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FORESTS ABLAZE

Causes and effects of global forest fires

Title page: 15-20 % of global annual carbon emissions are from forest destruction (especially fire clearance) and degradation. The title page shows east Sumatra with fire sources (outlined in red) and immense substance release (tornado-like smoke plumes)

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Fires release immense quantities of carbon stored in tree populations and soils.

Executive Summary

In many regions of the world, forest fires are natural processes. In these cases they can have beneficial effects on affected woodlands – for instance when cones only release their seeds to sprout new trees, after being exposed to the extreme heat of a fire. This report however is dedicated to an alarming aspect of forest fires: Whenever forest fires are too severe or occur in the wrong place, at an unusual time or too frequently, it is a sure sign that the ecosystem has been disturbed by human intervention. In these cases, forest fires pose a serious threat to humans and nature.

A forest fire can be divided into three phases: Usually, grass and the dry undergrowth ignite first. This generates a ground fire, which is easy to control. If it grows into a wildfire, it can leap into the treetops, especially in the case of conifers, leading to a crown or canopy fire where the flames spread rapidly. Crown fires are considerably more difficult to control and can easily grow into a conflagration, which is practically impossible to extinguish.

From WWF's point of view, the effects of forest fires on global species diversity are severe.

As a general rule, globally only around 4 % of all forest fires have natural causes such as lightning. In all other cases, humans are responsible for the fires – be it directly or indirectly, deliberately or due to carelessness. Often, forests are not able to regenerate from the effects of a fire on their own. Frequently, the burned areas and with it the entire ecosystem with the plants and animals living within it, are irretrievably lost.

From WWF's point of view, the effects of forest fires on global species diversity are severe: 84 % of the surface of all ecoregions that are critical for conserving global species diversity is threatened by changing fire intensities and frequencies. Only on the remaining 16 %, occurring fires are within ecologically acceptable limits. Fire sensitive ecosystems, like for example tropical humid rainforests, where plants and animals lack specific adaptations to natural fire, are even more threatened with 93 % of their surface being at risk.

The present study summarises causes and effects of forest fires according to regions and identifies the most relevant "hotspots" of our planet.

In Portugal, there were almost 20,000 fires per year in the last 10 years.

In the **Mediterranean region**, the average annually burned area has quadrupled since the 1960s. The causes are mainly carelessness or arson, coupled with extreme heat and drought in the summer months and degraded forests, where small fires spread rapidly. Particularly large-scale conflagrations in monocultures and bushlands have reached alarming proportions. Every year, there are 50,000 fires in these regions. The EU-member countries Spain, Portugal, Italy and Greece are particularly affected. In Spain, the number of forest fires has decreased significantly since 2006. However it still burns eight times more frequently than in the 1960s. The sad leading position for forest fire likelihood is held by Portugal, with an annual average of almost 20,000 fires in the last 10 years. It is assumed that in the southern Mediterranean region, wildfire risk, hitherto limited to the summer months, will remain high throughout the year from the middle of this century onward.

For 2014, only 6 % of the forest fires in Germany could be attributed to natural causes such as lightning.

In **Germany**, the federal state of Brandenburg is particularly affected by forest fires, with a focus on the pine forests south of Berlin. Except for this region, forest fire risk in Germany is considerably lower than in the Mediterranean region. The number of fires as well as the affected surfaces in hectares (ha) have been in the three-digit range for years. Most forest fires in Germany are deliberately or carelessly caused by humans. For 2014, only 6 % of the forest fires in Germany could be attributed to natural causes such as lightning. Economic losses amounted to 1.9 million Euro annually on average from 1991 to 2014. The amount annually spent on fire protection and control exceeds the losses caused by fires by far. In Brandenburg and other East German states for example, an automated forest fire monitoring system using high resolution cameras was established for the early detection of forest fires. The fire hazard can only be reduced in the long term by conversion of homogeneous pine monocultures into well-structured mixed stands of trees of different ages.

The last century has seen a dramatic increase in fire severity in the western USA.

In **North America**, forest fires are naturally recurring phenomena. The forests of western USA and Canada's boreal forests require periodic forest fires for regeneration. However, the last century has seen a dramatic increase in fire severity that now threatens humans and wildlife in many regions of the western USA. 2015 was one of the worst forest fire years in US history. 4.1 million ha of forests were burned, the highest forest cover loss figure since the beginning of records.

In **Russia**, the central and eastern parts of the country are most affected by forest fires, where huge fires rage in mostly unpopulated regions. Although every year several million ha of forests burn in these regions, these fires hardly receive any attention. By contrast, when more densely

Although every year seveal million ha of forests burn in Russia, these fires hardly receive any attention.

populated region are affected, like in 2010 in western Russia around the capital Moscow, the effects of fires are much more severe, even though the burned areas are comparatively much smaller. In Russia too, the largest proportion of fires is human-induced. Only in northern Russia, a high proportion of fires is caused by lightning. In large parts of Russia, forest ecosystems are adapted to recurring fire events. Forest fire incidence is increasing however, leading to ecological changes and to desertification in some parts of the country.

In 2016, even the temperate rainforests of western Tasmania experienced extensive fires.

In most parts of **Australia**, forest and bush fires are natural phenomena. Every year, vast areas of the tropical savannahs and grasslands burn in northern Australia. In the south, the burned areas are much smaller. Damage caused by fires in densely populated southern Australia is however considerably higher than in the sparsely populated north. Under normal circumstances, fires can hardly spread in the humid climate of Western Tasmania's rainforests. In 2016 however, extensive fires threatened this unique ecosystem. With advancing climate change, the number of hot and dry days with high fire risk will increase in southern Australia.

Southeast Asia's vegetation is not adapted to fire and forest fires are always destructive. Local populations have always used fire in slash and burn agriculture to fertilise their fields with ashes. With low population densities, the forest has enough time to recover. The pressure on forests is increasing however due to population growth and is intensified as big industries buy up vast areas for the cultivation of cheap resources like palm oil or pulpwood.

The forest fires in Indonesia in 2015 released almost twice as many greenhouse gases as Germany emitted in 2014.

Fire is usually employed to free burned parcels of land of wood debris and remaining vegetation. In unusually dry years this practice can lead to large conflagrations, which last for months and sometimes assume gigantic proportions. The *El Niño* effect in 2015 caused extreme drought, leading to severe forest fires in Indonesia from June to November. Smoke haze affected the environment and human health. The forest fires in Indonesia in 2015 released almost twice as many greenhouse gases as Germany emitted in 2014. Since 1990, Indonesia has lost 27.5 million ha of forests to logging, fires and conversion to timber, pulpwood and palm oil plantations. This corresponds to around twice the forest cover of Germany. From an international climate protection perspective, the Southeast Asian peat swamp forests play a significant role, as they represent the largest terrestrial carbon sinks in the tropics. When they are drained, for example for oil palm plantations, they become particularly vulnerable to fires, as dry peat is a perfect fuel. As these forests store enormous quantities of carbon underground, they convert into a gigantic source of carbon dioxide emissions when they are burned.

Due to forest cover loss, the regional climate of the Amazon basin is becoming increasingly drier.

The **Amazon basin** hosts the largest remaining block of rain forest of the planet. Forest fires are started to convert forest to soy fields or cattle pasture. There are concerns that the regional climate may break down once a certain deforestation threshold is exceeded. Ensuing drought in combination with further forest fires may further advance rainforest degradation. The Amazon rainforest would convert from a carbon sink to a source. By 2030, 55 % of the Amazon rainforest could be destroyed or severely damaged. This in turn would have serious impacts on the global climate and species diversity, creating a vicious cycle. At present, almost 20 % of the forest have been lost and another 17 % are degraded by human intervention.

WWF in action

In the **Russian Far East**, WWF helped to establish an early warning system for forest fires, and trained and equipped firefighting staff.

In **Indonesia**, WWF is supporting community-based management to fight fire clearance in protected areas and their peripheral zones. It advocates improved management methods in plantations and is politically active to prevent their further encroachment, one of the main reasons for arson in this South East Asian country. Moreover, WWF is helping to re-establish the water balance of a tropical peat swamp forest in Borneo, to prevent peat soils from burning and thereby releasing carbon.

In the **Mediterranean region**, WWF organises awareness raising campaigns. Besides, WWF lobbies for improved prosecution of arsonists and for the enforcement of punishments.

In the **Amazon basin**, WWF fights for increasing the area under protection where fire clearance and other destructive activities are not permitted.

WWF recommendations for preventing forest fires

Prevent fires - Fire prevention should receive highest priority in order to reduce forest fire risk and resulting damage. First of all, the determination of root causes and an evaluation of immediate and follow-up costs of forest fires are necessary for each region and requires an appropriate statistical data basis. Only on this basis is it possible to develop regionally adapted and cause-specific, effective and efficient strategies for forest fire management. Many countries lack this prerequisite. At the same time, public awareness of fire risk and appropriate behaviour should be strengthened by sensitisation and education activities, to prevent fires provoked by carelessness.

Do not establish eucalyptus plantations or other fire-prone monocultures – Forestry in the respective countries should always take the role of fire into consideration. In forest fire regions, there should be no planting of easily flammable tree species such as eucalyptus and pine. The fire-prone eucalyptus plantations of northern Portugal which have replaced fire-resistant cork oaks are a prominent example. Reducing fire vulnerability and increasing the resilience of forests by developing natural forests should be an objective of forestry. In fire-dependent ecosystems, the accumulation of fuel can be reduced by controlled natural and prescribed burning, thus maintaining natural ecological cycles. Burn areas should only be reforested when natural regeneration is out of the question and ecological damage such as soil erosion is to be expected.

Prohibit fire clearance by law – All relevant laws should integrate the aspect of fire risk. In some countries, conversion from forest to agricultural land is subsidised, while fire clearance can cause uncontrollable conflagrations. In these cases, law reforms are crucial. The conversion of burned areas to construction land should not be permitted, as this provides incentives for arson. In some countries, the provision for severe punishment and additionally improved law enforcement are required to prevent arson (for example in the course of land use conflicts or associated with illegal logging).

Reduce forest fire risk by adapted land use planning – Forest fire hazard should be more strongly integrated into spatial planning. New settlements should not be permitted in high-risk zones, and infrastructures like railway and power lines should be adapted accordingly to reduce risk. The decision to fragment a pristine forest should always be subject to an environmental impact assessment, as new forest roads draw in people and thereby inevitably increase the risk of human-induced fire.

Clearly assign and strengthen responsibilities – When a fire breaks out, clearly assigned responsibilities should be in place. Especially in forest fire regions, it should be clear who coordinates the relevant actors (authorities, fire services, population). Sufficient financial and human resources should be made available for forest fire monitoring, so that fires can be detected in time and suppressed at an early stage. Along with training programs, different forest fire scenarios should be developed for preparing emergency forces for timely and appropriate action. In case of a fire, a quick, tactically well thought out reaction is crucial to avoid a small fire from developing into a conflagration. In most affected regions, additional trained firefighting forces are required.

Water access in the forest facilitates fire prevention.

Fires eat up forests and badly needed wood.

1 Introduction

The history of forests is a history of fires. The oldest evidence of forest fires has been found inside coal seams, which consist of charcoal created during large fires millions of years ago. The burned forests later sank into swamps and formed coal beds. These fires that happened up to over 300 million years ago, were caused by lightning or volcanism. Fires in coal seams and their effects on surrounding forest landscapes have been verified even for prehistoric times. [1]

Humans have been using fire for a long time. Dating of the oldest prehistoric hearths in caves in southern Africa indicates that human ancestors started to use fire purposefully around 1.5 million years ago. In the earliest civilisations, apart from its use in the "household" (cooking, heating), fire was used for different purposes, for example for hunting (driving animals, luring game onto freshly planted burn areas), keeping forests and bushlands clear for safety reasons (from wild animals or in times of war), and later for slash-and-burn farming and clearing the landscape for pasture farming. In many cultures, traditional burn techniques have been preserved until today, such as burning tropical grass savannahs for game and livestock farming, or slash-and-burn for shifting cultivation agriculture.

Forestry should be able to adapt to incidental natural disturbances such as forest fires.

Disturbances are a fundamental element of all natural ecosystems. Forestry should therefore be able to adapt to incidental natural disturbances such as forest fires. For this purpose, a distinction has to be made between destructive and harmless, or more specifically, harmful or useful forest fires. Fire may sometimes be necessary for forest rejuvenation, or it can specifically benefit local populations. In other cases fire destroys forests and has severe ecological, social and economic consequences.

2 The ecological role of fire

Forest fires are a natural element of many, but not of all forest ecosystems. In cold or dry climates with limited decomposition of litter and accumulation of humus through soil microorganisms, forest fires ensure that future generations of trees are supplied with nutrients. Tree species like the North American lodgepole pine or the sequoias in California need the heat from a forest fire as an impulse for their cones to open and release seeds for new tree generations. These trees are protected by a thick bark. Heat from the fire rises up to the cones sometimes over 100m above ground and causes them to open. Their seeds fall onto the ground fertilized by the ashes rich in minerals and germinate. Through this adaptation, seedlings and saplings find optimal conditions for growth, as competition from other plants is still low and there is sufficient nutrient supply.

2.1 Fire-dependent ecosystems

Burns maintain the characteristic structure and composition of ecosystems that have evolved with fire.

Globally, around 46 % of all ecoregions are dependent on or influenced by fire. In these regions, forest fires are as integral to sustaining the natural flora and fauna as sunshine and rain. Typical fire landscapes are the taiga, the African savannahs, the monsoon and dry forests of South Asia, the eucalyptus forests of Australia, the coniferous forests of California, the Mediterranean region, as well as all pine forests from the taiga to the subtropics. All of these ecosystems developed with fire. The frequency and intensity of fires depend on natural factors like climate, vegetation type, lightning strike, accumulated biomass or terrain conditions. Burns maintain the characteristic structure and composition of ecosystems that have evolved with fire. However, all of these ecosystems don't burn in the same way. In many forests, grasslands, savannahs and wetlands for example, low intensity ground fires are typical and necessary to maintain an open landscape with a multitude of grasses and shrubs. Other forest and bushland ecosystems rely on infrequent but severe fires that rejuvenate the population. However, what distinguishes all fire-dependent ecosystems is the plant and animal populations' resilience and capacity to recover, as long as the fire remains within the limits posed by natural factors. Fire prevention can bring far-reaching, ecologically and socially undesirable changes to ecosystems. For example, complete fire prevention has caused the typical grass landscapes of some parts of the southwest USA, which provided food for wildlife as well as for cattle, to turn into dense pine forests with little grass growth, which provides fuel for extremely severe and destructive fires.

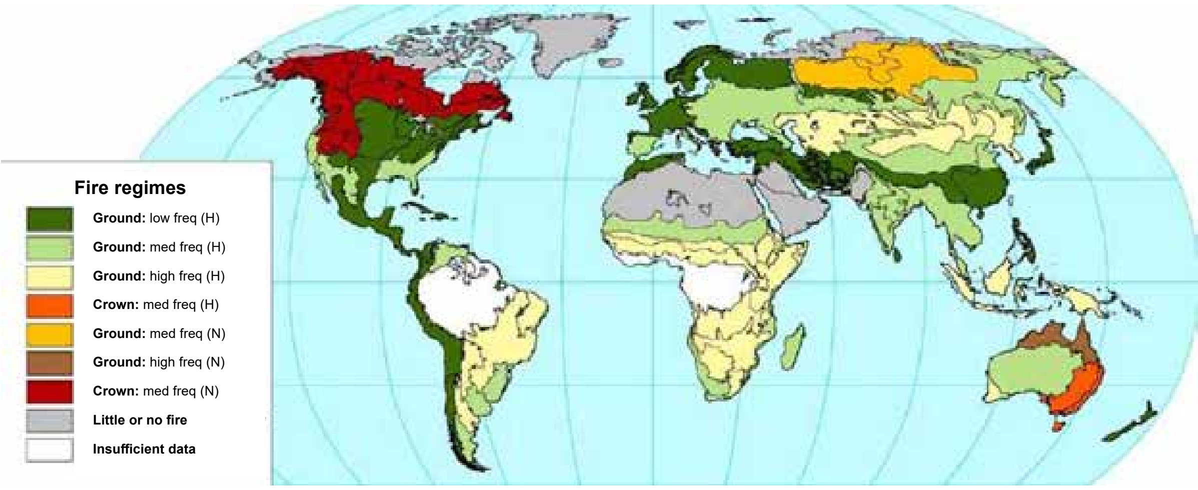


Figure 1: *World map of fire regimes. The map shows principal causes, type and frequency of forest fires. A distinction is made between natural or human-induced causes (N or H in the legend), and between the types ground fire and crown fire. Low freq means a fire cycle of over 200 years, med freq between 20 and 200 years, and high freq a cycle of less than 20 years.*[2]

In forests with natural fire regimes, tree rejuvenation is partially dependent on fire events or is promoted by burning.

2.2 Fire-sensitive ecosystems

In fire-sensitive ecosystems, frequent, large and severe fires were rare until recently. Most plants and animals in these ecosystems lack the ability to benefit from the positive effects of a fire or to recover quickly after a burn. 36 % of all ecosystems worldwide are classified as fire-sensitive. Their vegetation and structure usually prevent the outbreak and the spread of fires. In the long term, human-induced fires in a fire-sensitive ecosystem can affect its species composition or reduce its area. Typical examples of fire-sensitive ecosystems are the tropical wet rainforests in the Amazon and Congo basins and in Southeast Asia. In these ecosystems, even small fires have far-reaching consequences, as they trigger a cycle of increasingly frequent and severe fires which eventually generate ecological conditions that promote the establishment of vegetation vulnerable to fire, such as grasses.

2.3 Altered fire regimes

Changes in fire regimes have been identified as one of the most significant threats to global biodiversity.

A **fire regime** is a pattern in which fires occur in a certain area or ecosystem. A natural fire regime describes the entire characteristic pattern of fires over time for an ecosystem. [3] Different fire regimes are distinguishable according to fire frequency, seasonal pattern and intensity (figure 1). Frequent but mild ground fires are characteristic for African savannahs, for example. In the boreal coniferous forests of Canada and Alaska, burning is less frequent but tends to rage as severe crown fires. In tropical wet rain forests, forest fires under natural conditions are so rare that available data on natural regimes are scarce (figure 1).

In the case of an altered fire regime, the current fire pattern regarding key factors such as frequency and severity of fires, deviates from the natural, historical and ecologically acceptable variation range characteristic for the respective ecosystem. Ecologically acceptable fire regimes may be influenced by humans, in order to preserve plant and animal populations and the natural processes that characterise the ecosystem. Understanding fire regimes is critical to assessing whether human intervention is beneficial, uncritical, or harmful from an ecological point of view.

As key attributes of a fire regime are altered beyond an ecologically acceptable variation range, this creates living conditions that threaten the survival of native animals and plants typical to the respective fire regime. Changes to one or more key attributes of a fire regime can cause the degradation of an entire ecosystem, as they critically change its composition,

84 % of the area of priority ecoregions, which are crucial to the conservation of global species diversity, are at risk from altered fire regimes.

structure and processes. This may in turn trigger development towards a completely different ecosystem and fire regime. In the Mediterranean region for example, forest fires are assumed to be one of the causes of increasing desertification. Evidence from a number of different ecosystems suggests that it is difficult to impossible to halt or reverse such a development once it has been set in motion.

Changes in fire regimes have been identified as one of the most significant threats to global biodiversity. 84 % of the area of priority ecoregions, which are crucial to the conservation of global species diversity, are at risk from altered fire regimes. Fire regimes are only within their ecologically acceptable limits on 16 % of the area of priority ecoregions. 93 % of the area of fire sensitive ecosystems, such as tropical wet rainforests, where plants and animals lack adaptation to natural fires, is at risk. With 77 % of their area at risk, ecosystems dependent on or influenced by fire, such as the African savannahs of boreal forests, are slightly less yet still considerably endangered by altered fire regimes.[4]

Climate change can further aggravate the threat. It is assumed that, for instance, in the southern Mediterranean region wildfire risk will persist throughout the year by the middle of this century, and that the period of highest fire risk will be considerably extended on the Iberian Peninsula and in northern Italy.[5]

After fire disasters, it often transpires that the role of fire in the dynamic processes of the respective ecosystem has not or only insufficiently been considered in the area's spatial development plans. One reason is that the change in a fire regime is a slow and gradual process that can sometimes stretch over decades, with a multitude of underlying causes depending on specific human interventions. Changes are often not recognized until they reach a critical point. In North America and Australia for instance, real estate boom and urbanisation have brought people to settle in areas that experience regular fires. Subsequently, even small natural fires were completely supressed, causing fuel to accumulate over years, which resulted in exceptionally large, severe and destructive conflagrations.

Burns can become too frequent even in fire dependent ecosystems, like in the Siberian taiga. Here, rural population growth and increasing development through infrastructures such as railway and power lines have led to more frequent outbreaks of fire. This causes loss of forest area and releases millions of tonnes of stored carbon dioxide.

2.4 El Niño

Large and destructive fires repeatedly break out in fire sensitive ecosystems like wet rainforests. Frequently, they are caused intentionally in the course of large-scale logging or conversion to plantations. If climatic conditions are favourable, such as a long-lasting drought caused by the climate phenomenon *El Niño*, these fires can quickly grow to catastrophic scales and damage the economy and social life of an entire region.

El Niño is a climate phenomenon caused by altered warm water currents along the Pacific which occurs periodically approximately every 10 years. The currents bring warm water from the west Pacific (Indonesia and Australia) to the east Pacific (Westcoast of America), reversing the normal circulation pattern. In Southeast Asia and Australia, this causes droughts and destructive wildfires. In South America west of the Andes, torrential rains cause flooding while the Amazon region east of the Andes remains dry.

2.5 Forest fires and climate change

Forest fires cause 32% of global carbon monoxide and 10% of methane emissions, as well as over 86% of soot emissions.

By causing the release of greenhouse gases (GHG), forest fires contribute significantly to climate change. Warmer climate leads to forests becoming dryer and degraded, which increases their vulnerability to fire. The number and scale of fires increase, thereby creating a positive feedback loop. Savannah and forest fires annually release 1.7 to 4.1 billion t of carbon dioxide into the atmosphere; additionally around 39 million t of methane (CH_4; 1 t CH_4 = 21 t carbon dioxide, CO_2) as well as 20.7 million t of nitrogen oxides (NOx) und 3.5 million tonnes of sulphur dioxide (SO_2) are released annually. 15 % of the global GHG emissions are attributed to forest fires – most of them caused by fire clearance in tropical rainforests and resulting land conversion. Forest fires cause 32 % of global carbon monoxide and 10 % of methane emissions, as well as over 86 % of soot emissions. [2]

Different studies assume that climate change will increase the number of hot and dry days with high fire risk, extend the fire season and increase the frequency of electrical storms. This will increase the frequency of forest fires as well as the affected forest area.

Forest fires promote climate change and habitat destruction.

3 Development and suppression of forest fires

Only about 4 % of globally occurring forest fires have natural causes like extreme weather events (high temperatures, drought and storms), lightning or volcanic eruptions.[7] Humans cause fires deliberately by fire clearing or arson, or by carelessness, for example by bonfires or discarded cigarette butts or matches.

Glass bottles and shards can bundle sunbeams like a burning glass and cause dry leaves or grass to ignite. Hot catalytic converters, car exhaust pipes and motorcycles parked on forest floors are common but underestimated causes. Sparks flying from power or railway lines can also ignite adjacent forests.

The development of a forest fire can be divided into three phases: Usually, grass and dry undergrowth ignite first. This generates a ground fire, which is easy to control. If it grows into a wildfire, it can leap into the treetops, especially in the case of conifers, leading to a crown or canopy fire where the flames spread rapidly. Crown fires are considerably more difficult to control and can easily grow into a conflagration, which is practically impossible to extinguish.

3.1 Wildfire suppression

Appropriate firefighting measures depend on the type of fire. Creating firebreaks helps in the case of a ground fire. In this case several metre wide strips are cleared of fuel by controlled burning so that the fire cannot spread, however flying sparks may be able to pass the firebreak. A crown fire requires the use of firefighting planes and helicopters, which is dangerous as the pilots have to fly closely above the fire and sometimes crash. In 2012 in Turkey five people died in a helicopter crash during a firefighting mission. In Italy in 2007, all three pilots died when a helicopter and a plane crashed while fighting a forest fire. Despite the risks and high costs, countries primarily invest their resources in technical upgrading. Preventive measures for forest fires are often neglected, as illustrated by examples from different forest fire regions in chapter 4.

3.2 The problem of water supply

One issue for fighting forest fires is its water demand. Water supply is problematic for most forest fires, as water sources are often far away and water pumping and transport have to be set up over long distances. Additionally, forest fires mostly occur in areas with seasonal or year-long drought. Fighting forest fires requires tremendous amounts of water which then causes shortages for other important uses like agricultural irrigation. Large-scale fires can also affect a region's water household. With the loss of a forest, its water-retaining function and balancing effect on the water household also get lost. Instead, water quickly runs off the burned surfaces and can erode the soil down to the bedrock.

Extinguishing forest fires requires large amounts of water, which is then absent for agriculture or as drinking water.

4 Forest fires by region

4.1 Mediterranean region

Regarding its species diversity, the Mediterranean area is one of the most important regions of the world. As a transition zone between three continents, it hosts species from Europe, Africa and Asia. Although the Mediterranean region only occupies 1.6 % of the Earth's surface, 10 % of all flowering plants are found there. According to WWF estimates, only 17 % of the original forest cover of the Mediterranean area still remain after centuries of forest fires, over-logging and overgrazing.

4.1.1 Current situation and forest fires of recent years in Mediterranean countries

Every year, there are at least 50,000 fires in the Mediterranean region where 700,000 to 1 million ha of forest fall prey to the flames. This corresponds to 1.7 % of the entire forest cover of this region.

Small-scale fires are common in the Mediterranean region since ancient times. They are part of a natural dynamic or are used as a tool for managing natural resources. Recent decades however have seen a worrying increase in the frequency and scale of fires, following socioeconomic changes in the Mediterranean region. Every year, there are at least 50,000 fires. According to the FAO, 700,000 to 1 million ha of forest thus fall prey to the flames.[8] This corresponds to the area of Crete or Corsica, or 1.3 % to 1.7 % of the entire forest cover of the Mediterranean region.

The EU countries Spain, Portugal, Italy and Greece are particularly affected. In Greece for example, over 1.4 million ha of forests were destroyed by fire from 1985 to 2014, which is more than one tenth of the country's territory. Since the turn of the millennium, there have been three particularly severe fires in the Mediterranean region (table 1). In 2005, the Iberian Peninsula with Spain and Portugal was affected. In 2007 it burned in Italy and Greece. In 2012, following a dry winter, forest fires raged on the Iberian Peninsula and in Italy.

Forest fire disasters in the Mediterranean region in 2005, 2007 and 2012			
Country	**Burned area (ha)**		
	2005	2007	2012
Spain	188,672	82,049	216,894
Portugal	338,262	31,450	110,232
Italy	47,575	227,729	130,799
Greece	6,437	225,734	59,924

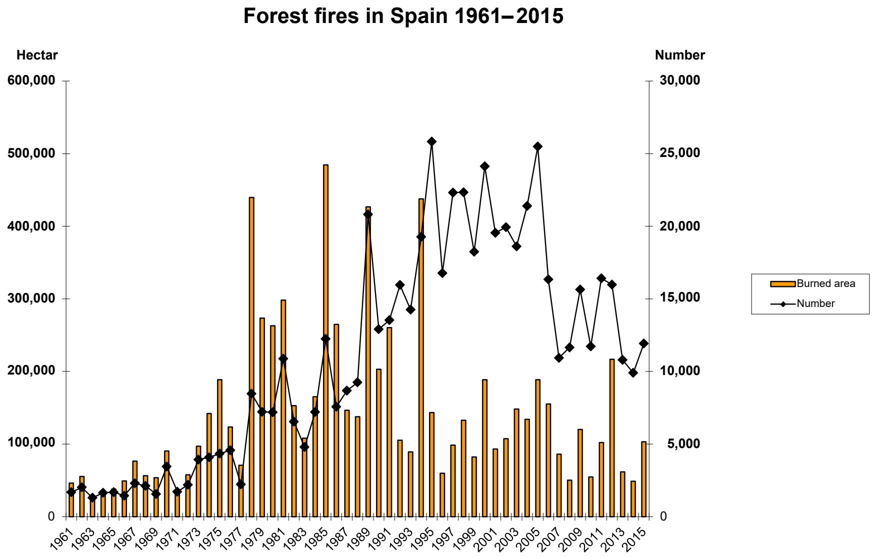
Table 1: *Overview over forest cover loss in Spain, Portugal, Italy and Greece in years with particularly severe fires (marked).*

Megafires only end with changing weather conditions or when they run out of fuel.

Since the beginning of the new millennium, the Mediterranean region has been fighting a new phenomenon called **megafires**. Extreme weather conditions help create firestorms raging with such ferocity and spreading so quickly that they become uncontrollable. They only end with changing weather conditions or when they run out of fuel.[9] Especially in the wildland-urban interface, which has significantly increased due to urban sprawl, these megafires cause serious damage and even loss of human lives. Megafires can also occur in an average forest fire year. In 2009 for example, the area affected by forest fires was not particularly large either in Greece or in Italy. However, on account of severe fires at the end of July, the island of Sardinia accounted for over half of Italy's entire forest cover loss that year. In Greece, forest fires in Athens' surroundings during the second half of August were responsible for around half of the country's forest cover losses in 2009.

In **Spain**, the number of forest fires increased from 1,680 fires in 1961 to a record of 25,827 fires in 1995 (figure 2). The number of burns remained high in the following 10 years. Between 1996 and 2005 there were on average around 21,000 burns per year. Since 2006, the number of fires has been dropping. In the 10 years from 2006 to 2015, the annual average was 13,131 fires; that's a decrease by 37 %.

Figure 2:
Development of number and area of forest fires in Spain.



Regarding the forest areas affected by fires per year, the climax was reached in the 1990s, when annually around 245,000 ha burned. 1985 holds the record with 484,476 ha of burned forests. In the 1990s, the annually burned area decreased to 161,000 ha, declining further to 127,000 ha per year in the 2000's.[10]

In **2005** there were 25,492 forest fires in Spain, the second highest figure since 1961, the beginning of records. Due to ongoing drought and heat, fire risk was high from March to October. [11] Over 188,000 ha of forest and bushland were consumed by flames, and the fires claimed the lives of 17 firefighters.[11]

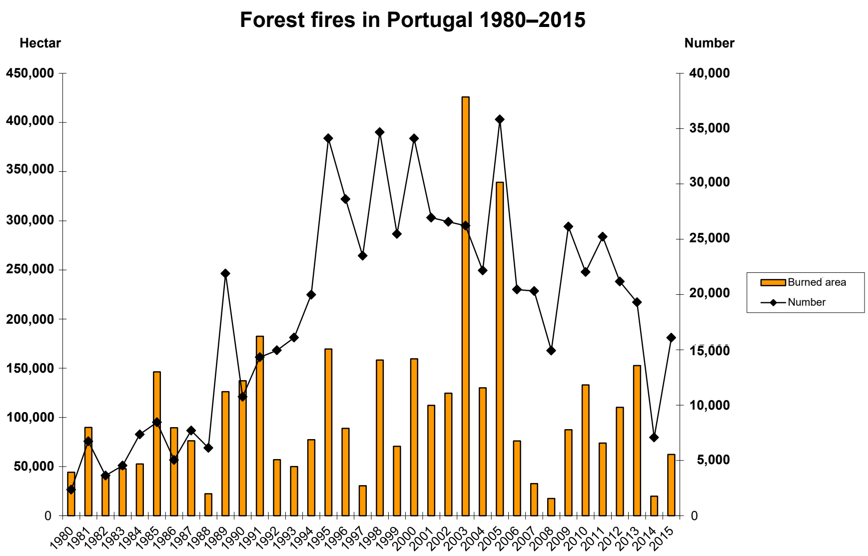
In **2012,** the number of fires (15,902) was slightly below the previous 10 year average. Forest cover losses however, at 209,855 ha, hit a record high since 1994. 39 large conflagrations were accountable for most of this (136,340 ha).[12] In 2011/2012, Spain had experienced the driest winter in 70 years. The ensuing drought created favourable conditions for the severe fires that ensued in the spring and summer months.

In the following years, the number of fires as well as forest cover loss declined due to favourable weather conditions. In 2014, the number of fires dropped below 10,000 for the first time since 1988. The burned area, at 48,833 ha, was the lowest since 1971.[13] In 2015 however, forest cover loss doubled again to 103,200 ha, while the number of fires only increased by 20 %. 40,000 ha alone were burned by 15 conflagrations, thus making 0.12 % of the fires responsible for 39 % of the burned area.[14]

In **Portugal**, the number of fires also dramatically increased from 1980, the beginning of statistical records, into the 1990s (figure 3), from 2,349 fires in 1980 to 34,116 in 1995. Fire incidence remained high in the following 10 years and reached a record level of 35,823 fires in 2005.[15] As in neighbouring Spain, the number of forest fires has been decreasing since then. While the decade from 1996 to 2005 saw an average of 28,400 fires per year, this number dropped to 19,271 average burns per year for the decade from 2006 to 2015[16], representing a decrease by 24 %.

Despite the growing number of fires, annual forest cover losses never exceeded the 200,000 ha mark until the 2000s. This changed in 2003, when over 425,000 ha were consumed by flames. Two years later in 2005, an additional 340,000 ha were burned.[17]

Figure 3:
Development of number and area of forest fires in Portugal.



After that, annual forest cover loss dropped to 17,500 ha in 2008, the lowest level since the beginning of records, but climbed back to 1990s levels again in the following years.

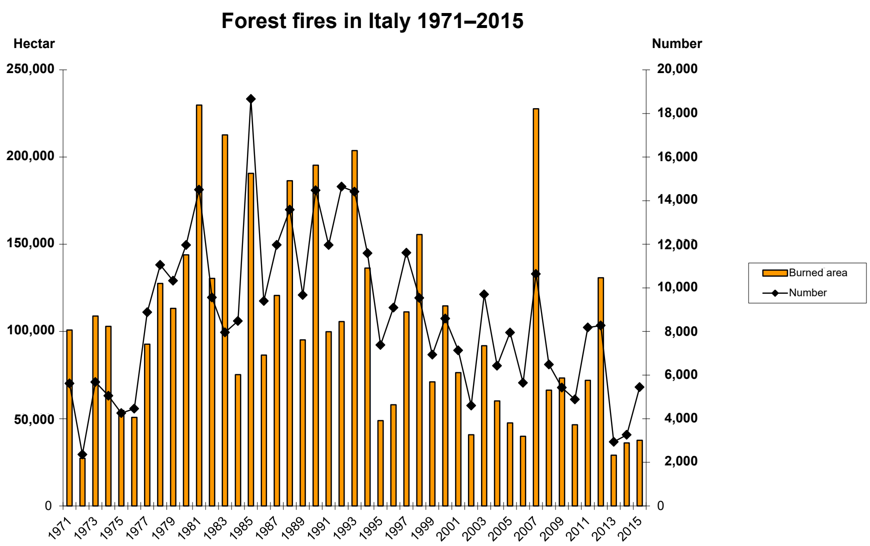
In 2012, 21,179 fires destroyed an area of 110,232 ha.[18] In the following year, the burned area even increased to 152,689 ha although the number of fires slightly decreased.[19] After both the incidence and the affected area dropped drastically in 2014, the number of fires in 2016 increased again to 15,328 affecting an area 63,855 ha. Preliminary data for 2016 indicate, that the number of fires remained on the same level than in the previous year, but up to mid-October 2016 the burned area already increased dramatically to 160,490 ha.[20]

Between 2003 and 2012 29% of Portugal's forest and bushland area burned.

The pine forests and eucalyptus plantations in northern Portugal are particularly hard-hit. Altogether, just under 1.5 million ha of forests and bushland burned in the decade between 2003 and 2012.[18] This represents 16 % of Portugal's national territory and 29 % of its forest and bushland area.

Italy saw an increase in forest fire incidence up to the 1980s. Since the record high of 1985 (18,664 fires), the number of fires has been noticeably decreasing (figure 4). The burn area also displays a decreasing trend since the 1980s. 2007 witnessed extreme fires, where 227,729 ha fell prey to the flames, the second highest recorded forest cover loss. Just in the previous year, 2006, forest cover loss (40,000 ha) had dropped to a record low since 1972.[21] In 2007, disaster in Italy was already looming when following the warmest winter in 200 years early summer already brought drought and heat. The dry forests thus offered conditions that arsonists had possibly been waiting for. According to investigations of the Italian state forestry department, two thirds of the forest fires in 2007 could be traced back to arson. Only 0.6 % of the fires were found to have natural causes, while for 20 % the cause could not be determined.[22]

Figure 4:
Development of number and area of forest fires in Italy.



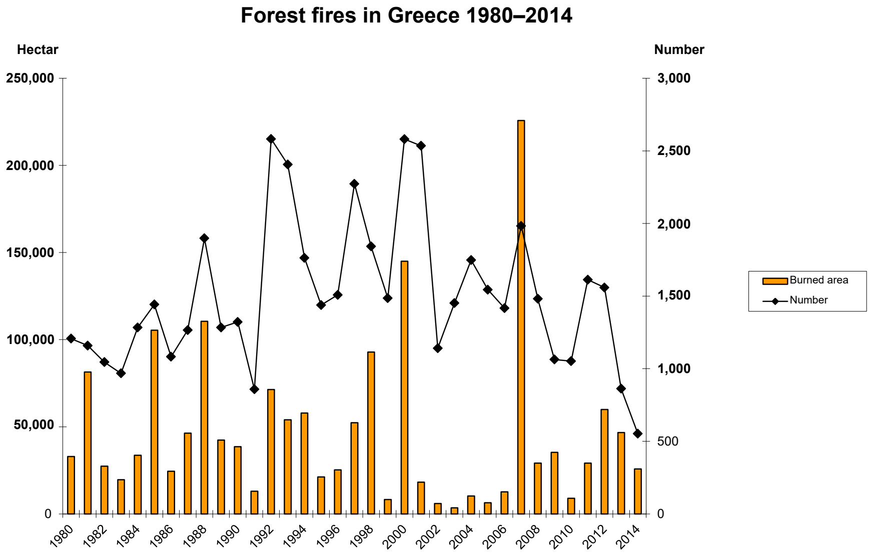
After a decreased in wildfire incidence and burned areas over the following years, they increased again in 2011 and 2012. In 2012, 8,274 forest fires destroyed an area of 130,799 ha. 35 % of this, 55,583 ha, burned in Sicily.[23] In San Mauro Castelverde near Palermo, even the cemetery burned after arsonists had lit several fires around the village.[24]

In the following two years, both the number of burns (2,936 in 2013[25] and 3,257 in 2014[26]) as well as the burned area (29,076 ha in 2013 and

36,125 ha in 2014) dropped to the lowest levels since 1972. In 2015 fire incidence increased by 67 % to 5,442 while the affected area, at 41,511 ha, remained at a similarly low level as in the preceding years.[27] Preliminary data for 2016 indicates that the number of fires went down to 4793, but the burned area slightly increased to 47,926 ha.[128]

In 2007, **Greece** witnessed the worst forest fire year in its history. Three heat waves followed several months of drought, bringing above-average temperatures of sometimes over 46°C. At the end of August, five fires broke out on the Peloponnese. Fanned by strong dry north winds, the flames quickly spread in the dry vegetation and developed into megafires raging on an area of 170,000 ha. The five megafires on the Peloponnese and further two in Evia accounted for over 70 % of the 225,000 ha that burned all over Greece in 2007. These forest fires claimed the lives of 69 civilians, 9 firefighters and 2 pilots, burned 1,710 houses and rendered thousands of people homeless.[2]

Figure 5: *Development of number and area of forest fires in Greece.*



In contrast, fire incidence and forest cover loss decreased in the following years (figure 5). However, in recent years Greece has increasingly been seeing conflagrations that are difficult to control, such as the huge firestorm in the surroundings of megacity Athens during the second half of August 2009. The fire broke out in the early evening hours of the 21st of August in Grammatiko, 40 kilometres northeast of Athens. Greece paid a high price for relying mainly on aerial firefighting. With darkness falling, it was not safe for the firefighting planes to extinguish the still small source of the fire. By the next morning, the fire, fanned by Meltemi, a strong dry north wind, had grown into an uncontrollable conflagration.[29]

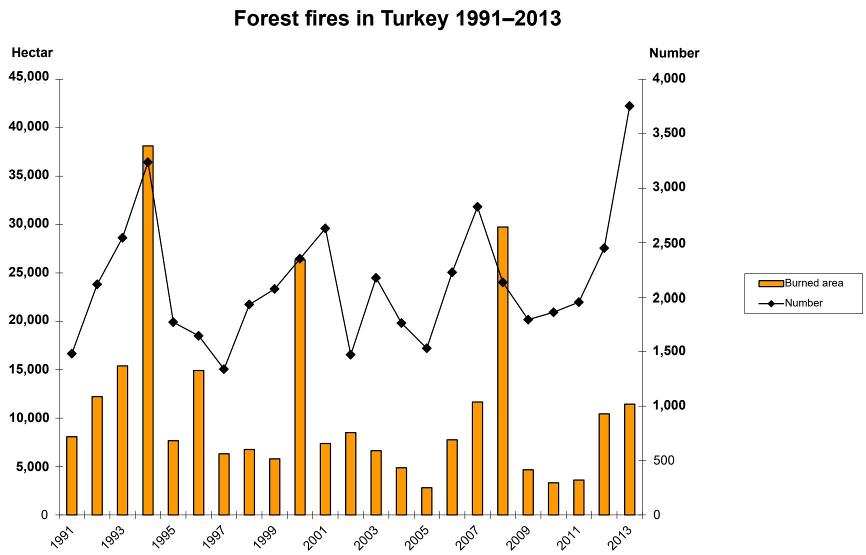
21,000 ha were burned[30], around half of Greece's entire forest cover lost to fire in 2009. 80 % were forest and bushland, the remaining were agricultural areas and settlements.[31] Agios Stefanos, a town of 10,000 inhabitants, had to be completely evacuated, and the ancient city of Marathon was also threatened.[32] The greenbelt around Athens, the lung of the capital and a popular recreational destination, was particularly hard-hit.[31] Around half of it consisted of old pine forests which will be able to regenerate naturally, according to experts of WWF Greece. The other half however had already been burned in previous years and had lost most of its regeneration capacity.[29]

Although Greece saw one of the hottest summers in 2012, the fires didn't take on the catastrophic proportions of 2007. 1,559 fires destroyed an area of just under 60,000 ha. There were however two significant conflagrations. On Athos Mountain, a fire lasting 27 days destroyed 4,683 ha of forest and bushland, and a conflagration on the island of Chios incinerated an area of over 11,000 ha in 12 days.[33] In the following two years, both fire incidence and forest cover loss dropped again significantly. 2014 was the year with the lowest number of fires since the beginning of records. In that year, 552 fires burned an area of 26,000 ha.[34]

In **Turkey**, there are over 2,000 forest fires every year on average. The coastal area from the Syrian border in the south to Istanbul is particularly affected. This area includes around 60 % of Turkey's forested area, around 12 million ha.[35]

Annual forest cover losses have been under 15,000 ha since the 1990s, with the exception of extreme fire events in 1994, 2000 and 2008. However even these values lie within a size range that its neighbour Greece reaches in an average fire year, even though Turkey's forest surface is almost three times as large as Greece's. For instance, in 2008 29,749 ha burned in Turkey, almost the same area as in Greece, where 29,152 ha burned.[36] For Turkey this represented the second largest forest cover loss since the beginning of statistics (figure 6). For Greece, in contrast, this value was below the 1991 to 2003 average (figure 5).

Figure 6: *Development of number and area of forest fires in Turkey.*



With a similar fire incidence, Turkey has been losing far less forest cover than its neighbour Greece. 5.5 ha are burned in an average forest fire in Turkey, compared with 26 ha in Greece; almost five times as much. One of the reasons may lie in the fact that forest fires are quickly controlled in the heavily populated Turkish coastal areas. In addition, Turkey has taken a number of preventive measures, like planting fire resistant tree species or establishing an early warning system for forest fires.[33]

The forest fires in Mediterranean countries are almost exclusively human-induced - be it by accident or intentionally.

4.1.2 Causes

The forest fires in Mediterranean countries are almost exclusively human-induced – be it by accident or intentionally. As official fire statistics reveal, the cases where fires were caused by natural phenomena are rare (table 2).

4.1.2.1 Arson

A large share of forest fires is started deliberately. Real estate speculation and building land reclamation are motives for arson especially in Greece and to some extent in Italy. Hunting and pasture management are also associated with intentional fire lighting in Italy, but mainly so in Spain and Portugal.

In Portugal just under one third, in Spain more than half and in Italy even 85 % of the wildfires whose causes could be determined are associated with arson. Natural phenomena such as lightning on the other hand only caused 1 % of forest fires in Portugal and Italy, and 7 % in Spain. However, the causes of fires could not be determined for 12 % of fires in Spain, just under a quarter in Italy, and over one third of the fires in Portugal (table 2).

Causes of forest fires in Portugal, Spain and Italy						
Country	Unknown cause	Known cause	of which			
			arson	careless-ness	re-ignition	natural
Portugal	38 %	62 %	31 %	57 %	10 %	1 %
Spain	12 %	88 %	59 %	31 %	3 %	7 %
Italy	24 %	76 %	85 %	14 %	-	1 %

Table 2: *Causes of forest fires in the Mediterranean region in Portugal (2014), Spain (2013) and Italy (2014).*
Sources: ICNF [20], Ministerio de medio ambiente [37], Corpo Forestale dello Stato[26]

When interpreting data about arsonists and their motives it has to be kept in mind that the statistics only cover the motives of perpetrators who were arrested by the police. Perpetrator groups that are easier to arrest are therefore overrepresented in the statistics. In Italy for instance, pyromaniacs with 29 % represent the largest share of the 97 arsonists caught red-handed between 2000 and 2006, while only two of the arrested offenders claimed that reclamation of building land was their motive.[38] When strong economic interests are involved, the person directly profiting from the arson is rarely the one who commits it. In these cases, professional arsonists are hired who know how to cover up their tracks and escape arrest. Italian investigators found that arsonists are paid from 200 to 300 Euro and up to 5,000 Euro for large fires.[39] Among the 2,200 persons charged with starting forest fires in Italy between 2000 and 2006, retired people make up a conspicuous 30 %. Other groups not directly benefitting from the fires are also strongly represented. Apparently they are hired by third parties and thus increase their meagre incomes or pensions. Every other arsonist is over 60 years old, while the age group between 21 and 30 years is only represented by 8 %.[40] Italian investigators found that accidents are often simulated in order to hide the offenders' identities and motives.[22]

In Italy, arsonists are paid from 200 up to 5,000 Euro for large fires.

Even when the direct cause is usually arson or carelessness, there are a number of socioeconomic, political and ecological factors that are responsible for the high incidence of forest fires and their devastating consequences in the Mediterranean region.

4.1.2.2 Socioeconomic factors

The traditionally rural socioeconomic system once characteristic of the Mediterranean region has collapsed over the last few decades. Small-scale agriculture has been given up in large parts of the northern Mediterranean region, for instance in Italy, Spain and Greece. In the southern Mediterranean area, for example in Cyprus or Turkey, mismanagement and over-exploitation have increased. Furthermore the entire Mediterranean region has experienced profound and rapid land use changes brought about by increasing urbanization, coastal tourism development and infrastructure expansion and improvement. The pace of these changes has prevented people from adapting to the new circumstances in a socially, ecologically and economically sustainable way.

When economic interests are involved, the person profiting from the arson is rarely the one who commits it.

The decline of agriculture in the last decades has led rural populations in the northern Mediterranean countries to migrate to cities and coastal regions. In large parts of the region, the use of agricultural areas and forests was entirely given up. Biomass accumulated in unused areas, acting as fuel for wildfires. Under these circumstances, the traditional use of fire in the maintenance of pasture and agricultural land can have disastrous effects when the flames spread onto abandoned plots and turn into uncontrollable wildfires.

With the migration of large parts of the rural population, social control was also lost. Italian investigators describe the most common type of arsonist as a middle-aged man who works as a farmer or shepherd and is very aware of the consequences of his actions. He lives in a landscape largely deserted by humans, allowing him to gain unlawful advantages. He uses fire to clear macchia* and forests from land that is almost always

* bush landscape of the Mediterranean region that is vulnerable to fire, which has evolved after the degradation of natural deciduous forests through millennia of over-exploitation.

owned by someone else, and thereby creates new pastures to increase his livestock. The same type of offender, particularly in southern Italy, also uses fire as a means to intimidate and threaten others in order to assert his interests.[38]

Due to the lack of income possibilities in rural areas, temporary jobs as firefighters or reforesting burned areas are gaining significance. There have been repeated incidences of firefighters or forestry workers starting fires in order to keep their jobs.[38]

The number of holidaymakers has dramatically increased due to improved tourism infrastructures, especially in the dry summer months when the fire risk is highest.

After decades of migration, some regions are currently witnessing an opposite trend: Weekend houses are being built and tourism infrastructure developed. All around cities, suburbs melt into neighbouring forest and bush landscapes, as more and more people want to realize their dream of a house in the country. This increases the likelihood of wildfires. Land speculation is increasing along with the demand for building land and rising property prices. Some try to convert forest into building land by arson. At the same time, the number of holidaymakers has dramatically increased due to improved tourism infrastructures, especially in the dry summer months when the fire risk is highest. The visitors are often not able to assess the risk and thus cause forest fires by carelessness (smoking, open fires).

The growing interface between urban areas and natural landscapes also poses new challenges to firefighting. The potential for damage and the danger to humans is multiple times higher when a fire breaks out in an interface zone than in an unsettled forest area. Additionally, in these areas firefighters have to focus on saving acutely threatened houses and infrastructure from the flames, leading to a lack of action forces in places that would be strategically more favourable to keep the fire from spreading.[41]

4.1.2.3 Ecological factors

Large parts of the natural and ecologically extremely valuable vegetation of the Mediterranean region have undergone rapid and profound changes: In the northern part of the region, it has been replaced by thick secondary forests and bushland landscapes, the macchia. In the south, the few remaining old-growth forests are fragmented and thinned out. In these degraded and secondary forests, as well as in unused agricultural areas, large amounts of dry wood accumulate and serve as an ideal fuel for extensive wildfires.

Long summers with practically no rain and with average temperatures far above 30 °C dry the litter layer to lower than 5% humidity, making one spark sufficient to ignite a huge conflagration.

Climate change further exacerbates the risk of forest fires in the Mediterranean region. Expected effects include longer drought periods during the summer and also the occurrence of droughts at other times of the year. This will considerably extend the wildfire season on the Iberian Peninsula and in northern Italy. In the southern Mediterranean region, wildfire risk will remain high year-round. With a global warming of 2 °C by 2050, the wildfire season in Spain will extend by two to four weeks.[42] Even today, climate conditions in the Mediterranean region – long summers with practically no rain and with average temperatures far above 30 °C – dry the litter layer to lower than 5 % humidity, making one spark sufficient to ignite a huge conflagration. Strong, dry summer winds like the Mistral in France or the Levante in Spain fan the fires and spread sparks.[43]

Climate change also increasingly triggers extreme weather conditions such as long hot spells with low humidity and strong winds, which permitted the fires in Greece in 2007 to assume devastating proportions. The incidence of sudden storms with strong rains reaching average annual rainfall levels within hours may also increase.[44] Strong rains wash the unprotected soil off burned surfaces, and soil erosion further leads to desertification. Even today, 300,000 km^2 are affected by desertification, jeopardizing the livelihoods of 16.5 million people.[45]

4.1.2.4 Political factors

Due to the climatic and ecological conditions of the Mediterranean area, forest fires are not the exception but a regularly occurring natural phenomenon. Despite this fact, rather than acting preventively and proactively, politics only react in the case of an emergency. Accordingly, investment goes mainly into technical equipment for direct fire suppression. Despite their soaring costs and little effect, society widely accepts these measures, as the media broadcasts impressive images of them, such as of fire-fighting planes in action. In reality, preventive measures would be much cheaper and more effective in the mid to long term, with numerous synergistic effects for humans and nature. Long-term prevention often fails because both wildfires and associated political promises are quickly forgotten, until some years later another catastrophic forest fire catches everyone by surprise. Only recent years have seen some steps in the right direction in a few Mediterranean countries where a comprehensive approach to developing preventive measures is taken, which considers relevant socioeconomic, ecological and political factors.

In the Mediterranean region, preventive measures would be significantly cheaper than firefighting - albeit less spectacular.

During the **financial crisis** which is primarily affecting Greece but also Spain, Portugal and Italy, financial means for forest fire prevention were also drastically cut. In Greece, firefighting equipment is outdated due to insufficient investment. Resources are also lacking for fire prevention. It is most likely only thanks to favourable weather conditions that Greece has been spared disastrous forest fires in recent years.[46] Firefighting planes are old and badly maintained; during fires in July 2015 in Greece a plane had to make an emergency landing due to technical complications.[47] Austerity measures are necessary to bring national deficits under control. Cost-savings should be well thought out however, so as to not jeopardize the success of past investments and ultimately increase both costs and damage through ineffective fire suppression.

In most Mediterranean countries, **laws** are in place that regulate responsibilities during fire suppression, provide for severe punishment for arsonists and prohibit the transformation of burned area to building land. Nonetheless, as the annually recurring fires indicate, these laws are often insufficiently enforced. In very few cases, arsonists are identified, arrested and brought to justice. In Italy for instance in 2014 there were 3,257 fires. Out of the investigated cases, 85 % were attributable to arson and another 14 % to carelessness. Only 1 % of the fires had natural causes. Nonetheless, charges were only pressed against 133 persons and three suspects arrested.[26] The situation is similar in Spain, where in 2013 for 10,797 fires only 134 arsonists could be identified, representing only 1.24 % of the fire incidents.[37]

The law provides for a construction ban in burned areas, but enforcement is impossible in many places.

The law provides for a construction ban in burned areas, but enforcement is impossible in many places, as essential instruments are missing, such as registers of forest areas and of burned surfaces. In some countries, land title registers are incomplete or do not exist. Resulting conflicts over ownership and usage rights can provoke forest fires, be it through arson or carelessness. On a national level, relevant legislation prohibiting dangerous agricultural practices like burning pasture land or harvested surfaces is frequently not in place. At the same time, inadequate laws prohibit effective preventive measures like controlled understorey burning in the winter months. By the same token, forest fire risk is inadequately addressed by land use planning in many Mediterranean countries. Relevant stakeholders are insufficiently involved in fire prevention. Instead, focus is placed on the suppression of already existing fires.

Moreover, financial incentives for fire prevention are frequently absent. The contribution of forest owners to preserving forests is often not sufficiently recognised. In fact, uncontrolled urban and infrastructure development generate additional costs for preventive measures, such as maintaining forest areas under power lines or along roads.[48] Preventive measures adapted to the respective land usage should be implemented year-round in order to keep the wildfire risk during fire season at a minimum. This could create year-round jobs for people who would otherwise only be hired seasonally as firefighters, and additionally eliminate a potential motive for arson.

By subsidising certain forms of agriculture under the common agricultural policy, the EU indirectly increases forest fire risk.

Within the framework of its rural development policies, the EU on one hand supports measures to prevent forest fires and to restore forests damaged by natural disasters and fires. The EU also funds studies on the causes of forest fires, awareness raising campaigns as well as training and demonstration projects. On the other hand, the EU, by subsidising forms of agriculture like plantations or the cultivation of water-intensive crops – e.g. under the common agricultural policy – promotes practices that indirectly increase forest fire risk. Their high water demand causes already dry soils to become more parched, which in turn creates favourable conditions for fire to spread quickly. The eucalyptus and pine monocultures found mainly in Spain and Portugal burn extremely well due to their high content of essential oils – another reason for the devastating dimensions of the forest fires in recent years. Not incidentally, in Portugal the largest forest cover losses occurred in the north and centre of the country which has extensive pine and eucalyptus plantations, while forest cover losses were by far lower in the south with its natural oak forests.

4.1.3 Effects

4.1.3.1 Ecological effects

Fires, in combination with overgrazing and logging, represent the greatest threat to forests in Mediterranean landscapes. The Mediterranean region is a typical fire landscape where tree species have adapted to occasional fires. Evergreen oaks in particular have built up resistance to fire, for example the cork oak (*Quercus suber*) with a thick insulating bark. However, the protection provided by these adaptations fails in the case of repeated severe fires. Evergreen sclerophyll forests first degrade into macchia, a light scrub vegetation one to five metres high. With continuing degradation, this vegetation gives way to sparse and open dwarf shrub vegetation, the Garrigue. It is often knee high with few woody species.

The shrub species in this degraded ecosystem have no fire resistance. Instead, they have adapted their reproduction to frequent fires by developing fire resistant seeds or by root propagation.

Reforesting burned areas or forests degraded by grazing or logging with pine species increases the risk of forest fires.

Reforestation after fires or in forest areas degraded by grazing or logging has also increased the risk of forest fires. The trees used for reforestation are pioneer species, especially pine, and are planted in monocultures of the same age. Pines are very flammable due to their high resin content. Short planting distances between the trees and a concentration of fine, flammable twigs increases the fire risk.[43]

If strong rains follow a forest fire, the soil can be washed away down to the bedrock, and degradation progresses to desertification. Advancing desertification in the European Mediterranean region is not only a significant ecological problem, it also has severe economic and social consequences. Even today, 300,000 km^2 are affected by desertification in the European Mediterranean region, jeopardizing the livelihood of 16.5 million people.[49]

National parks and habitats of endangered animal and plant species are also among the victims of forest fires in the Mediterranean region.

National parks and habitats of endangered animal and plant species are also among the victims of forest fires in the Mediterranean region. The Iberian lynx for example is classified as one of the world's most critically endangered cat species by the International Union for Conservation of Nature (IUCN). Large parts of its habitat in Spain have already been destroyed by forest fires. Over 1,000 Iberian lynxes existed in the 1980s, but their habitat shrank dramatically in the following decades until less than 100 were left in 2002. Their extinction was prevented by combined efforts of the Spanish government, the EU and non-government organisations (NGOs) like WWF. Meanwhile their population is recovering and was estimated at 404 lynxes in 2015.[50]

In the catastrophic year of 2007, forest fires caused substantial ecological damage in protected areas. In **Greece**, among other places almost one fourth (758 ha) of the protected area by Lake Kaiafa was destroyed.[51] In fact the pine forest is well adapted to fires and would have been able to recover quickly. However just one month after the destructive fires, it transpired that the Greek government was planning to develop the area, build hotels and resorts, and retroactively legalize 800 buildings that had been illegally erected in the past 50 years.[52] More than one fifth (67 ha) of the protected area around Olympia's ancient competition grounds was burned. These are also forests that are able to regenerate after fires, provided that development pressure can be controlled and that the transformation into building land can be prevented.[51] In Parnitha National Park adjacent to Athens in the northwest, 3,000 ha pine, spruce and oak forests fell prey to the flames, as did a large number of wildlife, among them protected animals like deer, tortoises and snakes.[53] The long-term ecological effects are immense, as Parnitha National Park is seen as the green lung of smog-ridden megacity Athens. On the Peloponnese, WWF Greece believes that the last populations of the Golden Jackal (*Canis aureus*) were considerably harmed and their future preservation threatened, as forest fires have destroyed extensive parts of their habitat.[51]

In **Italy**, according to investigations of the national forestry agency altogether 62,309 ha of protected areas were lost to fire in 2007, 34,106 ha of which were forest. This represents 29 % of the total forest area, which burned in Italy in 2007.[22] The most severe fires were recorded in the regions of Abruzzo, Apulia, Calabria and Campania, where respectively over 10,000 ha of protected areas went up in flames. The national parks of Cilento, where 273 fires destroyed 5,141 ha and Pollino, where 147 fires burned 6,959 ha, were especially hard-hit.[22] In Gargano National Park, 5,800 ha were lost while thousands of holidaymakers had to evacuate the peninsula.

In the Abruzzo and Majella National parks, forest fires affected the habitat of the Marsican brown bear, an endemic subspecies of the European brown bear found only there.

In the Abruzzo and Majella National parks, forest fires affected the habitat of the Marsican brown bear (*Ursus arctos marsicanus*), an endemic subspecies of the European brown bear found only there. The Abruzzo chamois (*Rupricapra rupricapra ornata*), given the by-name *ornata* (the adorned) for its beauty, is also found only there. The national park harbours numerous other endangered wildlife and plant species, such as wolves, eagles or the Marsican iris (*Iris marsica*).[54] The Italian national forestry agency argues that the high incidence of fires in protected areas indicates that these are still seen as obstacles to different economic interests and are therefore often targeted by arsonists. One solution would be to create schemes to share the benefits of value creation opportunities within national parks with local populations, in order to increase their interest in preserving the protected areas.[22]

The contribution of forest fires in the Mediterranean region to global GHG emissions and climate change is relatively low. According to the Joint Research Centre of the EU, **emissions** from forest fires in the entire affected region amounted to 12.3 million t CO_2-equivalents (CO_2-e), 6.9 million tons of which are attributed to affected EU member countries. This represents around 0.4 % of their total annual emissions.[55] The contribution of forest fires in the Mediterranean region to global GHG emissions in 2007 was thus roughly 100 times lower than the emissions released into the atmosphere by fires in the tropical rainforests in the same year.

The forest fires in Italy (here in Sardinia) also destroy forests in protected areas and prevent reforestation.

4.1.3.2 Economic and social effects

Forest fires do not only devastate forests; they also endanger human lives and destroy property. During the severe fire events of 2005, 32 people died in the flames in Spain and Portugal alone. 23 of them were firefighters. The disastrous fires in 2007 claimed 80 lives in Greece and 23 in Italy. In addition to the tragic loss of lives, the suffering caused by losing all personal belongings when a house burns to the ground should not be underestimated. In Portugal alone, forest fires destroyed over 2,300 houses and buildings in 2003. In 2007, 1,710 houses burned down in Greece, rendering thousands of people homeless. When factories and production facilities are affected, jobs are lost in addition to economic losses, with according social implications.

The economic damage and costs of forest fires are difficult to estimate. Beyond the direct costs of fire prevention, suppression and reforestation, and the damage through loss of timber, buildings and infrastructure, there can be additional financial implications for the entire region. In August 2000 for example, the entire pine forest of the island of Samos in Greece was incinerated. Apart from tourism, the forest had provided the only income for the island's population. Moreover, the fire caused over half of the tourists to cancel their holidays in 2001. Official sources therefore only give rough estimates of the magnitude of economic damage. There is no way to determine the exact costs.

In Portugal, the costs of the forest fires destroying over 420,000 ha in 2003 were estimated at over 1 billion Euro[56], almost 1 % of the gross national product**. The severe fires of 2005 caused damage amounting to 757 million Euro. The average annual damage caused by forest fires in Portugal from 2004 to 2013 amounted to 191 million Euro.[16]

Apart from producing wood, forests provide a number of services such as securing drinking water supply, soil protection or recreational use. These services are lost after a fire.

In neighbouring Spain, the disastrous forest fires of 2005 caused damage of 505 million Euro. 126 million Euro were attributable to direct material damage, for instance to buildings or to the forestry sector. Apart from producing wood, forests provide a number of services such as securing drinking water supply, soil protection or recreational use. These services are lost after a fire. Indirect damage through lost ecosystem services of the burned forests in 2005 added up to 376 million Euro, more than double the direct material damage.[57] In the long-term average from 1961 to 2005, indirect damage was also around twice as high as direct losses. Altogether in Spain the average annual losses and damage through forest fires from 1961 to 1970 amounted to 8 million Euro. This figure increased tenfold to 81 million Euro in the following decade, rose further to 295 million Euro per year between 1981 and 1990, and finally reached an average of 325 million Euro per year in the decade 1991-2000; 40 times higher than three decades ago.[58]

Between 2000 and 2005, average annual damage climbed further to 332 million Euro.[57] In 2013, while Spain was less affected by forest fires, they still caused losses of over 23 million Euro. This number does not include 4.6 million Euro spent on fire suppression.[37]

According to an analysis of the University of Padua, forest fires in Italy cause annual damage of over 500 million Euro. Each Italian thus pays 10 Euro per year for the effects of forest fires. Over 10 million trees are destroyed annually on an average burn area of 55,000 ha. This represents one tree per Italian family. Furthermore, Italy offsets its forest areas

** In 2003 the gross national product of Portugal was 130.5 billion EUR. *Source: Auswärtiges Amt* within the framework of the Kyoto protocol as a contribution to reducing their CO_2 emissions. had the fires been prevented, Italy could have saved up to 1 billion Euro in the period between 2008 and 2012.[59]

After a fire in 2001 on the Greek island Samos, half of the holiday bookings were cancelled.

4.1.4 Solutions

Forest fires in the Mediterranean region are unavoidable. There are however solutions that help to keep fires within a tolerable range for humans and nature. In the fire-prone ecosystems of the Mediterranean, a comprehensive forest fire policy has to be implemented, which takes into consideration all four pillars of a balanced fire management – prevention, preparation, reaction and restoration – instead of relying solely on direct fire suppression.[60]

The key element of such a policy is preventive land use planning that adequately addresses fire risk and seeks to reduce as much as possible both the incidence of fires and the damage they cause. This can be achieved by separating settlements from forests and other fire-prone areas by adequate safety zones, and by preventing further uncontrolled development. This requires a register with spatially explicit records of all areas regarding their uses (forest, agricultural land etc.) and their owners. The registers additionally have to indicate whether the area is a burned area, in order to enable the enforcement of laws prohibiting construction on burn areas. Moreover, the register should include a classification of areas

Planting monocultures of foreign trees vulnerable to fire in managed forests should be avoided.

regarding their wildfire risk. In order to prevent damage and putting human lives at risk, as a general rule no building permits should be issued in areas with high fire risk, as is already the case in Portugal. Land use planning should adequately and equitably consider all affected stakeholders in order to avoid land use conflicts – a possible motive for arson.

Beyond that, fire risk should be adequately addressed in all relevant planning areas. Coordination and collaboration of all stakeholders should be optimized for direct fire suppression as well as for prevention and restoration. Priority actions should be identified for each of the four pillars of fire management and implemented year-round. Increasing civil society involvement can be an economic and effective possibility to significantly decrease fire incidence and severity.

The promotion of traditional farming methods can also contribute to fire prevention. In the Mediterranean region, these methods have adapted to fire risk over thousands of years. In Portugal for example, grazing on sheep pastures is subsidized, as these act as firebreaks that prevent the spread of fires.

Mediterranean ecosystems are adapted to fire and usually recover quickly after a wildfire. Reforestation is usually unnecessary and can in fact be a motive for arson, for example by forest workers. Where possible, natural regeneration should therefore be favoured. Furthermore, the ecological role of fire in Mediterranean ecosystems should be given more consideration. For example, natural processes can be reproduced in managed forests by controlled burning of the undergrowth in a safe season.

The establishment of eucalyptus and pine plantations should not be subsidised.

It should also be determined under which conditions it is possible to tolerate fire as a natural process, like a ground fire in the core zone of a protected area, as long as it remains within limits the ecosystem is adapted to and no further risks exist. Virgin forests should not be encroached on with the argument of wildfire prevention, as this will draw people in and increase fire risk by carelessness or arson. Planting monocultures of foreign trees vulnerable to fire in managed forests should be avoided. And above all, the establishment of eucalyptus and pine plantations should not be subsidised.

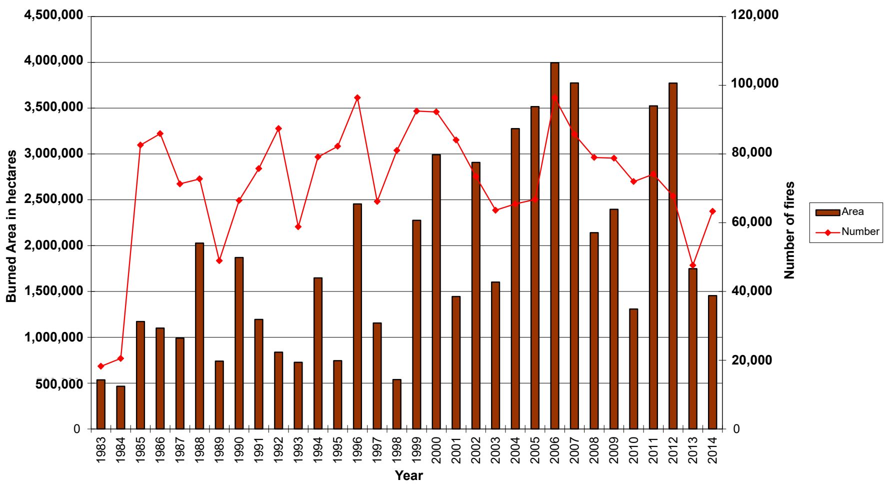
4.2 North America

4.2.1 USA

Forests in the USA cover an area of 310 million ha, this is 31 % of the country's territory.[61] Forests in the west, where wildfires are a naturally recurring phenomenon, depend on these periodical fires for regeneration. However, the last century has seen a dramatic increase in fire severity that now threaten humans and wildlife in many regions of the western USA.

This trend has further intensified since the new millennium. Between 1983 and 1989, annually one million ha burned on average. In the 1990s annual average forest cover loss increased to 1.3 million ha. Between 2000 and 2009, the annual burn area rose to 2.8 million ha – over twice the ten year average of the 1990s. After reaching new record highs every year in 2000, 2004 and 2005, in 2006 finally almost 4 million ha were burned - the sad peak until today (figure 7).[62] Between 2008 and 2010 forest cover loss values significantly decreased again, reaching 1.3 million ha in 2010, the lowest figure since the new millennium.

Figure 7: *Development of number and area of forest fires in the USA. Source: National Interagency Fire Center [62], area converted to ha.*



Compared to previous decades, this number is still high. In 2011, forest cover loss increased to 3.5 million ha again, despite an only slight increase in the number of fires to 74,126. Average forest cover loss has increased again since 2011. In 2011 for instance, there were 14 conflagrations over 100,000 acres (40,468 ha), while in 2010, there had only been three such large fires.[62] In 2012 the burn area rose to 3.8 million ha again, while the number of wildfires, compared to the previous year, decreased to 67,774. The average burn area per fire, at 56 ha, was the highest since the beginning of records. The largest conflagration in New Mexico's history burned an area of 120,000 ha. In Oregon, 225,000 ha of forest and bushland were destroyed in one of the largest fires in its history.

In the two subsequent years, the fire season was comparatively calm. In 2013, forest cover losses were only 59 % and in 2014 53 % of the average of the previous decade. The incidence of fires was also below average, with 47,579 burns in 2013 and 63,912 in 2014.

Since 1960 there have been four years in which more than 3.6 million ha burned. All of these were within the last 10 years!

However, this positive trend was reversed in the following year. 2015 was one of the worst forest fire years in the history of the USA. 68,151 fires burned an area of 4.1 million ha, the highest forest cover loss figure since the beginning of records. Since 1960 there have only been four years in which more than 9 million acres (3.6 million ha) burned, and all of these (2006, 2007, 2012 and 2015) were within the last 10 years![63]

Land use planning should adequately and equitably consider all affected stakeholders in order to avoid land use conflicts - a possible motive for arson.

The size of the burned area alone gives no information about the damage and the number of people affected. In 2014, forest fires destroyed 1,953 buildings, among them 1,038 homes.[64] California, where 341 homes were destroyed, was particularly hard-hit, and two people died, among them one firefighter.[65] Two destructive fires in September 2015 were among the 20 forest fires with the highest death toll in California's history.[66] Four civilians died and four firefighters were injured in the "Valley Fire" about 120 km north of San Francisco, and 1,958 buildings were destroyed, among them 1,280 single-family homes and 27 apartment buildings.[67] The "Butte Fire" 170 km east of San Francisco claimed the lives of two civilians and destroyed 818 buildings, among them 475 homes.[68]

Table 3: *Fires caused by lightning and by human activity in the USA. Source: National Interagency Fire Center.*[71]

Year	Number of fires caused by...	
	Lightning	**Humans**
2001	14,094	70,066
2002	11,435	62,022
2003	12,776	50,815
2004	11,384	54,101
2005	8,323	58,430
2006	16,165	80,220
2007	12,261	73,446
2008	8,856	70,093
2009	9,142	69,650
2010	7,164	64,807
2011	10,249	63,877
2012	9,443	58,331
2013	9,230	38,349
2014	7,933	55,679

Besides extreme drought and high temperatures, increasing urbanisation is responsible for exorbitant forest fire damage in California, as suburbs eat their way into the fire-prone forest and bush landscape. Exposition to wildfire risk is accepted in exchange for a life in the country. 61 % of new houses built on the west coast in the 1990s, more than one million dwellings, were built in or bordering fire-prone wilderness.[69] This not only extremely increased the damage caused by fires, but also the cost of fighting them. The United States Forest Service and the United States Department of the Interior alone spent 3.7 billion US$ in 2012 and 3.4 US$ in 2013 on fighting forest fires.[70]

The majority of fires in the USA are caused by human activity. Between 2001 and 2014, 85 % of forest fires on national average were human-induced.[71] 15 % of fires were caused by lightning (table 3) – this varies regionally however. In some parts of the western USA, lightning strike is the principal cause of forest fires. Air humidity during summer storms can get so low that the low precipitation is not sufficient to extinguish the fires caused by lightning. In the east of the country, thunderstorms are usually accompanied by strong rains, so that lightning rarely causes large fires.[72] In this region, 98 % of fires are human-induced.[71]

The number of forest fires in the USA fluctuated between 60,000 and 100,000 per year over the last 20 years, without an increasing trend (figure 7). Only the burned area has increased drastically, as fires are increasing in severity. This increase is attributed to past mistakes in fire prevention and suppression. Since the 1950s, every kind of forest fire has been systematically supressed and fought. By the suppression of smaller ground fires, their ecological function of clearing fuel from the undergrowth was lost. Instead, most of the old fire resistant trees were cut and replaced by densely planted and flammable artificial forests. In the USA alone, over 700,000 km of logging roads cut through public forests, facilitating fires caused by carelessness and arson. Through grazing, many of the native grasses, which kept the fire on the ground, have been replaced by flammable brush. This makes it easier for fire to leap into the forest canopy. Climate change extends the fire season and leads to more frequent droughts, which degrade forests and make them more susceptible to burning. Climate change, to which the CO_2 emissions of the USA are a major contributor, is responsible for the escalation of forest fires since the mid-1980s.[73]

There are 60,000 to 100,000 forest fires in the USA every year. Image: fire in Yellowstone National Park, USA.

4.2.2 Canada

34 % of Canada's national territory, or 347 million ha, is covered with forest.[61] In many forest ecosystems in Canada, fires are a natural process. In Canada's boreal forests, tree species are adapted to fire to such an extent that they require high-intensity crown fires for regeneration. Other forest regions in Canada require periodic ground fires to clear fuel from the undergrowth to prevent an outbreak of severe fires.

In the 1970s, it was recognised that complete fire prevention was neither economically feasible nor ecologically desirable. Despite increasing costs, no decrease in fire incidence was observed. At the same time, the important natural role of fire in maintaining the stability, productivity and biodiversity of forests was recognised, particularly for Canada's boreal and temperate forest regions. The forest fire strategy was adapted accordingly. Considerable efforts are made to protect areas near settlements or with a high value for the wood-processing industry, as well as recreational areas. Meanwhile, fire is often tolerated in remote forest areas with low economic value.

In Canada's forests, there were on average 7,084 forest fires per year between 2004 and 2013.

In Canada's forests, there were on average 7,084 forest fires per year between 2004 and 2013. Average forest cover loss was slightly below 2.3 million ha. In 2014, wildfire incidence at 5,126 was considerably below this average, while the burned area (4.6 million ha) was twice as high as the previous decade's average. 56 % of this area were attributed to fires in remote regions that were tolerated under controlled conditions for ecological reasons. These areas in 2014 were mainly in the interior provinces Northwest Territories, Saskatchewan, Quebec, Manitoba, as well as Newfoundland and Labrador. These 548 fires only represented 11 % of the total number of fires.[74]

In 2014, the provinces of British Columbia and Northwest Territories were particularly affected by forest fires. In British Columbia, 1,455 fires destroyed 368,785 ha forest. In the Northwest Territories, the fire season started in May and lasted until September. In this province alone, 385 fires, including conflagrations spreading at speeds of up to 150 meters per minute, destroyed 3.4 million ha of forest. Controlled fires were permitted on 2 million ha, while on 1.4 million ha, forest fires had to be completely suppressed to protect communities and infrastructures.[74]

The fire season of 2015 was calmer compared to the previous year. 6,765 fires until mid-September destroyed just below 4 million ha forest. Most fires occurred in British Columbia (1,819) and Alberta (1,698). The largest affected area was 1,777,488 ha in Saskatchewan, where controlled burns accounted for over one million ha and fires on the remaining 700,000 ha had to be suppressed.[75]

Causes and the average size of burned areas reveal significant regional disparity. On national average, lightning causes 35 % of forest fires, which however account for 85 % of the burned area.[72] Lightning strike is the most common cause in the expansive remote forests of northern Canada, where fires can spread unchecked. Human-induced fires usually occur in developed forests and require quick intervention to stop them from spreading. Around half of the burned area therefore lies in remote regions. The largest burn areas run in a strip along western and central Canada's northern edge, where forest fires occur naturally and population densities are low.

In other regions of Canada, especially where ground fires play a natural role, the successful prevention of forest fires has led to the accumulation of fuel. Severe fires that are difficult to control could be a consequence. Complete fire prevention also creates favourable conditions for forest pests. Large forest fires are often a consequence of insect calamities, as they provide large amounts dead and dry trees as fuel.

Recent years have seen a rapid increase in the number of buildings and communities in the direct vicinity of forests, as more and more people move to the country. These home owners have little knowledge of forest fires and appropriate preventive measures. The general public first became aware of the considerable threat by forest fires in 2003, when the number and extent of fires in British Columbia exceeded firefighting capacities and over 45,000 people had to be evacuated. Since then, several programmes for disaster prevention have been elaborated, posing a considerable challenge given a growing urban-wildlife interface and increasing fire risk. Additionally, communities in northern Canada are also expecting improved fire protection. For these communities, the forest is their livelihood, so that even fires that do not directly affect residential areas have considerable effects on the communities. Almost every year, a number of communities in northern Canada has to be evacuated in order to protect people from fires and smoke.

Consequently, in recent years, forest fire prevention has gained increasing significance in public discourse. In addition to protecting their property, particularly indigenous communities, forest owners and residents of zones adjacent to forests expect the responsible authorities to involve them in decisions regarding forest fire prevention. This involvement requires an informed public that understands the positive effects of fires and that they cannot always be prevented.

Firefighting involves high costs and requires large investments in infrastructures and equipment like airplanes and helicopters. Equipment has to be renewed regularly, which has been neglected in the last decades due to budget cuts. By now, for instance half of the tanker planes are older than 30 years and will have to be replaced within the next 10 years. Firefighters are also getting older, while new hires have been reduced on account of budget cuts. About half of the firefighters will retire within the next 10 years. As the training period for firefighters is long, staff shortages cannot be resolved by new hires on short notice. Some districts are already experiencing a shortage of suitable junior staff.[72]

As in other countries, climate change will dramatically increase the incidence and severity of forest fires in Canada. Parallel to a warming climate, an increase in forest fires in boreal Canada has been observed since 1970.[76] A positive feedback loop is expected, when carbon stored in the forests is released into the atmosphere as carbon dioxide, thus further amplifying the effects of climate change as CO_2 is one of the responsible GHG. In the long term, more frequent fires will decrease the proportion of old forests and replace them with young forests with less biomass and thus lower CO_2 storage capacities.[75] Furthermore, climate models for Canada predict an earlier start of the fire season and an increase in the regions subject to high to extreme fire risk.[75]

The costs of fire suppression are predicted to greatly increase due to climate change. The extent of today's fire suppression measures will not be economically sustainable in the future. This has direct implications for the wood supply and competitiveness of Canada's wood-processing industry, as well as for around 300 communities depending on the timber industry.[72]

In order to meet these challenges, innovative strategies considering the main causes as well as the implications of forest fires have to be developed and implemented in a timely manner all over Canada.[72] In addition to the adequate equipment of firefighters with human and technical resources, land use planning should be adapted to separate forests from developed areas in order to limit material damage and the danger to human lives.

Half of the Canadian tanker planes are older than 30 years and will have to be replaced within the next 10 years.

4.3 Germany

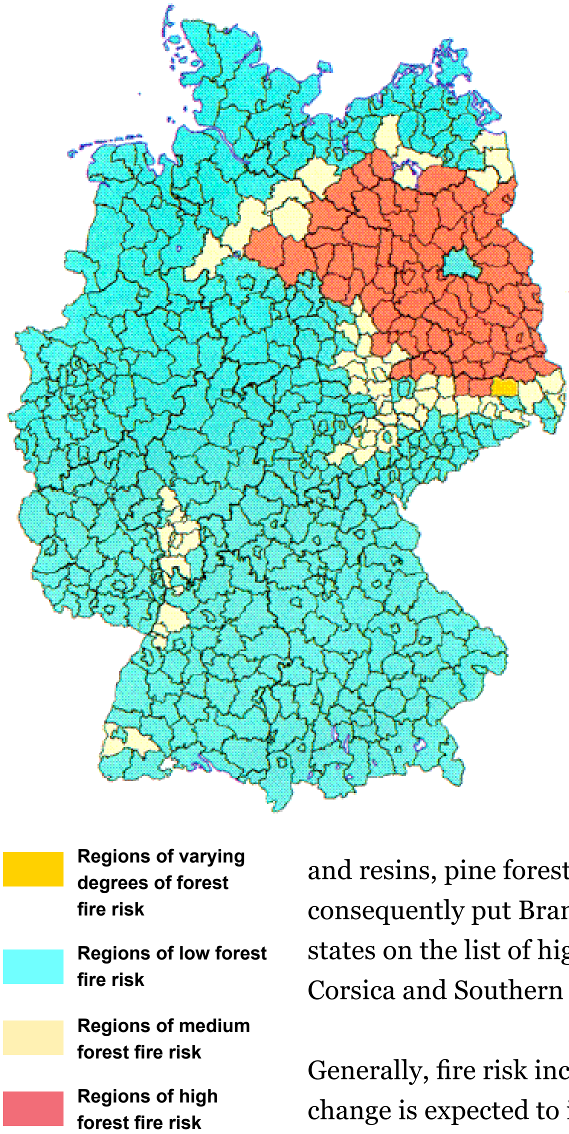


***Figure 8:** Division of Germany into forest fire risk regions.*[187]

In Central Europe, Germany, after Poland, is the country with the highest incidence of forest fires, albeit most regions are at low fire risk (figure 8). The eastern federal states are the ones most at risk. 225 of the 429 forest fires in Germany in 2014 (over 50 %) occurred in East German federal states, although their share of Germany's forest cover is only 28 %. The forests of Brandenburg are particularly affected, accounting for one third of all forest fires in Germany. Within Brandenburg, the focal area of high fire risk lies in the pine forests south of Berlin (figure 9).[77]

This particular fire hazard is explained by climate conditions, as Brandenburg is the driest federal state. Its loose sandy soils hardly store precipitation, and the artificially high percentage of pine trees (70 %) further exacerbates the fire risk. Their wood being rich in essential oils and resins, pine forests are particularly prone to fire. The EU commission consequently put Brandenburg and adjacent districts of other federal states on the list of high fire risk regions, together with Southern France, Corsica and Southern Spain (figure 8).

Generally, fire risk increases during dry and hot summers. Climate change is expected to increase the frequency of exceptionally hot summers, like in 2015 when the fire hazard was particularly high. Additionally, dry and hot summers create favourable conditions for the growth of highly flammable grasses. Almost every forest fire starts as a ground fire, as grasses and other ground vegetation are the first to ignite. The invasion of forests by grasses has increased in recent decades through atmospheric nitrogen input and is a relevant factor for fire risk. Two of the most flammable grasses, feather reedgrass and wavy hair-grass, are among the vegetation profiting from these changes.[78] This has led to an even higher fire risk in northeast German pine forests. Grass invasion can be counteracted by specific forestry practices. In FSC®-certified forests threatened from grass invasion for example, canopy thinning is carried out very carefully during timber harvesting. Keeping light irradiation on the forest floor to a minimum reduces the competitiveness of grasses and promotes forest regeneration.

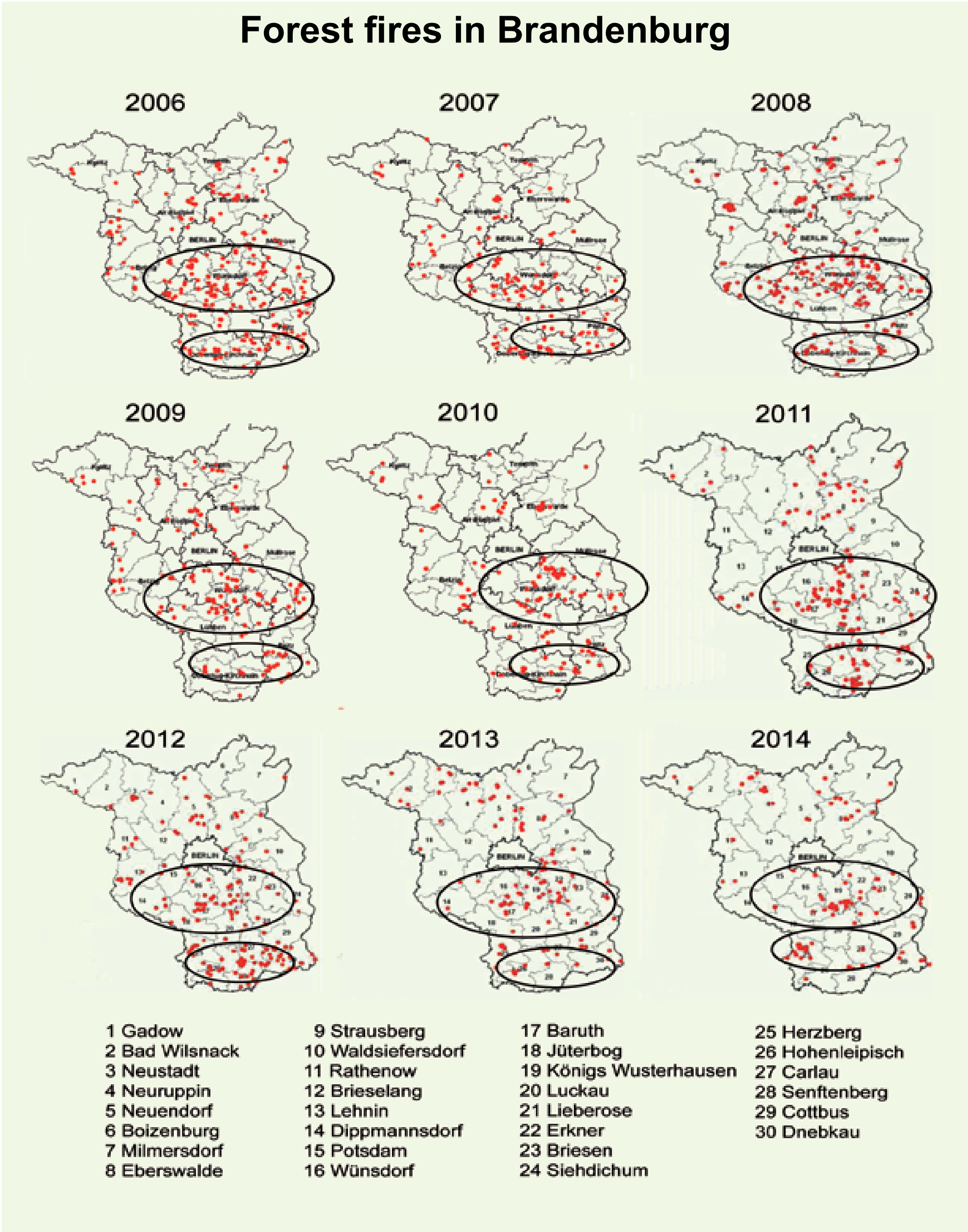


Figure 9: *Forest fires in Brandenburg.*
Source: Landesbetrieb Forst
Brandenburg; 2014[188]

Most forest fires are human-induced. In 2014, only 6 % of forest fires in Germany were attributable to natural causes like lightning. In 41 % of the cases, the cause could not be determined. 20 % of fires were verifiably provoked by arson, another 24 % were caused by carelessness. Fires caused by carelessness are mostly attributable to campers, forest visitors or children. Between 10 % and 25 % of carelessly caused forest fires are associated with agricultural and forestry activities. Additionally, in 2012, railway and power lines were responsible for 11 fires.[79]

Forest fires caused by old ammunition and unexploded bombs in military training areas in hot and dry weather are officially responsible for 11 % of the fires in 2014 (table 4).[79]

During hot and dry weather, forest fires can be started by exploding old ammunition.

Causes of forest fires											
	Number of fires										
Cause	Average 1991 - 2000	Average 2001 - 2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Natural causes	68	37	76	23	33	41	27	37	42	19	17
Carelessness	396	190	216	224	230	199	126	193	179	124	103
Arson	356	225	154	187	200	140	167	148	131	95	84
Old ammu-nition, unex-ploded bombs in military trai-ning areas	158	66	42	30	58	26	103	80	60	60	49
Unknown causes	634	431	442	315	297	357	357	430	289	217	176
Total	**1,612**	**949**	**930**	**779**	**818**	**763**	**780**	**888**	**701**	**515**	**429**
	Burned area in ha										
Cause	Average 1991 - 2000	Average 2001 - 2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Natural causes	111	6	15	2	13	12	7	8	10	12.4	2.5
Carelessness	286	64	202	75	137	41	58	64	55	29.8	19.1
Arson	153	92	35	48	41	34	29	20	30	14.8	11.5
Old ammu-nition, unex-ploded bombs in military trai-ning areas	244	104	26	32	279	69	307	28	33	71.2	42.9
Unknown causes	446	136	204	98	69	107	121	94	141	70.5	44
Total	**1,240**	**403**	**482**	**256**	**539**	**262**	**522**	**214**	**269**	**199**	**120**

Table 4: *Causes of forest fires in Germany. Source: Federal Office for Agriculture and Food*[79]

The temporal course of the fire season in Germany depends on weather conditions in the respective year. Frequently, the fire season reaches its first peak in March and April, when dry remains of the previous year's ground vegetation serve as excellent fuel. In 2014 for example, 20 % of the year's forest fires occurred in March, the same proportion as in July. Only June had a higher fire incidence, at 24 %. In the preceding year, only 1 % of the forest fires had occurred in March, while the peak was in July with 40 %.[79]

2014 was the year with the lowest number of forest fires (429) and the lowest affected area (120 ha) since 1977 when statistical records started. With respect to the ten year average of the previous decade, fire incidence decreased by 41 %, while the affected area decreased by 63 %. Annual economic damage between 1991 and 2014 averaged 1.9 million Euro. In 2014, economic damage caused by forest fires amounted to 0.2 million Euro. 8,000 solid cubic metres of wood were destroyed. The average damage per fire amounted to 471 Euro. The greatest damage by forest fires in the last 20 years was recorded in 1992, causing losses of 12.8 million Euro and burning 4,908 ha (table 5).[79]

In 2014, 120 ha forests burned in Germany – the lowest forest cover loss since the beginning of fire monitoring.

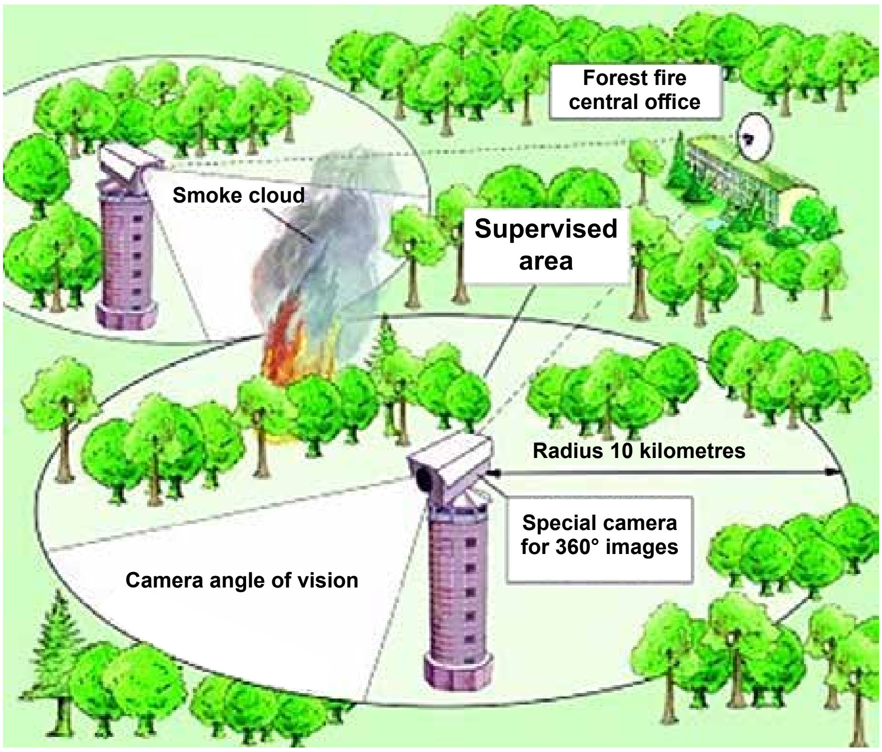
Year	Burned area (ha)	Number of fires	Surface loss (ha per forest fire)	Damage (Mill. €)
1991	920	1,846	0.5	1.7
1992	4,908	3,012	1.6	12.8
1993	1,493	1,694	0.9	5.4
1994	1,114	1,696	0.7	1.3
1995	592	1,237	0.5	1.5
1996	1,381	1,748	0.8	4.2
1997	599	1,467	0.4	1.5
1998	397	1,032	0.4	1.6
1999	415	1,178	0.4	1.4
2000	581	1,210	0.5	2.1
2001	122	587	0.2	0.5
2002	122	513	0.2	0.5
2003	1,315	2,524	0.5	3.2
2004	274	626	0.4	0.5
2005	183	496	0.4	0.4
2006	482	930	0.5	0.9
2007	256	779	0.3	0.8
2008	539	818	0.7	1.0
2009	262	763	0.3	0.6
2010	522	780	0.7	1.2
2011	214	888	0.2	0.9
2012	269	701	0.4	0.5
2013	199	515	0.4	0.5
2014	120	429	0.3	0.2

Table 5: *Number, area and damage of forest fires in German, 1991 to 2012. Source: Federal Office for Agriculture and Food*[79]

The biggest fire disaster in the history of the West German federal states occurred in 1975 in the Lüneburg Heath, when multiple fires ignited at the same time. Around 15,000 firefighters from all over Germany were deployed, supported by nearly 11,000 soldiers and firefighting planes from France. Five firefighters died when the wind shifted and they were enclosed by the flames. In this fire, 7,418 ha forest were destroyed and losses amounted to the equivalent of 18 million Euro. As a consequence of this disaster, the organization of fire prevention was noticeably improved all over Germany. Today, in high risk areas, firefighter plane service are employed for aerial forest observation during critical seasons.

The amount annually spent on fire protection and control exceeds the losses caused by fires by far. In the last decade, Germany invested an average of 4 million Euros per year, in 2006 it was almost 10 million Euro. 80 The forestry authorities bear the majority of these costs. In Brandenburg for example, a forest fire monitoring system was developed that is now also employed in Mecklenburg-Western Pomerania, Saxony-Anhalt, Saxony and Lower Saxony, as well as in other European and non-European countries.

__Figure 10:__ Early detection system for forest fires „Fire Watch". Source: Landesbetrieb Forst Brandenburg[83]



A high resolution optical sensor system is installed on mobile masts or fire guard towers at least 10 metres above the treetops, and can thus monitor a forest area of up to 700 km² (figure 10). Its special filters recognize a fire by its smoke cloud.[81] Computer software automatically evaluates the images on site by comparing chronological sequences of images of the horizon. In case of an alert, the images, along with the direction and range, are sent to the central office. The operator decides whether it is smoke or merely a dust cloud, and can alert the firefighting department if necessary.[82] Altogether, in Germany 175 such sensor cameras survey an area of just under 1.9 million ha. The focal area is Brandenburg with 108 sensors surveying the entire forest cover of the state (1.1 million ha).[83]

By means of automatic early warning systems for forest fires such as "Fire Watch", firefighters can be deployed immediately and the burned area can thus be kept low. The fire hazard in northern Germany can only be reduced sustainably and in the long term if the ecological changes that have led to increasing fire risk can be reversed. First of all, the 23,000 km of channels draining the forests of Brandenburg of the already little precipitation should be filled in. Mainly however, the homogeneous pine monocultures, which favour the emergence and spread of forest fires, should be converted into well-structured mixed stands of trees of different ages.

Water retention reduces the forest fire hazard by elevating the groundwater level and causing high soil humidity.

4.4 Australia

Australia's national territory covers 7,617, 930 km², reaching from the subtropics to deep into the southern temperate climate zone. The nature, frequency, extent and season of forest fires are subject to large regional variation. Every year, vast areas burn in northern Australia. Figure 11 shows this for 2015. The tropical savannahs and grasslands in this part of the country burn easily and frequently. People are used to fire and benefit from it as it promotes the growth of fresh grass for pastures and for wildlife.

In the south, the burn areas are much smaller. Population densities however are much higher, and the landscape is highly fragmented. Damage caused by fires in southern Australia is therefore considerably higher than in the sparsely populated north. The relatively smaller fires in the south draw public attention and command political response, as they burn houses and endanger people. Consequently, a culture of complete fire prevention has been established to protect valuable property at risk from fire.

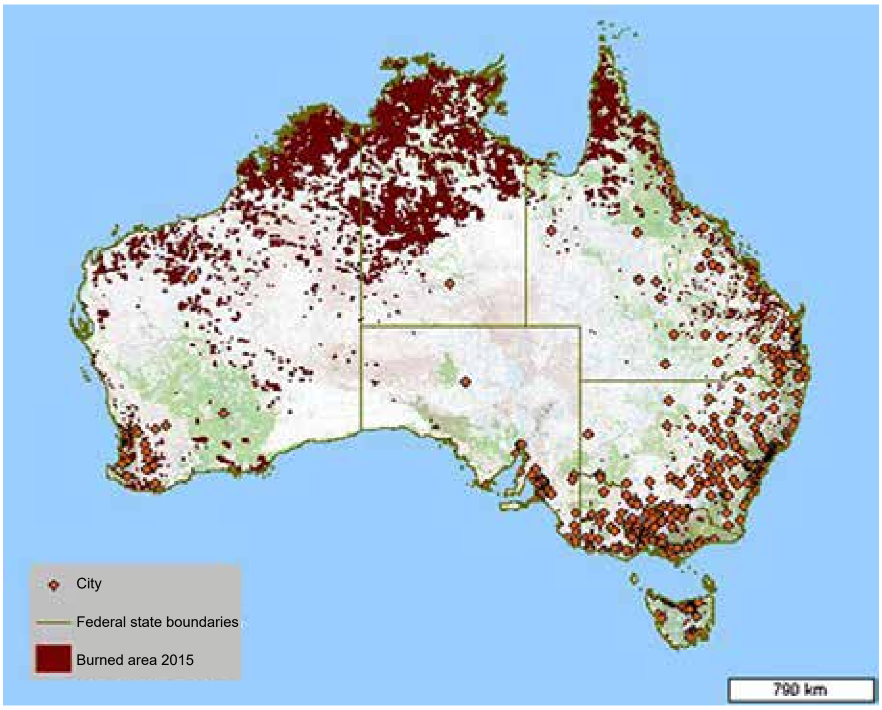


Figure 11: *Map of burned areas in Australia in 2015. Source: Western Australian Land Information Authority (Landgate)*[84]

Between 2000 and 2015, Australia lost 5.6 million ha of forests to fire and drought. Australia's loss of forest cover is second only to Brazil's for this period.

The effects of fires are therefore highly different. In the north, millions of ha can burn without causing significant material damage, while in other parts of the country, a single fire covering a small area can cause considerable loss of lives and property. This explains why 2003 is considered one of the most disastrous fire years, even though compared to the long-term average, only a small area was burned. Actually, the annually burned area has significantly decreased since European settlement due to land use changes, fire prevention and the end of traditional burning by Aborigines. This has led to changes in forest structure, to forest degradation and even forest decline. Between 2000 and 2015, Australia lost 5.6 million ha of forests to fire and drought. Australia's loss of forest cover is second only to Brazil's for this period.[85] By 2015, 1.5 million ha were reforested.[86]

4.4.1 Forest fire disasters of this century

The **fire season 2002/2003**, in the wake of a severe and long drought period, was one of the most dramatic since European settlement. Conflagrations occurred in New South Wales, the Australian Capital Territory and Victoria, and a fire disaster in Canberra on the 18th of January 2003. The fires claimed ten lives, destroyed over 1,200 buildings, killed over 12,000 head of cattle and caused extensive environmental damage. The insured amount of loss is estimated at over 400 million Australian dollars (around 237 million Euro). Environmental damage was not estimated.[87]

During the investigations of the fires of 2002/2003, uncertainties were detected in the available statistics and remain until today. For example, they only cover fire data from public forests, but not from national parks or private forests. Data collection methods can thus influence data accuracy. The data partially cover the controlled use of fire, and partially don't. Lastly, available data mostly date back only a few years. However, reliable forest fire statistics established using standardized methods are necessary to evaluate the success of past interventions, improve planning and to create a basis for technical and political innovations.

The **drought in 2005/2006** caused extensive bushfires in the states of Victoria, New South Wales and South Australia, as well as in Tasmania. At least two people died, dozens of houses were destroyed and thousands of animals killed. In **2006/2007**, Victoria again witnessed destructive forest fires that claimed one life and incinerated 51 houses.[88]

On the 7th of February **2009**, the state of Victoria in the southeast of the continent was hit by the most devastating bushfire of Australia's history. 173 people died, 1,800 houses were destroyed and 450,000 ha land burned. Previously, several consecutive years with low precipitation had lowered the groundwater level, dried out soils and vegetation, and thus created the conditions for the fire disaster. On the day of the conflagration, an extreme weather situation preceded the event, as it had before fire events in 1939 and in 1983. A low pressure area over the Tasman Sea led to strong winds carrying hot dry air masses from the interior to southeast Australia. Experts worry that climate change will increase the occurrence of such extreme weather conditions.[96] The hot winds parched the litter and ground vegetation, generating ideal conditions for destructive fires. The extent of the fires took the residents of the suburbs by surprise, as they had not been aware of a fire risk and were thus unprepared. A subsequent investigation of the fires[89] revealed that over half of the houses burned in areas that had not been classified as at risk. Houses even burned down several hundred metres from the nearest forest. A week earlier, an unprecedented fire risk had been predicted for the 7th of February, but the affected communities were not aware of the possible consequences. Additionally, as the investigation report established, no timely warning had been issued, so that many people were surprised by the fire.[89]

In **October 2013**, around 100 fires burned in the east of New South Wales, among them sixconflagrations. They reached their peak in mid-October in the Blue Mountains west of Sydney. On the 16th of October, a military manoeuvre sparked the "State Mine Fire". The conflagration spread to a diameter of 190 kilometres and burned an area of around 45,000 ha. At its peak, the fire spread at a speed of 25 kilometres per hour. Thousands of inhabitants of the town of Lithgow and surrounding communities had to be evacuated. The following day, two more conflagrations broke out in the Blue Mountains, prompting the declaration of a state of emergency for New South Wales on the 20th of October. The fires could only be extinguished on the 13th of November 2013. Two people died in the fires, among them a pilot whose firefighting plane crashed. 200 houses were destroyed. Altogether, an area of 118,000 ha was lost. The damage is estimated at 183 million Australian Dollars – around 120 million Euro.[90]

In early **2016**, a series of fires occurred in Tasmania, an island south of Australia. Tasmania's unique ecosystem allows insights into earth history: its flora and fauna are a living testimony to the supercontinent Gondwana over 100 million years ago, when dinosaurs roamed the Earth.

Around 40 % of Tasmania's territory is protected, and around half of that, around 1.6 million ha, are classified as UNESCO world heritage.[91]

In 2015/2016, winter, spring and summer had been extremely dry as a result of El Niño. On the 13th of January 2016, a thunderstorm crossed Tasmania and lightning ignited over 300 fires.

The temperate rainforests of Western Tasmania are a fire-sensitive ecosystem. Under normal circumstances, a fire caused by lightning can hardly spread in the humid climate.[92] In 2015/2016, winter, spring and summer had been extremely dry as a result of *El Niño*. On the 13th of January 2016, a thunderstorm crossed Tasmania and lightning ignited over 300 fires, 15 of them in UNESCO world heritage sites. As the majority of the fires raged in remote and inaccessible regions, suppression proved difficult. 1,000 firefighters and up to 40 firefighting planes from the mainland flew in to support the 5,600 Tasmanian colleagues.[93]

The fires in January and February 2016 burned an area of altogether over 100,000 ha, 20,100 ha of which was UNESCO world heritage. Of these, around 2,700 ha of fire-sensitive plant communities of high ecological value were lost. Additionally, the fires damaged soils, waters and swamps.

4.4.2 Causes

Lightning strike can be responsible for causing up to one fourth of the fires in unpopulated areas of Australia, but plays a minor role in the global picture. However, lightning in remote areas can cause huge forest cover losses, and these make up a large proportion of the annual burn area. In Australia, as in other places, human activity is the underlying cause of most fires. Natural factors like lightning only cause 6 % of wildfires. 13 % are attributable to arson, and another 37 % to suspected arson - together making up half of the fires. Another 35 % of fires are caused by carelessness.[94] The highest fire rate occurs in communities with a large proportion of children und below-average education levels, employment rates and household income. This structure is often found in suburban populations.[95] At the same time, the wilderness-urban interface offers plenty of opportunities to light a forest fire. Most fires destroy less than 5 ha, but can cause substantial damage and endanger human lives in populated areas.

Through climate warming, the number of days of high fire risk has increased since the 1970s and could double by 2050.

Through climate warming, the number of days of high fire risk has increased since the 1970s and could double by 2050. Especially southern Australia is affected by these changes, increasing the risk for humans, property and infrastructures. Many high risk areas will see an extension of the forest fire season.[96] This could have implications for the availability of technical and human resources for fire suppression. The Australian summer and thus the peak of the fire season fall on the winter season in the northern hemisphere, so that until now, firefighting equipment and staff could be shared between Australia and North America. International companies rent out some of their largest extinguishing planes to North America in the summer and to Australia in the winter. Additionally, there are agreements on the exchange of staff between North American countries and Australia, under which highly specialized firefighters are deployed for fighting forest fires on both continents. If the fire seasons extend both in North America and Australia and start overlapping, this kind of resource exchange will be impossible.[97]

4.4.3 Effects

Financial damage

Available information about the economic damage caused by fires is limited to insured losses. Some of the destroyed property however was either not or not adequately insured and is thus not included in these figures. In addition, there are further economic losses in productivity, tourism, by smoke, by infrastructure restoration, or job losses.

According to the Food and Agriculture Organisation, budgets for fire suppression have been increasing while expenses for prevention have decreased.

Comprehensive national information about the cost of fire suppression is also insufficient. According to the FAO, available information points towards increasing budgets for fire suppression and decreasing expenses for prevention. As an example, the cost of fire suppression has exploded in New South Wales. In financial year 1992/1993, the budget of the Rural Fire Service was 28 million Australian Dollars (AU$). In financial year 2002/2003, this budget was five times as high (141 million AU$), and in financial year 2014/2015, it was twelve times as high (332.9 million AU$)[98] – equivalent to 218 million Euro. It is questionable how long this kind of budget increase for fire suppression can be financially sustained. Instead, the balance between prevention and suppression should be reconsidered. Especially the aspect of fire risk should be better integrated in land use and development planning processes. To this end, the expertise and experience of firefighters, emergency services, insurers and agricultural and forestry stakeholders should be engaged.

Ecological damage

Australia's native species have adapted to recurring fires over millions of years. Since European settlement however, the frequency, extent and intensity of fires have changed considerably with distinctive regional differences. In regions with increased fire incidence and severity, the habitat of fire-sensitive species has decreased, and vegetation composition and structure have changed. Fire-prone grass species invaded, and animals are lacking nesting and retreat options. In areas where fires are prevented and suppressed, bushes and shrubs have replaced species that require fire for reproduction.

Great Desert Skink (Egernia kintorei), a highly endangered Australian lizard species.

The Great Desert Skink is adapted to a patchwork of burn areas of different ages. It has difficulties surviving a large fire.

Change in fire regimes threaten many endangered species like the bilby (*Macrotis lagotis*), a marsupial that looks like a rabbit and is one of Australia's vulnerable species. While it was very common all over Australia 100 years ago, it is now only found in the northern parts of the country. An increase in massive bushfires endangers its food sources and retreat options.[99] Another example is the Great Desert Skink (*Egernia kintorei*), a highly vulnerable native lizard. The Great Desert Skink is adapted to a patchwork of burn areas of different ages typically generated by traditional fire management practices of the Aborigines. Its last populations are found in regions where this fire management is still practiced, on 3 to 15 year old burn areas. It has difficulties surviving a large fire. Conflagrations significantly reduce its food sources and possibilities to hide from predators.[100]

Among the plant species endangered by fire, *Boronia viridiflora* is prominent. The last populations of this 1.5 to two metre high shrub are only found in two sites on the vertical sandstone faces of the Arnhem Plateau. Its survival depends on the preservation of appropriate sites, which are increasingly exposed to fire. Together with the Australian government, WWF has therefore initiated the „Arnhem Land Fire Abatement Scheme". This programme combines satellite-supported fire surveillance and helicopter missions with the on-ground action of indigenous rangers. Annual forest cover losses could thus be significantly reduced in the 40,000 km^2 project area.[101]

4.4.4 Solutions

Due to the highly different conditions between northern and southern Australia, there is no *one* concept for all of Australia. The fires in the savannahs in northern Australia should be tolerated as natural processes even though they burn vast areas. Preventing fires would have negative consequences for these ecosystems.

The situation is very different in southern Australia. Climate change will significantly increase fire risk. At the same time, inflicted damage is far greater in the densely populated south. Quick and effective fire response is crucial, however more emphasis should be laid on fire prevention. Forest fire risk should be taken into consideration in all relevant areas in order to reduce fire risk and potential damage. Land use planning should aim at preventing further uncontrolled development and landscape fragmentation and at clearly separating urban areas from forest and bushland.

In Australia, the effects of anthropogenic climate change are already noticeable. An increase in the number of hot and dry days with high fire risk is unavoidable. These effects can be effectively reduced by adaptation and climate protection.[96] Most of all, this requires the reduction of anthropogenic GHG emissions. Australia needs to take action, along with all other (developed) nations. Australia's GHG emissions at 762 million t CO_2-e are just slightly below Germany's emissions. Per capita emissions at 33 t CO_2-e however are almost three times as high as in Germany. Forest fire risk in Australia will only be controllable if politicians commit to an ambitious climate protection programme to limit global warming.

Properties on the wilderness-urban interface are especially at risk from forest fires.

4. 5 Russia

4.5.1 Current situation and the forest fire disasters of this century

Russia, as the largest country on Earth, boasts the largest forest cover of 815 million ha.[61] Regional differences regarding population densities and forest ecosystems are pronounced. The forests of Russia's more densely populated west are made up of fire-sensitive tree species and are not adapted to forest fires. In the sparsely populated regions of central and east Russia on the other hand, fires are part of the ecosystem and forests are adapted to fire events.[102]

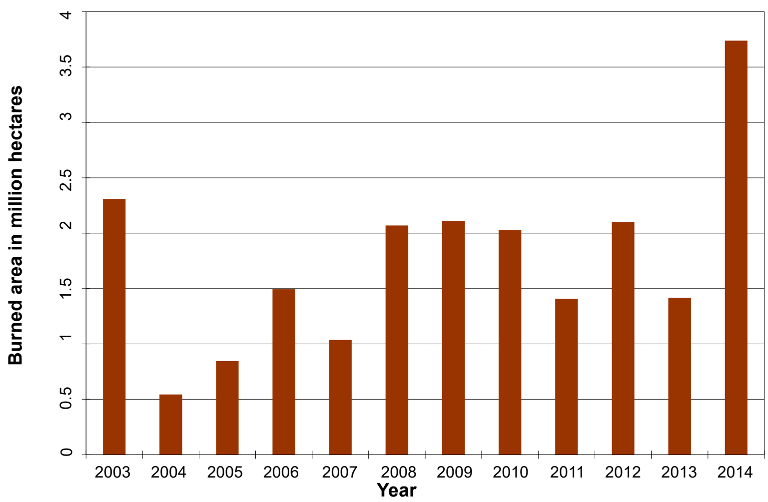


Figure 12: *Development of forest fire area in Russia from 2003 to 2014. Source: FAO[61], EFFIS[103, 104]*

Every year, several million ha of forest burn in Russia (figure 12). Even according to conservative estimates, 11 million ha of forests were lost within the last 5 years alone, between 2010 and 2014. This is equivalent to Germany's entire forest cover.[61, 103, 104] In **2015** altogether 2.875 million ha forests burned in 12,238 forest fires.[129]

There are however considerable differences in the available information about burned areas, depending on the source and data acquisition method. The figures presented above originate from Avialesookhrana, the Russian special aerial firefighting unit, and rely on data collected on the ground or from the air. The Sukachev Institute of Forestry, an independent remote sensing institution of the Russian Academy of the Sciences, identifies burned areas using satellite images. A comparison of the burn area data reveals that the areas identified by the Sukachev Institute are considerably larger than the surfaces specified by Avialesookhrana. For some years the differences are six to seven-fold. Other studies and evaluations lead to the assumption that the real extent of the burned areas is closer to Sukachev Institute's data.[105]

In most years, central and eastern Russia are particularly affected, as vast forest fires rage in remote regions. Although frequently cities in the Russian Far East are shrouded in haze for days and weeks, these fires receive little political and media attention.[102]

In **2010** however, forest fires occurred in densely populated western Russia around the capital Moscow. Although the burned area, at 300,000 to 400,000 ha, was comparatively small (up to August 2010, altogether around 5 million ha had already burned in Russia that year), politicians and the public grew alarmed as thick smoke clouds descended upon Russia's capital. The fires claimed over 50 lives, and around 2,500 houses were burned by flames fanned and rapidly spread by strong winds.[102]

The severe fires of 2010 were fanned by hot air masses streaming from the Sahara into western Russia, as they had to Greece in 2007. This triggered the most severe heat wave and drought period since the beginning of records 130 years ago. This extreme weather event created ideal conditions for high flammability and a quick spread of forest fires. Nevertheless, most of the fires were not caused by natural factors but by humans, for example during agricultural, forestry and especially recreational activities like bonfires.

Altered socioeconomic structures in rural western Russia are an important underlying factor for the fire disaster. Like in many European regions, traditional agriculture is gradually being abandoned. Young people increasingly migrate to cities, and many previously agricultural villages turn into holiday resorts. Vacationers from the cities however often have no awareness of responsible interaction with their surrounding nature. The number of bonfires gone out of control has increased in recent years, as has solid waste pollution of forests and along rivers, without prompting any reaction from society or the authorities.[102]

According to the code, private logging concessions sprawling all over the country are responsible for fire prevention, but rarely abide by these regulations.

The 2007 Russian Forest Code transmitted the responsibilities for fire management to the regions. By the summer of 2010, many regions had invested too little into capacity building, equipment acquisition and other necessary measures for fire prevention and preparedness. According to the code, private logging concessions sprawling all over the country are responsible for fire prevention, but rarely abide by these regulations. By cutting 70,000 forest supervisor jobs, the government's authority for implementing sustainable forestry and reducing illegal forestry activities has been drastically reduced. The traditional, centrally coordinated system of forest fire prevention, which had been implemented by the National Aerial Forest Fire Centre Avialesookhrana, with specialized forest firefighters, was abolished.[102]

During the summer of 2010, local fire brigades, task forces of the Emergency Ministry EMERCOM, and the military tried to fill this gap, but were understaffed and ill equipped to fight the fires. The airplanes of EMERCOM were far too few to cover the 600 million ha of forest cover classified to be protected from fire. By the immediate mobilisation of emergency funding however, EMERCOM played a key role in handling the situation.[102]

4.5.2 Causes

72 % of forest fires in Russia are caused by carelessness or arson. 7 % are provoked by the use of fire in agriculture. 14 % originate from other causes like sparks flying from power or railway lines. Lightning only causes 7 % of forest fires, although in the sparsely populated areas in northern Russia, the proportion of fires caused by lightning lies around 50–70 %.[105] Extreme forest fire situations like in 2003 can be attributed to a complex interplay of multiple factors: extreme drought, reduced firefighting capacities, ill-adapted forestry, as well as economically motivated arson or carelessness. Precipitation was extremely low in the regions northwest and southeast of Lake Baikal between August 2002 and May 2003, for example a mere 36 mm in the Republic of Buryatia. The usual annual precipitation in this area lies around 190 mm. Vegetation was experiencing extreme drought stress. At the same time, budget cuts led to fewer surveillance flights. Thus, fire sources were not detected in time and grew into uncontrollable conflagrations.[105] Climate change is likely to further increase the number of forest fires, especially in Siberia with its vast expanses of forests and weak firefighting infrastructure.[106]

Forestry practices involving clear cutting significantly increase the vulnerability of forests to fire.

Forestry practices involving **clear cutting** significantly increase the vulnerability of forests to fire. The size of the clear cuts exceeds the distance that tree seeds can travel by wind. Under the extreme climate conditions prevalent in some parts of Russia, natural regeneration is thus no longer possible. Recurring fires create favourable conditions for the evolution of extensive grasslands where fires occur regularly.[105]

Arson is also associated with **illegal logging**, which has assumed alarming proportions in the trans-Baikal region as well as in entire southeast Russia. Around 50 % of timber in these regions is harvested illegally. The driving force is the huge demand for wood in neighbouring China.[107] Fires are deliberately started and the damaged trees are then felled for a small fee.[105] At the same time, the temptation is high to cut down trees from adjacent undamaged forests.

4.5.3 Effects

Financial damage
It is challenging to make a financial estimation of the damage, as indirect losses and environmental damage are difficult to quantify. Damage including the costs of fire suppression amounted to 42 million US Dollars (US$) in 1999, according to official Russian figures. For 2000 and 2001, this figure doubled to 84 million US$, and doubled again for 2002 to 164 million US$. In 2003, these costs reached a record peak of 695 million US$.[105] Between 2010 and 2013, average damage amounted to 1 billion US$ per year.[108]

Effects on health
Smoke arising from extensive fires creates significant health risks for the population. Thick haze, like 2010 around Moscow, usually arises when dry peat swamps catch fire. In western Russia, during Soviet times large expanses of peat swamps had been drained for agriculture or energy production. Forest fires quickly spread into these dry peat soils.

Compared to forest fires, peat fires are very difficult to extinguish. The restoration and rewetting of drained peat swamps would thus not only be desirable from an ecological point of view, but also from a public health perspective.

Haze from fires is particularly critical for persons with respiratory and cardiovascular diseases, as well as for the elderly and small children, as it contains toxic substances like carbon monoxide, fine dust, formaldehyde and polycyclic aromatic hydrocarbons. While Moscow was shrouded in smoke, the death rate doubled. A higher rate of stillbirths was also recorded.[102]

While Moscow was shrouded in smoke, the death rate doubled.

Ecological effects
Large parts of Russia's forest ecosystems are adapted to periodic fires. Nonetheless, forest fires have become more frequent. In the Russian Far East for example, historically there were extreme forest fires every 40 to 80 years. Over the last four decades, this interval has decreased to ten to twelve years.[105] This has grave ecological implications. Large, particularly hot fires adversely affect the entire forest ecosystem, as they destroy both undergrowth and tree cover over vast expanses. Given time to recover, these surfaces will eventually be recolonised by plants and animals

Repeated fires however can lead to desertification. The deforested surface has increased by 8 million ha in the last 50 years. Reforestation would require a major effort and natural regeneration of these areas would take hundreds of years. However, small fires that only affect the undergrowth and leave trees intact can also have negative effects when they occur repeatedly (caused by human intervention). In this case fires contribute to species uniformity, leading to homogeneous, monotonous forests.

The loss of forest cover adversely affects the water balance and reduces water retention capacity, increasing the frequency of floods. Water contamination by ashes and soil erosion potentially causes high fish mortality. After forest fires, trees are weakened, damaged or die. This can promote the mass proliferation of insects, which then attack the remaining forests.

Forest fires, especially when they spread into peat soils, release significant amounts of CO_2 into the atmosphere, accelerating global warming.

Forest fires, especially when they spread into peat soils, release significant amounts of CO_2 into the atmosphere, accelerating global warming. Climate change is associated with increasingly frequent extreme weather events like long droughts, which in turn increase the incidence and severity of forest fires. The European Commission's Joint Research Centre estimates that the fires in Russia in 2010 released around 140 million t CO_2, where the largest part was attributable to peat fires and the subsequent decomposition of peat soils.[109] However, these appraisals are merely a rough indicator of the order of magnitude, as data on the burned area vary significantly depending on the source. Furthermore, CO_2 emissions vary between affected forest ecosystems.[110]

When forest fires spread to radioactively contaminated areas, such as the Oblast Brjansk in the southwestern part of Russia near the Ukrainian town Chernobyl,[189] radioactive particles can be released into the atmosphere along with smoke and cause radioactive fallout in other places. Therefore special attention has to be given to fire prevention in these areas, by adapted forestry or automatic fire surveillance systems.[102]

Implications for species diversity, exemplified by the Amur leopard and the Siberian tiger

Forest fires have considerable effects on species diversity. The southwest of the province Primorye harbours the last retreat of the Amur leopard. Around 30 to 40 of these elegant creatures remain in a thin 180 km by 20–30 km strip of land between the Chinese border and the Sea of Japan. They take refuge in the mountainous forest where they prey on Sika deer, roe deer and other animals. Endangered Amur tigers also roam these forests. The land between the mountains and the ocean is populated and cultivated. Farmers burn their fields every year, and fires often spread into adjacent forests. These annually recurring fires cause the forest fringe along developed areas to become monotonous. They offer little food for deer, and thus no prey for leopards and tigers. Therefore leopards and tigers avoid these areas.

A study assessing the effects of forest fires on leopards and tigers in this region found that within the investigation period of six years, a total of 46 % of the investigated area of almost 3,500 km^2 burned at least once. Fires in hunting leases were far more frequent than in protected areas. It also found that the frequency with which an area was burned was directly related to its proximity to villages and roads. The drastic loss of habitat, partially attributable to forest fires, represents a major threat to Amur leopards and Amur tigers and is bringing them to the brink of extinction.[111]

In six years, almost half of the Russian leopard habitat burned at least once.

4.5.4 Solutions

To date, all approaches to stop the burning of fields in southwest Primorye and to intensify fire prevention have not proved effective – WWF is therefore testing a new innovative method: The most important forests for leopards that are threatened by fire will be protected by planting larches in 20–30 metre board strips. Larches repress the growth of understorey and provide no fuel for smaller fires caused by burning fields, thus being able to stop them. However this requires larches to be older than 10 years. Until they reach that age, these trees, as well as the adjacent forests, have to be particularly well protected from fire. At the same time, WWF collaborates with border patrols, trains them in fire suppression and provides them with simple firefighting equipment. Fires along the Russian-Chinese border in southwest Primorye can thus be fought more effectively.

Another important approach is the establishment of protected areas without or with limited economic activities. Since 1994, WWF has helped protect 7.4 million ha of temperate mixed forests in the Amur region, an area larger than Bavaria. WWF also works with logging companies who seek to manage their logging concessions sustainably and want to guarantee this by certification following Forest Stewardship Council (FSC) guidelines. By early 2015, 6.6 million ha of forests in the Russian Amur region were FSC certified. WWF also supports anti-poaching units in this region, who work to protect endangered species as well as to fight illegal logging. WWF's work with protected areas and anti-poaching patrols is complemented by massive educational work with local populations. To this end, WWF collaborates with journalists and schools, and supports youth groups who advocate nature conservation.

Regarding the entire Russian Federation, before fighting fires it is imperative to fight the causes of fires which explain their increasing frequency and severity. Capacities for fire suppression should be strengthened in such a way that forest fires can be detected and suppressed at an early stage, thereby reducing threats to people and communities and preventing ecological damage. Besides that, fire prevention should be understood as a part of forest management. This means refraining from large-scale clearcutting which increases the forests' vulnerability to fires. Additionally, controlled burning in fire-dependent forest ecosystems should be seen as a management tool to reduce the amount of fuel, promote natural regeneration and to improve the natural habitat for wildlife.[105]

Creating public awareness of fire risk is necessary to reduce the number of human-induced forest fires, for example through education campaigns in schools. On the other hand, forest fire risk should be considered in infrastructure planning, for instance for the construction of railway or power lines.

Law enforcement in the forestry sector should be improved, in order to fight illegal logging and associated arson.

Most of all, law enforcement in the forestry sector should be improved, in order to fight illegal logging and associated arson. WWF has been appealing to the government for years to improve international cooperation to eliminate illegal logging and illegal trade. Among others, this has resulted in the Northern Asia Forest Law Enforcement and Governance (ENA-FLEG) process with the participation of Russia, the EU member states, China, Japan and other European and Asian countries. Apart from licence agreements for verifying the legal provenance of wood, the ENA-FLEG process also includes support for forestry sector reforms. Within this process, existing laws and regulations governing the protection of forests from fires will be analysed and strategies for forest fire prevention will be developed.[112]

4.6 Amazon

If the Amazon basin were in Europe, it would stretch from Lisbon to Warsaw and from Palermo to Copenhagen. The Amazon basin hosts the largest remaining block of rain forest of the planet (5.4 million km^2). Over half of its surface is on Brazilian territory, smaller proportions are in the adjacent Bolivia, Peru, Colombia, Guyana, Suriname, Venezuela and French Guyana.

The Amazon region is a true treasure trove of species diversity: It harbours an estimated 10 % of global biodiversity. Until today, around 40,000 plant species, 427 mammal species (among them jaguar, ocelot, giant otter and river dolphin), 1,294 bird species (among them imperial eagle, toucans, macaws and hummingbirds) as well as 3,000 different fish species have been identified. Many among them are endemic, meaning they are only found in the Amazon. Vast parts remain mostly unexplored. In the decade between 1999 and 2009 alone, 1,200 new plant and vertebrate species were identified in the Amazon region, not including invertebrates. This shows how species-rich the Amazon is and how little we still know about it.[113]

In the last 50 years alone, 17 % of the Amazon rainforest was lost irrevocably.

Another around 17 % were altered and degraded by human intervention, mostly in connection with fire.

The Amazon rainforest originally covered around 4.1 million km^2 in Brazil; meanwhile it has shrunk to 3.4 million km^2. In the last 50 years alone, 17 % of this habitat were lost irrevocably.[114] Another 17 % have been altered and degraded by human intervention and mostly in connection with fire.

4.6.1 Current situation and the forest fire disasters of this century

On average, between 1995 and 2015, annually 1.46 million ha of the Amazon rainforest were destroyed – this is the equivalent of 2.78 ha or 4 soccer fields per minute!

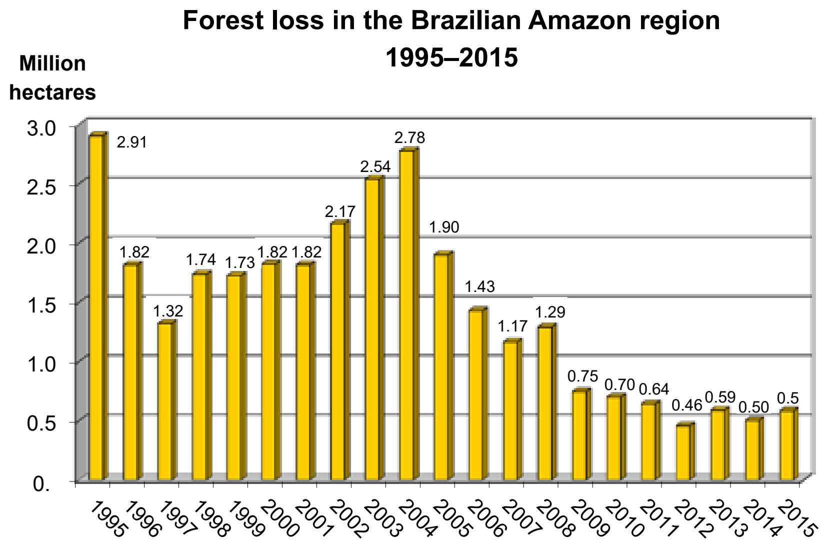


Figure 13: *Loss of forest cover in the Brazilian Amazon region from 1995 to 2025. Source: INPE*

Between August 2003 and August 2004, 2.74 million ha of rainforest, almost the size of Belgium, were lost. This was the second highest deforestation rate since the record year 1995. Since then, deforestation rates have been declining significantly (figure 13). While annually 2 million ha of forest had been lost on average in the decade between 1996 and 2005, the average deforestation rate fell to 0.8 million ha per year in the following decade (2006 to 2015).

In 2012, deforestation reached its lowest rate at 0.46 million ha since the beginning of records in the 1980s. [115] In recent years, the deforestation rate does not appear to be declining further, but instead stagnates at 0.5 million ha per year. 2015 even saw an increase in deforestation by 16 %. According to WWF, this is due to a weakening of strong protection laws and amnesties for illegal logging.[116]

In 1998, the Brazilian state of Roraima experienced a severe drought due to El Niño, which led to immense losses by forest fires. Hundreds of forest clearance fires could not be brought under control and developed into huge conflagrations that ended up killing 700 people and destroying around 1.2 million ha of rainforest. The burned area made up around 6–7 % of Roraima's entire forest cover, or more than twice the

Hundreds of forest clearance fires could not be brought under control and developed into huge conflagrations that ended up killing 700 people and destroying around 1.2 million ha of rainforest.

area that had been deforested to that date.[117] Smoke shrouded big cities, causing severe and persistent respiratory diseases in the population and affecting air traffic. The fires released about 4.4 million t CO_2 into the atmosphere.[131] 2003 saw another extreme drought with numerous forest fires. These primarily occurred in areas that had already been damaged by the fires of 1998 and were thus more susceptible to burning. Experts estimate that the fires in 2003 affected a similar area as the 1998 fires, but less severely.[117] In 2005, the Amazon region experienced the most severe drought in over 100 years. During the dry season, water levels of the Amazon usually drop by 9–12 metres, but in 2005, they dropped up to 5 metres more. Some rivers dried up entirely and were navigable by bicycles instead of boats. Towns and villages depending on waterways were experiencing food, medicine and fuel shortages, as they could not be reached by supply ships. The state of Amazonas declared a state of emergency in 61 towns and villages. Chemicals for water treatment were distributed to prevent disease outbreaks. As rivers dried up, fish stocks died, leading to the deaths of dolphins and manatees as they ran out of food. The drought also promoted forest fires; satellite images registered almost 170,000 fire sources.[118]

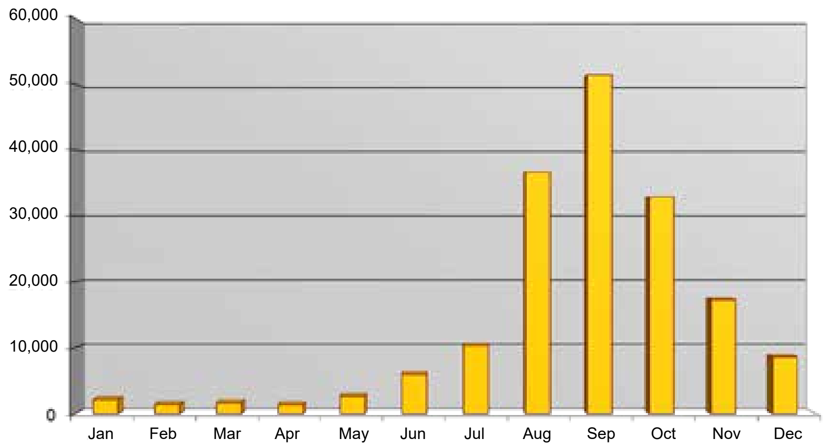
After heavy flooding in the Amazon region in 2009, another drought followed in 2010, even exceeding the drought of 2005 in intensity. Water levels of the Amazon sank to their lowest in 40 years. Brazil experienced its worst forest fire season in years, and numerous fires got out of control.[119] In September 2010, due to the forest fires, the Brazilian Environmental Ministry declared a state of environmental emergency in 14 states and the district of the capital Brasilia.[120] Numerous protected areas, as well as the largest river island of the planet, the Illha do Bananal, were devastated.[121] Severe forest and bush fires also raged in neighbouring Bolivia, Peru and Paraguay in the summer of 2010.[122]

Summer and autumn of 2010 brought another extreme drought to the Amazon region, similar to 2005. In addition to the southwest, which had already been affected in 2005, this time also the south (northern Bolivia) and the southeast (the state of Mato Grosso) of the Amazon basin were affected.[123] In August and September 2010, massive forest fires were reported from the Brazilian Amazon region and northern Bolivia. In Bolivia, the fires destroyed at least 1.5 million ha of forests[124] and clouded northern Bolivia in thick haze. Due to the fires that had gone out of control, the Bolivian government declared a national emergency on the 18th of August.[125] In Brazil, the number of fire sources in August and September 2010 was three to four times higher than in the same months of previous years. In September 2010 alone, the Brazilian Space Agency registered 56,543 fire sources.[126] Satellite images show that the fires mostly occurred in forests adjacent to already cleared areas. This points to forest clearance as the origin of the fires, which got out of control due to the drought.[125] In humid rain forests like the Amazon, forest fires are very unlikely to have natural causes.[131] The forest fires visible on satellite images (figure 14) are an indicator for human pressure[127] and are located in areas where forests are currently being cleared. The highest loss of forests occurs along an "arc of deforestation" along the southern and south-eastern fringes of the Amazon rainforest, in the states of Maranhão, Mato Grosso, Pará and Rondônia.

Figure 14: *Fires in the Brazilian Amazon region (Amazônia Legal) in 2015. Data of NOAA satellite.[15] Source: INPE; visualised with Google Earth*

The number of fire sources usually increases in late summer (figure 15) and peaks in September.[130] During the dry season, which lasts from June until November, the flames can develop into uncontrollable conflagrations, especially when the drought is exacerbated by *El Niño* events. The dry period is brought about by large-scale seasonal air current changes. In the winter and spring, warm air rises above the Amazon basin. This draws humid air from the tropical north Atlantic, which cools as it rises, causing cloud formation and rainfall. In the summer, the tropical north Atlantic warms up, causing a reversal of the air currents. Warm air rises above the ocean and generates rain there, while dry air masses descend on the Amazon basin. The length and intensity of the dry period in the Amazon basin is thus determined by the temperature of the ocean surface.[131] Ocean surface temperatures have increased by an average of 0.5 °C since 1970. In the tropical Atlantic, summer water temperatures have increased to 28°–30°C since 2004. At the same time, an earlier start and longer duration of the dry period in the Amazon has been observed. As one of several factors, global climate change in particular is responsible for the droughts in the Amazon.[132]

Figure 15: *Average monthly number of forest fires from 2000 to 2015 in Brazil. Source: INPE* [130]



In indigenous Xingu Park, by early September 2016 there had already been 3,891 fires. 10 % of the park's 2.6 million ha were burned. By comparison, in 2015 there had been 2,728 fires and 2,677 fires in 2014.

4.6.2 Causes

Forest fires in the Amazon region are almost exclusively human induced. Tropical thunderstorms are accompanied by strong rains, usually precluding ignition by lightning.[133]

The forest fires and accompanying forest destruction are mostly attributable to land conversion for cattle ranching and to a minor degree for agricultural use. At the same time, according to Embrapa, the research institute of the Brazilian Ministry of Agriculture, there are 70 million ha of open land available for agriculture. However, the costs of rehabilitating one hectare of depleted soils to make them suitable for agriculture amount to at least 800 Real, or 290 Euro.*** The costs of obtaining the same area by fire clearance on the other hand equal the cost of one match.[134]

Logging companies are the first to enter the rainforest. In 2004, 24.6 million cubic metres of timber, 36 % of which were destined for export, were processed in the Brazilian Amazon region.[135] Logging operations leave twigs and unusable wood behind. Sunlight enters through the gaps in the canopy, dries out the remains on the forest floor and kills the forest understory used to shady conditions. The remaining forests are left more susceptible to fire when settlers or illegal squatters enter on the logging roads and start clearing them.

*** Conversion rate of 30.08.2006

Small farmers are usually displaced and the land converted to cattle ranches. Cattle pastures cover 70 % of the entire deforested area. The number of cattle in the Brazilian Amazon region rose from 27 million in 1990 to 64 million in 2003. Meanwhile only 13 % of the produced meat is consumed regionally.[135] Expanding soy cultivation in turn pushes cattle farmers deeper into the Amazon. In Brazil, the area under soy cultivation increased from 6.9 million ha in the mid-1970s to 21.5 million in 2009. Production during this time increased from slightly over 12 million t of soy to 58 million t.[136] In 2010, this number reached 68.5 million t. In terms of value, soy is Brazil's third most important agricultural product, after sugarcane and beef.[137] The bulk of soy is produced to export. In 2011, Brazil exported 33 million t of soy, around half of its soy harvest. 70 % of these go to China, other important markets are Spain and the Netherlands. Only 1 % of Brazil's soy is exported to Germany, 370,879 t in 2011. However, in the same year Germany imported 616,338 t of soy from the Netherlands.[137] Most of this originated from Brazil, as soy is not cultivated in the Netherlands. The imported soy is usually used as animal feed in industrial farming. It is predicted that the area under soy cultivation in Brazil will increase to 30 million ha by 2020.[136]

Only 1 % of Brazil's soy is exported to Germany, 370,879 t in 2011. However, in the same year Germany imported 616,338 t of soy from the Netherlands. Most of this originated from Brazil.

After the suspension of Brazilian president Dilma Rousseff and the change of government in May 2016, it is unclear whether the previous rainforest protection policy will be continued. A few hours before her suspension, the departing president declared five new protected areas in the Amazon, encompassing an area of altogether 2.69 million ha.[138] Currently 1 million ha of these protected areas are under threat again. Cattle ranchers, and more importantly mining companies are lobbying hard to decrease or annul these areas. The Brazilian parliament however is currently negotiating several legal reforms such as the constitutional amendment PEC 215, the environmental licencing law, the mining code etc., which would allow for the cancellation of protected areas when this serves short-term economic interests, among others. There is concern that with a weakening of forest protection, fire clearance and deforestation will increase drastically and thus reverse the positive trend of recent years.[139] Deforestation in the Brazilian Amazon has already increased substantially in the past years, reaching the highest level since 2008 in 2016.

Fire clearance in the Amazon region.

4.6.3 Effects

Forest fires and slash-and-burn practices in the Amazon basin cause severe ecological damage and contribute to global climate change by releasing GHG. Smoke represents a human health hazard, especially for children. Continued deforestation may lead to regional climate change. The destruction of the Amazon rainforest is regarded as one of the causes of the drought of 2015 in southern Brazil.

Large-scale forest fires have more far-reaching consequences in a vulnerable rainforest ecosystem than in ecosystems adapted to fire, such as savannahs of forests of the temperate zones, as they cause sustained landscape changes. The original rainforest flora and fauna dies and is replaced by more fire prone vegetation.[140] Repeated fires at short intervals lastly lead to the establishment of grassland vegetation. These landscape changes endanger numerous birds, mammals and reptiles, even when they manage to escape the fire itself.[133]

Smoke from fires prevents precipitation and evidently extends the dry period. Dryness promotes fires. A dangerous feedback loop is started.

A dangerous feedback loop is started. Smoke from the fires prevents precipitation and evidently extends the dry period. Smoke in the atmosphere provides numerous condensation cores, around which water vapour condenses into small droplets. The droplets however do not coalesce into larger raindrops that eventually fall to the ground.[141] Additionally the loss of forest cover reduces the amount of water vapour released from the rainforest into the atmosphere. Trees transport water from deeper soil layers by their roots and transpire it through their leaves. The water vapour condenses in the atmosphere as it rises and falls back on the forest as rain. According to current knowledge, the rainforest has to remain largely intact in order to maintain this cycle. Deforestation reduces precipitation, especially when 30 % or more of the forest cover are destroyed.[141]

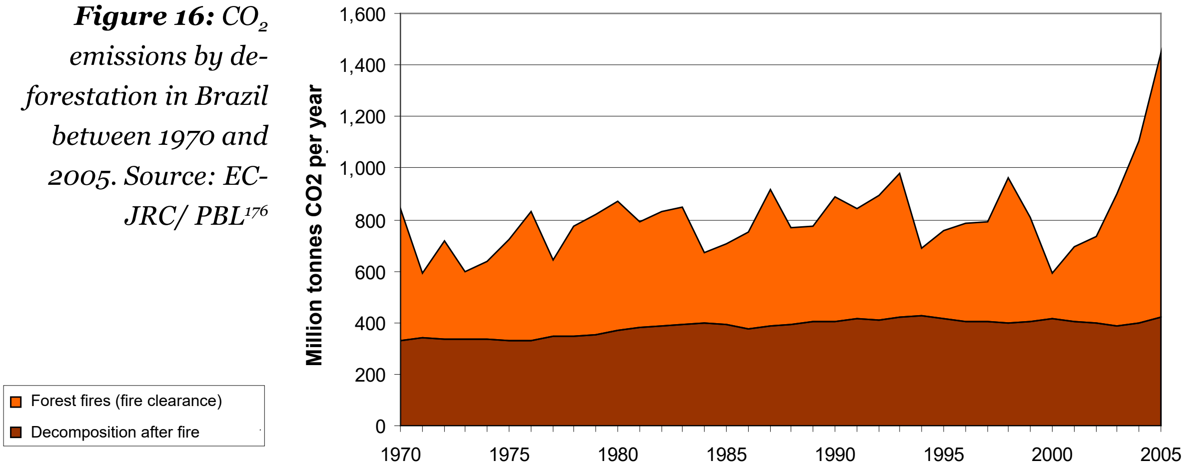
Large parts of the Amazon rainforest are faced with a situation where evaporation through the vegetation exceeds precipitation in the dry period. The enormous capacity of the vegetation for storing precipitation usually prevents plants from experiencing water stress. A slight decline in rainfall can disturb the equilibrium of these rainforests, whereby they become more vulnerable to forest fires and lose their capacity to uphold the water cycle.[141]

A study of the University of Bristol assumes that a temperature increase by 2 °C will lead to a loss of 30% of the forest cover of the Amazon basin, and an increase by 3 °C to a loss of more than 60%.

This situation is further exacerbated by global climate change. Climate models predict an increase in temperatures by 2–3 °C by 2050 for the Amazon basin, as well as a decrease in precipitation in the dry season, leading to widespread drought.[142] A study of the University of Bristol assumes that a temperature increase by 2 °C will lead to a loss of 30 % of the forest cover of the Amazon basin, and an increase by 3 °C to a loss of more than 60 %.[143] Additionally, there is worry that a global temperature increase may result in a permanent *El Niño* effect.[144] An increase in surface temperatures of the Pacific has already led to more frequent and severe *El Niño* periods, which cause severe drought in the Amazon region. During *El Niño* in 1997/1998, there was practically no rainy season, precipitation merely reached 25 % of its normal values. Groundwater reserves were not replenished and trees could not get enough water through their roots. The resulting partial loss of their foliage allowed sunlight to enter through the canopy, further exacerbating dryness. An experiment of the Woods Hole Research Center shows that tall trees that have grown over hundreds of years to reach the canopy are particularly sensitive to prolonged drought. In the first year of an artificially provoked drought, 1 % of the giant rainforest trees died. In the fourth year this number rose to 9 %. This experiment indicates that a decrease in precipitation may lead to the degeneration of the Amazon rainforest into a low forest stunted in its development.[145] At the same time, sunlight enters through the canopy and dries out fallen trees. The combination of a reduced tree population and large amounts of dry organic matter on the forest floor extremely increases a forest's vulnerability to fire.[145] While the forests in the study site were at extreme fire risk for eight to ten weeks per year, surrounding forests were only at high risk for ten days.[134]

This again provokes a positive feedback loop. Lower forest with stunted growth absorb less carbon dioxide from the atmosphere; increasingly frequent forest fires release more carbon dioxide into the atmosphere. During *El Niño* years and associated drought, the Amazon rainforest converts from a carbon sink to a source.[142]

Figure 16: *CO_2 emissions by deforestation in Brazil between 1970 and 2005. Source: EC-JRC/ PBL*[176]



Fire clearance of the Amazon rainforest perceptively contributes to global CO_2 emissions, as data of the European Commission's Joint Research Centre covering the period from 1970 to 2005 indicate (figure 16).[176] Between 2000 and 2005, average CO_2 emissions from fire clearance and the subsequent oxidisation of former forest soils in Brazil amounted to 911 million t per year. This is more than Germany's total annual CO_2 emissions.[146] In extremely dry 2005, CO_2 emissions in Brazil dramatically increased to over 1.4 billion t.[176] Long-term CO_2 emissions caused by the drought in 2005 are estimated at around 6 billion t for the entire Amazon basin.[123] 37 % of Amazonia were affected by the drought. The drought of 2010 even exceeded the 2005 drought, affecting 57 % of the Amazon basin. Long-term CO_2 emissions associated with the drought in 2010 are thus estimated at 8 billion t.[123] This corresponds to more than twice the CO_2 emissions caused by fossil fuel combustion in the EU.[146]

4.6.4 Solutions

Forest fires in the Amazon region are a result of land use conflicts. Fire is used as a tool.

Forest fires in the Amazon region are a result of land use conflicts. Fire is used as a tool to convert rainforest to agricultural land and cattle pasture. Forest fire prevention thus calls for comprehensive approaches that include solutions to land use conflicts. However, to date political measures have either been reactions to catastrophic events or are closely linked to the interests of political parties. A comprehensive approach requires the reform and implementation of policies and laws governing agriculture, mining and traffic planning.[133] This particularly involves coordinated land use planning, as well as the creation of international financing tools to act as incentives for national governments to decrease their national deforestation rates below a defined threshold. In South America, there are a number of laws for fire prevention and forest protection. Most of these are not enforceable, as they are either incomplete, are lacking further regulations regarding their implementation and capacities, or because responsibilities for their implementation have not been assigned. Frequently, implementation is also hampered by political instability or widespread corruption.[133]

During the UN Conference on Biological Diversity (CBD) in 2008 in Bonn, Brazil's environmental minister Carlos Minc pledged to WWF to stop net deforestation by 2020.[147] In August 2008, the Brazilian government under President Lula da Silva created the Amazon Fund to finance measures for forest protection. This fund receives donations by governments, businesses and private persons and aims to raise 21 billion US$ by 2021. It is designed to provide an incentive for Brazil and other tropical rainforest countries to voluntarily reduce their GHG emissions from deforestation.[148] In recognition of Brazil's success in reducing deforestation, Norway donated one billion US$ by instalments by 2015.[149] The German federal government supported the Amazon Fund with 18 million Euro, as agreed during an official visit of the Brazilian president in December 2009.[150]

Involving all stakeholders is crucial for a successful solution. In the "arc of deforestation" in the southern Amazon for example, partnerships between government agencies from federal down to community level and NGOs are being subsidised. At the same time, measures are being decentralised and moved to the local level in order to improve the protection of the rainforest.[133]

According to the FAO, voluntary forest certification is a particularly powerful incentive for forest protection in the Amazon basin.

Private sector sustainable land use initiatives represent another promising approach. According to the FAO, voluntary forest certification is a particularly powerful incentive for forest protection in the Amazon basin. In Bolivia for instance, owners of certified forests collaborate closely with the local population. Fires can thus be detected in time and suppressed before spreading into the forest.[133] As over one third of the wood logged in Amazonia is exported, the demand for credibly certified wood in western industrialized countries can further advance the forest certification process in the Amazon region. According to WWF and several other environmental organisations, the *Forest Stewardship Council (FSC)* certificate guarantees the provenance of wood from forests managed according to the highest responsibility standards to date.

Besides sustainable land use, it is imperative to maintain the Amazon rainforest above a critical size by the designation of extensive protected areas, in order to prevent the establishment of a destructive feedback loop between forest fires and global climate change. WWF has been work-

Besides sustainable land use, it is imperative to maintain the Amazon rainforest above a critical size by the designation of extensive protected areas, in order to prevent the establishment of a destructive feedback loop between forest fires and global climate change.

ing towards saving the Amazon region on various levels for a long time. In 1998, the Brazilian government pledged to officially protect 10 % of the Amazon rainforest. As a consequence, WWF, along with other stakeholders, was substantially involved in bringing to life one of the globally most ambitious conservation efforts, the Amazon Region Protected Areas (ARPA) programme. The goal of the programme is to permanently establish a network of protected areas covering an area of over 60 million ha, larger than France's national territory. To date, 50 million ha of protected areas have been designated. Around 9 million ha are protected areas where wood and non-timber forest products are used sustainably. The long-term financing of the protected areas is secured by the returns of a fund established with private donations and funds from international donor organisations. Since 2006, WWF Germany has been responsible for one of the ARPA protected area landscapes and is in charge of the over 1.9 million ha Juruena National Park and the Apuí mosaic consisting of nine protected areas covering an area of 2.4 million ha.

Intact rainforest landscape with low fire hazard.

4.7 Indonesia/ Southeast Asia

4.7.1 Current situation

Wildfires in Southeast Asia are almost exclusively caused by humans to convert rainforest to plantations or to prepare it for other land uses.

Southeast Asia does not have typical fire landscapes with naturally occurring wildfires, and thus the vegetation is not adapted to fire. Wildfires in Southeast Asia are almost exclusively caused by humans to convert rainforest to plantations or to prepare it for other land uses. Indonesia is the most fire-affected country in Southeast Asia. Each year, every island experiences wildfires, but Sumatra and Kalimantan, the Indonesian part of the island of Borneo, are particularly hard-hit.[151]

In years when strong *El Niño* effects exacerbate drought, the number of forest fires in Indonesia assumes catastrophic proportions. *El Niño* is a climate phenomenon provoked by altered warm water currents along the Pacific and occurring naturally around every 10 years. *El Niño* transports warm water from the west Pacific (Indonesia and Australia) to the east Pacific (America's west coast), reversing normal circulation patterns. This causes droughts in Southeast Asia, providing ideal conditions for fires to spread uncontrollably. In 1997/1998 and 2006, such conditions led to the expansion of forest clearance fires into vast conflagrations that had dramatic effects on humans and nature.

The disastrous forest fires that started at the end of June 2015 and could only be brought under control at the start of the rainy season in November 2015, assumed similar proportions as in 1997/1998 and 2006. Around 140,000 fire sources originating form rainforest clearance were detected via satellite imagery. 10 % of these fires were in protected areas. The fires reached their peak in September and October.[15] According to the Indonesian Ministry of Forestry, over 2.6 million ha were burned from June to October[186], the equivalent of one quarter of Germany's forest cover. 41 % of the fires burned in peat swamps, where they caused particularly high GHG emissions. Altogether, the GHG emitted by Indonesian forest fires in 2015 are estimated at 1750 million t CO_2-e.[154] This is almost twice the amount of Germany's GHG emissions of 908 million t CO2-e in 2015.[155] According to the World Bank, the costs of the fires in Indonesia amounted to 16.1 billion US$ by affecting trade, tourism, agriculture and forestry, including acute health costs (respiratory problems, 19 deaths), environment (loss of carbon sinks) and the costs of firefighting. This amount does not include long-term health costs and the loss of ecosystem services, nor regional and global damage outside of Indonesia. The follow-up costs of the fires were thus twice as high as the reconstruction costs after the tsunami in 2004.[186] On 26 out of 44 days between early

September and mid-October, the GHG emissions from these fires exceeded the average daily emissions of the USA.[156]

Since 1990, Indonesia has lost 27.5 million ha of forests to logging, fires and conversion to timber, pulpwood and palm oil plantations.

Since 1990, Indonesia has lost 27.5 million ha of forests to logging, fires and conversion to timber, pulpwood and palm oil plantations. In 1990 two thirds of the country's territory were covered in forest, in 2015 only half. However, only 50 % of the remaining 91 million ha of woodlands are pristine primary forest. The other half has already been degraded by logging and other human intervention.[157] Usually, only the valuable types of wood, making up the smallest fraction of above-ground biomass, are extracted for trade, and the rest is burned. During dry periods, this can cause uncontrollable conflagrations.

Peat swamp forests are particularly at risk from fire during *El Niño* years. Peat swamp forests are lowland rainforests growing on peat soils. Indonesia is home to extensive peat swamps covering an area of 22.5 million ha, or 12 % of Indonesia's territory and over 50 % of its lowland area.[158] Due to the terrain's low incline, water flowing from inland towards the coast accumulates during the rainy season. Over thousands of years, peat accumulated in thick layers up to 20m deep.[159] Around half of the fires detected by the end of October 2015 were burning in peat swamp forests.[152] Fires originally intended to burn forest remains after clearcutting enter the peat layer and continue to smoulder even after the surface has burned down. This generates thick smoke clouds. 94 % of the fire smog of 1997/1998 was caused by smouldering fires in the peat swamp forests of east Sumatra and south Kalimantan.[175]

Fire suppression measures are limited to surface fires, as fighting fires smouldering in the deep peat layers requires special equipment or sufficient time to isolate the burning layers or to flood them with water. Aerial firefighting is not effective.[160] According to the *Global Fire Monitoring Centre* (GFMC), burning peat layers can cause further sinking and eventually lead to flooding of low-lying coastal areas. Valuable habitats would thus be lost for biodiversity. Fire prevention and monitoring and enforcement of fire bans should therefore be given highest priority in this vulnerable ecosystem.[161]

4.7.2 Causes

The only natural origin of fires in Indonesia is burning coal seams. These have been smouldering for up to 17,000 years, ever since they ignited by lightning or other natural causes during the last ice age when the climate of the Indonesian lowlands was much drier. In times of extreme drought these underground fires possibly ignite dry leaves and twigs on the forest floor and thus cause forest fires.[162] The largest proportion of forest fires in Indonesia however is human-induced. Reasons for the increase in forest fires are found in Indonesia itself, and also in the development of global markets, as trade commodities like cellulose, natural rubber or palm oil are planted in huge plantations on former Indonesian rainforest sites.

One quarter of the fires detected by late October 2015 were in pulpwood plantations, and another 4 % in logging concessions, while 10 % of the fires burned in palm oil plantations.[152] An evaluation of satellite images of Sumatra shows that 39 % of the island's fires occurred on concessions of the pulp and paper producer APP, a company of the multinational Sinar Mas group, and its suppliers. In the peatland forests of Sumatra, even 53 % of fires were in concessions of APP/Sinar Mas suppliers.[163] The Ministry of Forestry suspended the licence of one of the suppliers, PT Bumi Mekar Hijau. A district court rejected the ministry's lawsuit demanding 797 million US$ in damages in December 2015. The Ministry however plans to file an appeal.[164]

Indonesia's weak judicial system and weak executive authorities are among the major obstacles to effectively fighting fires and prosecuting perpetrators.

Indonesia's weak judicial system and weak executive authorities are among the major obstacles to effectively fighting fires and prosecuting perpetrators.[165] Widespread corruption only adds to the problem. On *Transparency International's* corruption index ranging from 0 points for highly corrupt to 100 points for not corrupt, Indonesia reaches a mere 37 points and thus ranks among countries like Columbia or Liberia.[166] Plantation operators starting forest fires hardly ever face sanctions. Only in a few cases, NGOs and local communities have successfully managed to sue big plantation companies for environmental destruction as a result of illegal burning. In August 2015 for instance, the Indonesian supreme court imposed a record fine of 25.5 million US$ on the Indonesian palm oil company PT Kallista Alam.[167]

In the past, development cooperation measures of western donor countries for Indonesia have mainly focused on technical approaches.

In the past, development cooperation measures of western donor countries for Indonesia have mainly focused on technical approaches.[165] Official relief efforts were mostly limited to fighting symptoms, for example by discussing the use of firefighting planes. Due to a powerful forestry lobby, it has not been possible to assert changes in the logging and plantation system itself and in the social and political land use and tenure structures. In the wake of the fires of 2015, the Indonesian president declared a ban on new clearing and conversion of peat swamps, albeit without legal rights of intervention. In May of 2016, he declared a moratorium on the issue of new palm oil and coal licences and an examination of existing licences. It remains to be seen whether the president will be able to assert himself against the industry lobby.[168] In the meantime, it is becoming increasingly clear that fire prevention has to be enforced to avert disaster.

Due to a powerful forestry lobby, it has not been possible to assert changes in the logging and plantation system itself and in the social and political land use and tenure structures.

Extensive destructive logging, large-scale fire clearance by agribusiness multinationals and traditional slash-and-burn practices of the local population are the direct causes of forest fires. The expansion of areas under cultivation by agribusinesses on an industrial scale creates conflicts with the local population about ownership rights and natural resource use.

Plantation owners assert their ownership claims by burning down common land.

Both sides employ arson as a weapon. Plantation owners assert their ownership claims by burning down common land. Embittered locals in turn take revenge by destroying camps and plantations established without their consent.[165]

This development is likely to be reinforced by the global paper industry boom and an increasing demand for "bio" fuels. Most western industrialized countries as well as China are not able to meet their demand for renewable resources with their own production and thus increasingly rely on imports. Renewable resources replacing fossil fuels can contribute to decreasing global CO_2 emissions and to mitigating the effects of climate change. However, this is not the case when rainforest is cleared by fire to make place for plantations for these resources, releasing vast amounts of CO_2 into the atmosphere. If, as is often the case, the forests in question are primary rainforests that are destroyed for new plantations, the fossil fuel and GHG emission balance will only be negative after plantations have been in use for long periods or over several growing cycles (the cycle of oil palms is about 25 years). Previous experiences in Indonesia however do not suggest that this will be the case.[169]

4.7.3 Effects

4.7.3.1 Ecological effects

In Kalimantan, orang-utan habitats were strongly affected by fire and smoke.

The fires in 2015 destroyed 2.6 million ha of rainforests that were home to endangered wildlife such as the Asian elephant (*Elephas maximus*), tiger (*Panthera tigris*), rhinoceros (*Dicerorhinus sumatrensis harrissoni*) and orang-utans (*Pongo spec.*). In Kalimantan, orang-utan habitats were strongly affected by fire and smoke. The dense haze had severe effects on the health and behaviour of orang-utans. In Sumatra, important elephant and tiger habitats were exposed to smoke and fire, among them the Tesso Nilo National Park. In the Way Kambas National Park, the habitat of the Sumatran rhino was ablaze.[170]

The extensive fires of 1998/1997 had dramatic effects on wildlife and on several protected areas, among them, Kutai and Tanjung Putting National Parks in Kalimantan. Undamaged primary forests are usually much more fire resistant than thinned-out forests or plantations. However, considerable illegal fire clearance had taken place in the protected areas, thereby making some national parks very vulnerable.

During the fires in 1997/1998, around 40 % of the detected fire sources in Kalimantan were within orang-utan habitats. At the time, presumably around one third of the orang-utan population died from the direct impacts of the fires or succumbed to their long-term effects. Today, no more than 55,000 orang-utans are estimated to be left in all of Borneo. The fire of 1997/1998 also spread to protected areas that were home to Sumatran rhinos. Today, in all of Asia less than 2.900 members of the three Asian rhinoceros species remain in the wild. The most critically endangered is the Sumatran rhinoceros, which has been decimated from an estimated 600 in 1994 to a maximum of 100 today. It is assumed that no members of the Borneo-subspecies of the Sumatran rhino have survived in the north of the island, but up to 15 animals may be left in eastern Borneo. Asian elephants may become extinct in Sumatra and Borneo if the destruction of their favoured habitat, a mixture of grasslands and forest, continues unabated. The Sumatran tiger, the last remaining tiger subspecies in Indonesia, is facing a similar fate. In Bali and Java, these animals were wiped out in the last century. Sumatra currently still has around 370 individuals, however ongoing habitat destruction is acutely threatening their survival.

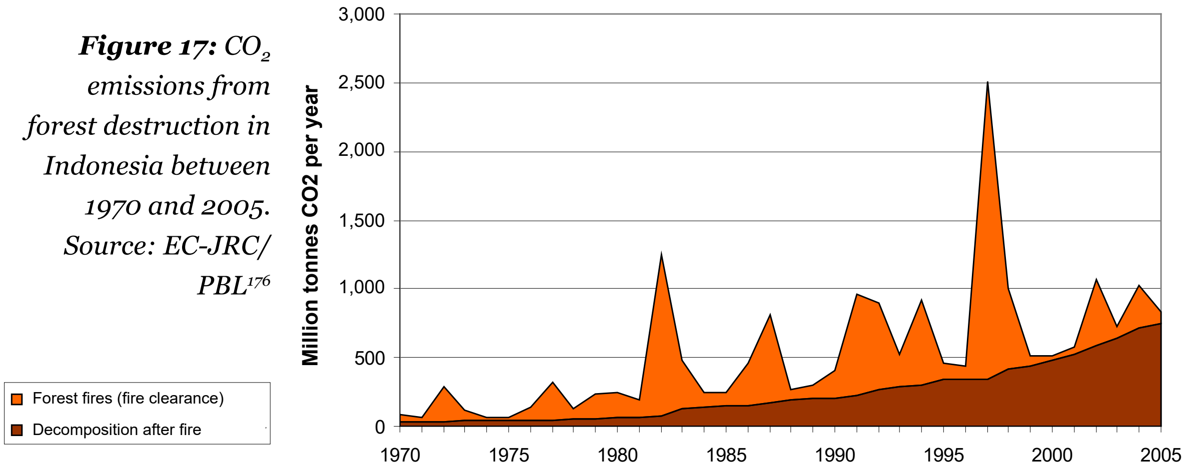
4.7.3.2 Climate change

Including land-use change and forestry, Indonesia ranks fifth among the top global GHG emitters, after China, USA, India and Russia.[171] With the fire crisis in 2015, Indonesia surpassed Russia as the fourth largest emitter.[172] According to FAO, the above and below-ground biomass of the Indonesian forests growing on mineral soils stores 12.5 billion t of carbon[61], which in case of forest destruction will be released as CO_2. A complete release would be equivalent to 1.3 times the total global CO_2 emissions of 2013. **** In 1990, the amount of carbon stored in Indonesia's forests was still over 17 billion t.[61] One quarter of that has already been released into the atmosphere as GHG over the last 25 years.

Indonesia's **peat swamp forests** represent the largest terrestrial carbon sinks in Southeast Asia. On average, tropical peat swamp forests store around ten times more carbon than rainforests of equal size growing on mineral soils.[173] Altogether, Indonesian peat swamp forests retain a staggering 55 to 61 billion t of carbon.[174] Oftentimes, forest fires spread into peat soils, where they are very difficult to extinguish. Emissions from peat fires are the origin of transboundary smoke haze pollution that spreads all over Southeast Asia.[175] Various studies demonstrate that emissions from peat fires are up to fifty times higher than emissions from vegetation fires. During the devastating fires of 1997, while only 20 % of the burn area was made up of peatlands, these were responsible for 94 % of total emissions.[175] The fires in 1997 caused the release of 2.2 billion t of CO_2.[176]

Further CO_2 emissions are caused by the oxidation of deforested peat soils after a fire. These have substantially increased over recent years and are by now significantly higher than the emissions directly caused by fires (figure 17).

Figure 17: *CO_2 emissions from forest destruction in Indonesia between 1970 and 2005. Source: EC-JRC/PBL*[176]



**** 12.5 billion t carbon correspond to 45.8 billion t CO_2. In 2013, total global CO_2 emissions amounted to 35.3 billion t.

Between 2000 and 2005, Indonesia's annual emissions by forest destruction and peat soil oxidation averaged around 800 million t CO_2, almost the equivalent of Germany's annual CO_2 emissions. 22 % of these emissions were directly released by the fires, the remaining 78 % were gradually released in their aftermath due to the decomposition of the peat soils.[176] Between 2000 and 2005 alone, CO_2 emissions from the oxidation of deforested soils increased by 57% from 478,000 t to over 750,000 t per year.

In the province Riau in Sumatra alone, altogether 3.66 billion t CO_2 were released into the atmosphere by forest destruction and land-use changes between 1990 and 2007. Of these, 1.17 billion t CO_2 are attributable to fire clearance and 0.32 billion t CO_2 to forest degradation and thinning. Another 1.39 billion CO_2 were released by burning peat soils, and further 0.78 billion t CO_2 by decomposition processes in drained peat soils. The driving force of deforestation in Riau is the pulp and palm oil industries. In contrast, pulpwood and palm oil plantations established during the same period on burned areas only store 0.2 billion t CO_2, less than 10 % of the amount released by fires and the processes they triggered.[177]

Within the last 25 years, Riau has lost 65% of its forest cover to fire clearance for pulpwood and palm oil plantations. This Indonesian province annually produces more CO_2 than the amount Germany reduces to achieve its Kyoto target!

Within the last 25 years, Riau has lost 65 % of its forest cover to fire clearance for pulpwood and palm oil plantations. This Indonesian province annually produces more CO_2 than the amount Germany reduces to achieve its Kyoto target![177]

4.7.3.3 Economic and health effects of fire smog

Forest fires and fire smog cause considerable economic losses. By October 2015, Indonesia's costs of fire suppression amounted to 200 million US$. Under consideration of the effects on tourism, agriculture, forestry, health and the transport sector, this figure increases to an estimated 14 billion US$. The thick haze generated by the fires affected Indonesia and its neighbours Malaysia, Singapore, Thailand and Brunei. On the 4th of September, six Indonesian provinces in Sumatra and Borneo declared a state of emergency due to haze.[178] 43 million people were exposed to smog in Indonesia alone. Over half a million people developed respiratory diseases, at least ten people died.[179] In neighbouring Malaysia, schools were temporarily closed in September and October, and the Kuala Lumpur city marathon was cancelled. Numerous flights were cancelled because of poor visibility.[180]

4.7.4 Solutions

Participants of an international fire prevention project came to the conclusion that the most effective solution for preventing forest fires in

Indonesia lies in improved land use planning on the local level with the involvement of local communities. The goal should be to achieve a sound balance of land intended for small-scale farming and agroforestry, forestry, plantations and settlements, and as permanent forests. Weak law enforcement and widespread corruption hamper all efforts to address the root causes of forest fires and to implement sustainable forestry practices.

Weak law enforcement and widespread corruption hamper all efforts to address the root causes of forest fires and to implement sustainable forestry practices.

The private sector, cultivating large areas and in possession of relevant resources and expert knowledge, equally has to assume its responsibility in fire management. This applies to all Indonesian logging, paper, pulp and palm oil companies operating in a global market. These companies, along with their business partners in other countries, should align their measures with unambiguous and verifiable criteria, such as a ban on converting forests of high conservation value. For the wood and paper sector, FSC certification***** guarantees international customers and consumers responsible forestry in the source country, and prevents fire clearance. For palm oil, certification according to RSPO (Roundtable on Sustainable Palm Oil) criteria is an attempt at establishing minimal ecological and social standards. This includes a ban on establishing new plantations on recently burned rainforest areas.

Credit institutions providing companies with financial capital also play a key role. A study published by WWF in May 2015 revealed that to date only four of 18 banks in Indonesia, Malaysia and Singapore consider environmental governance issues in their client approval and credit processes.[181] In the face of the devastating fires in Indonesia, whose haze ended up affecting Singapore's business life, the banking association in October 2015 declared its intention to develop guidelines for responsible lending.[182] The future will tell if these voluntary guidelines are followed once the smog has cleared.

A study published by WWF in May 2015 revealed that to date only four of 18 banks in Indonesia, Malaysia and Singapore consider environmental governance issues in their client approval and credit processes.

Rural communities have to be offered stronger incentives to prevent or suppress local fires. One prerequisite for this is the clarification and definition of land use rights. At the same time, traditional burning methods for maintaining and cleaning agricultural lands have to be adapted to present conditions in an ecologically compatible way.

Regular monitoring and data collection are crucial to assess the success of measures. The information system on fires and droughts should therefore be improved substantially. The establishment of an early warning system on province level is equally necessary.[183] Most importantly, uncertainties about the responsibilities for fire prevention and suppression have to be eliminated by appropriate legal and institutional reforms.

***** www.fsc.org

Lastly, the justice and executive systems should be strengthened in order to be able to enforce laws and prosecute violations, which requires fighting corruption on a large scale.

Neither technical nor political measures alone will be able to eliminate the social and political causes of forest fires. Rather, approaches have to be developed that integrate all measures mentioned above.

In Indonesia, WWF works on multiple levels to stop deforestation which is additionally „fuelled“ by forest fires. On a political level, WWF advocates to ASEAN countries for collective action against the fires in Indonesia as the source of transboundary smoke pollution. At the same time, WWF supports improved land use planning as a member of the Sumatra Land Use Forum. Additionally, WWF supports local authorities in developing appropriate regulations to reduce fires. It supports improved law enforcement by closely following lawsuits against perpetrators and organising law enforcement workshops. Generally, WWF works closely with the local population to promote sustainable development. This involves the application of techniques of cultivating land without fire, as well as training courses on fire or peat forest management. Besides these preventive measures WWF organises events to restore drained and thus fire-prone areas.[184] For example, WWF is active in rewetting the tropical peat swamp of Sebangau National Park. To this end, drainage ditches are closed by building dams to allow for a recovery of the drained and degraded area's water balance. The dams retain water in the peat and in the long term contribute to the recovery of the natural groundwater level in the peat dome. This inhibits peat decomposition and thereby stops any further CO_2 emissions by oxidation. Rising water levels in the peat dome significantly reduce its fire vulnerability.[185] At the same time, the local population is trained in fire prevention and an early warning system is established.

WWF helps to restore tropical peat swamps in Sebangau National Park by building dams.

Fires often precede large-scale land conversion that completely replaces natural forest ecosystems (image: oil palm plantations in the Malaysian state Sarawak).

5 Recommendations

According to WWF, the fight against destructive forest fires should build on four pillars:

Prevention

Prevention is the most important pillar of a successful fire management system. It should be significantly strengthened to reduce forest fire risk and associated damage.

First of all, the **determination of root causes** is necessary, requiring an appropriate statistical data foundation. Many countries lack this prerequisite.

According to WWF, the fight against destructive forest fires should build on four pillars: Prevention, Preparation, Reaction and Restoration

Forestry should always take the role of fire into consideration. This means avoiding clearcutting or planting non-native species like eucalyptus when this increases forest fire risk. Reducing fire vulnerability and increasing the resilience of forest ecosystems by developing close to natural forests should be an objective of forestry. In fire-dependent ecosystems, the accumulation of fuels should be controlled by prescribed burning, thus maintaining natural ecological cycles.

At the same time, **public awareness** of fire risk and appropriate behaviour should be strengthened by sensitisation and educational activities.

Forest fire hazard should be more strongly integrated into **spatial planning**. New settlements should not be permitted in high-risk zones, and infrastructures like railway and power lines should be adapted accordingly to reduce risk.

All relevant **laws** should integrate the aspect of fire risk. In some countries, conversion from forest to agricultural land is subsidised, while fire clearance can cause uncontrollable conflagrations. In these cases, law reforms are crucial. The conversion of burn areas to construction land should not be permitted, as this provides incentives for arson.

Some countries require additionally improved **law enforcement** to prevent arson associated with illegal logging.

Preparation

Responsibilities for forest fire prevention should be clearly assigned and effective coordination between the different authorities should be guaranteed. Sufficient financial means should be made available for forest fire monitoring, so that fires can be detected in time and suppressed at an early stage. Along with training programs, different forest fire scenarios should be developed for preparing emergency forces.

Evaluating immediate and follow-up costs of forest fires is necessary for developing regionally adapted, effective and efficient strategies for forest fire management. The availability of this information can facilitate decisions in fire-dependent ecosystems as to where fire suppression is necessary for economic reasons, and where fires can be tolerated on economic and ecological grounds. Most of all, a calculation of all immediate and follow-up costs of forest fires can provide a strong political argument for fire prevention as a more cost-effective alternative.

Reaction

In the case of a fire, reaction should be quick and tactically well thought out, in order to be able to extinguish fire sources in their early stages before they can develop into conflagrations. This should not serve as a justification for encroaching on pristine forests, as improved access dramatically increases the risk of human-induced fires.

Restoration

Whenever possible, the natural regenerative capacity of ecosystems should be harnessed. Burn areas should only be reforested when natural regeneration is out of the question and ecological damage such as soil erosion is to be expected. Reforestation should be oriented towards natural forest stands. Monocultures and homogeneous forest stand structures should be avoided, as they increase the risk of further fires. All relevant stakeholders should be involved in planning and implementing these measures to guarantee their success.

Examples for measures that should be implemented urgently are:

» Adapt regional planning, appropriately support regional development

» Evaluate the entire economic costs of forest fires

» Create additional jobs in fire prevention

» Adjust legislation or create appropriate laws to prevent land use changes after fires, to provide for more severe punishment for arson and to regulate price speculation on the timber market.

Sources

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Why we are here
To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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