (Source: EM-DAT, 2013).

Country	Year	N. Events	Damage (millions $)
Indonesia	1997	1	8,000
Canada	1989	1	4,200
United States	2003	3	3,500
United States	2007	3	2,815
United States	1991	2	2,500
United States	2000	7	2,500
Spain	2005	1	2,050
United States	2008	2	2,000
Russia	2010	2	1,800
Greece	2007	2	1,750

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