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Portugal Wildfire Management in a New Era

Assessing Fire Risks, Resources and Reforms

February 2018

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Glossary of Acronyms and Abbreviations

AGIF: Agency for the Integrated Management of Rural Fire (Agência para a Gestao Integrada dos Fogos Rurais)
AHBV: Humanitarian Association of Volunteer Fireman (Associação Humanitária de Bombeiros Voluntários)
ANPC: National Authority for Civil Protection (Autoridade Nacional de Protecção Civil)
CB: Firefighter Corps (Corpo de Bombeiros)
CIM: Intermunicipality community (Comunidade Intermunicipal)
CLF: contribution on forest clearing (contribuição para o limpeza florestal)
DECIF: Directive for Forest Fire Fighting (Dispositivo Especial de Combate a Incêndios Florestais)
EFFIS: European Forest Fire Information System
EU-JRC: European Union- Joint Research Center
FEB: Special Forces Firefighters (Força Especial de Bombeiros)
FWI: Fire weather index
GIPS: Intervention Group for Protection and Rescue (GNR-Grupo de Intervenção de Proteção e Socorro)
GNR: National Republican Guard (Guarda Nacional Republicana)
GTF: Technical Forest Office (Gabinete Técnico Florestal)
ICNF: Institute for Nature Conservation and Forests (Instituto da Conservação da Natureza e das Florestas)
ITC: Independent Technical Commission (Comissão Técnica Independente)
NLTN: National Lookout Tower Network (RNPV: Rede Nacional de Postos de Vigia)
NUTS: Nomenclature of Territorial Units for Statistics
PNDFCI: National Forest Fire Protection Plan (Plano Nacional de Defesa da Floresta Contra Incêndios)
PORDATA: Database of Contemporary Portugal (Base de Dados de Portugal Contemporâneo)
SEPNA: Service for the Protection of Nature and the Environment (GNR-Serviço de Proteção da Natureza e do Ambiente)
ZIF: Forest Intervention Zone (Zona de Intervenção Florestal)

Preface Has Portugal Entered a New Era of Wildfire?

In 2009, we were contracted to conduct an extensive review of Portugal's forest fire defense strategy following growing concerns about increased fire risks in the Southern European countries. Our Report was based on interviews with nearly 60 experts in the fields of forestry, civil protection, emergency management, meteorology, and forest fire research from government agencies, universities, the pulp and paper industry, forest owner associations and municipalities. We followed numerous fire responses and observed the actions taken in Portugal. Forest fire data for previous decades were assembled to assess whether the annual burned area totals confirmed a new level in fire activity in Portugal. The decadal average increased from under 75,000 ha during the 1980s', to 100,000 ha in the 1990s', to over 150,000 ha since 2000.

Our Report affirmed those trends and noted: *"Over the next decade, the catastrophic risk of a potential fire season burning 500,000 ha or more in Portugal must be a serious consideration."* It included a wide range of recommendations for change in Portugal's forest fire suppression, planning, and prevention strategies. While some of the recommendations in the report were marginally implemented, the majority dealing with structural prevention (fuels management) and ignition reduction were set aside. The lengthy world economic recession, with major fiscal stress for all of Europe, made commitment of resources difficult and unrealistic. Low to moderate fire years in Portugal pushed the report into the background. Political posturing, downward economic cycles, budget scarcity, and rural depopulation were more than sufficient to focus attention elsewhere on other higher priorities.

The fate of such a tepid response was entirely predictable. Sadly, in 2017, this forecast was all but realized. Severe drought, heat waves, massive oceans of flammable forests and scrublands, and a weather phenomenon – the Hurricane Ophelia in mid-October - came together in a "perfect storm" situation. All that was needed was the match, and Portugal has thousands of uncontrolled matches.

Why has Portugal found itself in this profoundly horrible situation? The answers are basically the same today as they were evident a decade ago: (1) the high percentage of forest lands that are unmanaged; (2) the increase in fuel loads, both in amount and extent; (3) the high number of unwanted fire ignitions during moderate to severe burning conditions; and (4) climate change and increasing periods of hot and dry weather that both lengthen and increase the severity of critical periods for extreme fire.

What remains to be seen following Portugal's catastrophic 2017 fire year is whether there is now consensus on seeing the fire problem as a real national priority. Equally important – can municipal vigilance, public awareness and media attention be sustained in the future and the "out of sight, out of mind" national attitude that prevails in mild fire years be avoided? Portugal's fire problem is not regional and not just rural, but is spreading into every part of the country. Extreme fires won't happen every year, but will happen several times a decade. Fires are not just destroying hectares of forests and woodlands, but are taking human lives and destroying livelihoods. Portugal has indeed entered a new era of fire!

Incremental change and reforms at the margins will not be enough as Portugal's fire risks are exacerbated by the impacts of climate change. Without serious and immediate intervention, Portugal can expect worse than what happened in 2017. This 2018 Report has had to include a new worst-case scenario – of fires approaching 750,000 hectares that would redefine catastrophic as horrific. This is exactly why the Extraordinary Minister Council of October 21st was called, to assure citizens that all levels of government understand the seriousness of what happened and would take decisive actions to prevent a recurrence of the 2017 disasters. We support their effort, but urge that there is no time to waste.

This report is dedicated to the citizens and firefighters who lost their lives in 2017.

Executive Summary

Portugal has one of the highest forest fire risk rankings in Europe. Fire researchers all point to the same combination of contributing factors: shifting demographics with population moving from rural to urban areas, changes in land use with more agricultural and forested areas left unattended and not being maintained, and fragmentation of land ownership patterns that discourage investment in forest management and fire planning. The trend of annual burned area for the last four decades confirms a new level in fire activity in Portugal, despite an increased investment in the amount of firefighting assets.

A much greater range in burning conditions can be expected into the future as demonstrated by the wide variation in climate and weather episodes experienced in Portugal over the last two decades. Some years experienced an extended period of higher severity burning conditions, often adding additional weeks on both the front and back ends of the traditional July through September peak fire season. Other years experienced cooler, moister summers. These years with very low annual burned areas have led to prematurely declaring success because of the increase in aerial firefighting assets, new policies and organizational reforms. History has now proven otherwise. The changes made were not sufficient to significantly alter the outcome during the hot, dry extended summer of the catastrophic 2017 fire year.

Climate studies now project even more disturbing developments, particularly for Portugal and other Southern European countries. Rising temperature and decreasing precipitation are now firmly established as the new normal and show no signs of abating in the near future. Indeed, the most recent report of the European Union Joint Research Center forecasts the situation to only get worse, especially in the Iberian Peninsula. These major changes in climate and seasonal weather patterns will place additional environmental stress on vegetation which, in turn, will spur an increasingly severe round of larger and more damaging wildfires.

Portugal's Wildfire Risk Continues to Rise

The factors contributing most to the increase in burned area are those related to increasing fuel load and continuity across large landscapes and an abundance of human-caused ignitions. Scientists are now focusing on global climate change and its effect on regional summer weather temperature and precipitation patterns as the catalyst that will turn fire potential into actual catastrophe. For short periods of time, most notably during 2003, 2005, and again in 2017, burning conditions were so severe that Portugal's fire protection system capability was clearly overwhelmed. Even milder summers are an important factor in this equation of increasingly larger burned areas because vegetation grows at an accelerated rate providing yet more fuel for future fires occurring in the next hot and dry period.

While seasonal climate variations and the occurrence of severe weather events are important in the development of destructive forest fires, they're not the only relevant factors. A unique set of structural environmental factors have made Portugal extremely prone to forest fires. The fine scale geographic mosaic of less flammable vegetation patterns that once existed due to well-tended private and community agricultural plots are now overgrown with dense stands of highly flammable trees and shrubs. Marginally productive agricultural lands once converted to forest plantations are increasingly left unmanaged as too costly to maintain. The abandoned areas are overtaken by shrubs and woody species making the landscape increasingly uniform in burning characteristics. Ironically, areas that once stopped fires, now fuel increased fire intensity. In many areas of Portugal, the ingredients already exist for more disastrous large fires waiting only on the next severe fire weather event.

Another contributing factor that cannot be ignored is that 98% of all fires in Portugal stem from human-caused ignitions. To say "the Portuguese people are the problem" is not an understatement. Portugal, when compared with Southern European countries having similar fuel and weather conditions,

has a disproportionately high number of human-caused ignitions relative to population. While the Portuguese dislike being compared to their Iberian Peninsula neighbor, Spain is five times larger with four times the population, yet has fewer total human-caused ignitions. When combining the effects of climate change and associated weather, fuel and vegetation conditions across vast landscapes, and the propensity of human ignitions, an almost incomprehensible range of fire years is possible from the benign to the catastrophic. In the next decade without long-term and sustainable intervention, the risk of an extreme fire year burning 500,000 hectares or more is growing.

Assessing Portugal's Wildfire Management Reforms

Over the past several decades, Portugal has been the subject of several reviews by fire experts. The recommendations have been relatively consistent, identifying four major areas needing improvement; (1) preventing unplanned human ignitions, (2) creating a structural fire defense system of fuel breaks and by reducing fuel load in critical areas, (3) improving firefighting capability by implementing perimeter control tactics and large fire management strategies and, (4) restructuring Portugal's fire organization. However, in 2006, Portugal elected to go with a national strategy that emphasized increasing firefighting assets over making serious investments in fire prevention and fuel reduction. Since 2000, almost three times as much has been spent on suppression as was invested in prevention. Yet, the annual trend in area burned has continued on a steady increase despite all efforts to change it. Clearly, a new era of fire demands a more comprehensive and balanced strategy.

Since the devastating fires of 2003 and 2005, several attempts have been made to reform state entities to more effectively address the growing forest fire problem. Authorities and responsibilities have been juggled around in response to political posturing in what has been termed "successive restructuring". It's now clear that the existing structure of government agencies has not adequately addressed the growing fire problem in rural areas. What's essential is the creation of an agency that specializes in all aspects of rural fire management. It's also important that this new organization has authority at the same levels of government as those responsible for civil protection firefighting to ensure that new approaches and policies are receiving appropriate consideration.

The backbone of any firefighting system isn't aircraft or vehicles, but firefighters. Unfortunately, numbers of professional and volunteer firefighters in Portugal have experienced a 33% drop in just 11 years. The two primary causes, increasing age and a general disinterest by young people, must be addressed. Firefighting is a physically demanding job for which a healthy, younger workforce is required. Increased pay is the most obvious improvement that's needed to attract younger recruits to firefighting jobs in rural areas, but career ladders are also needed to retain older, experienced firefighters in key leadership and training roles.

Firefighting tactics also contribute to the wildfire problem. Of the fires for which a cause is known, 16% are due to rekindles. This number can range as high as 30% in some districts. The two primary reasons are: first a volunteer firefighter culture of only using hoses and water, staying on roads, and not using hand tools. Second is too many daily fires forcing brigades to move prematurely from one first intervention action to another and not checking suppressed fires to insure they are extinguished. This pattern can continue over weeks making most firefighters unavailable to return to check previous fires. Another workforce, such as the army, or some other method needs to be used to check suppressed fires and make final determinations that all fires are completely extinguished.

Renewing Portugal's Fuel Management and Prevention Efforts

As fires become more intense, and faster spreading, civil protection firefighting forces become less effective. In this new era of severe burning conditions, future investments should be made that

promote a more strategic, less reactive approach. Portugal needs to acquire a skilled force of technical fire specialists and meteorologists equipped with the latest remote weather monitoring and fire behavior prediction support tools. Also needed are a cadre of rural firefighters and commanders experienced in perimeter control strategy and tactics and proficient in the use of fuel and topographic mapping tools and technology to capitalize on every geographic advantage.

Portugal is aggressively moving to complete a 130,000 hectare primary fuel break system. But fuel break construction and commercial harvesting alone won't result in sufficient fuel removal. Many flammable species that now choke forest understories need removal but have little commercial value. Increasingly, stands of eucalyptus go unharvested because the wood is not of acceptable quality for pulp. There's a massive amount of biomass growing in Portugal that, if not removed and disposed of, will fuel the next series of catastrophic fires. Some success has been made in addressing this by constructing large, low emission, biomass fueled electric generation stations scattered about the country. Stations in the north are working efficiently while others further south, are not. Lessons learned from these experiences should be used to create a strategy that locates many smaller stations closer to biomass sources and potentially increase the electricity generating output.

While completely fire-proofed forests aren't economically feasible, or realistic, they can be managed in a way that greatly improves their ability to survive fire. Unfortunately, fuel and vegetation risk reduction options come at a cost, either in upfront investments in fuel treatment or reduced profit at harvest. Forest owners need a collective push in the right direction with financial incentives designed to reward forest management practices that reduce fuel load. They also need more confidence that the fire response system can better protect their forest investment. By ranking reduced fuel load managed forests and agricultural lands as a higher fire response priority than unmanaged forests and abandoned lands, owners may be more willing to make fuel reduction investments.

Another significant obstacle to achieving a greater percentage of managed forests is the abundance of small forest plots and inadequate property records and ownership information. The Forest Intervention Zone (ZIF) is an approach established in 2005 to organize small forest holders and create a joint intervention for forest management and protection. Currently over one million hectares are included in 189 approved ZIFs. These are impressive figures, but in terms of actual results in fuel reduction, investments have not measured up. While ZIFs have had positive results in landowner identification and participation, several reforms are needed before any real improvement in landscape level fire risk can be achieved.

As a response to the excessive number of ignitions and the limited number of fire and public safety officers, Portugal needs to greatly increase citizen participation. National fire and safety awareness programs coupled with an anonymous fire reporting hotline telephone number can promote this. Portugal should also seriously consider implementing a "Reverse 911" cellular based phone system to warn citizens of impending dangerous situations like fast spreading fires.

There is no single game changing fix to the dilemma Portugal now finds itself in regarding the threat of catastrophic fire. Rather, the solution will involve numerous strategic improvements made over several years. It must be emphasized that changes to the Portuguese fire system be made in a reasonable and sustainable way that encourages collaboration and maximum participation from all levels of government, especially with municipalities, and truly engages the public. No matter which type of fire year Portugal experiences in the coming decades, catastrophic or benign, it must stay focused on improving the underlying conditions that put it at higher risk—expansive landscapes of highly flammable fuel and thousands of potential ignition sources.

Part I

Assessing Wildfire Risk—Will Tomorrow Resemble Yesterday?

The threat of wildfire is especially pronounced in Portugal which has one of the highest fire risk rankings in the European continent. Fire researchers in Portugal have been studying this problem for decades assessing fire activity and its severity extensively from a number of perspectives including fire behavior, population patterns, spatial distributions, land cover, climate factors, and weather conditions among others. Leading fire researchers all point to the same phenomena driven by a combination of contributing geo-economic factors. These include:

- Shifting demographics with population moving from rural to urban areas
- Changes in land use with more agricultural and forested areas being unattended and not maintained
- Fragmented land ownership that discourages investment in forest management and fire planning

This report is designed to review risk by examining wildfire occurrence and burned area primarily since 2000, when wildfires rose to unprecedented levels, notably the years of 2003, 2005 and now 2017.

One need only examine the trend of annual burned area totals for the last four decades to confirm a new level in fire activity in Portugal (Figure 1). Whereas between 1980 and 1999, there were six years in twenty where area burned exceeded 100,000 ha (dotted line box), since 2000, eleven out of eighteen years exceeded this level (dashed line box). In risk terms; a 30% probability that a fire year greater than 100,000 ha will occur has doubled to a 61% chance in just two decades. Figure 1 clearly shows how dynamic the recent two decades have become in terms of fire activity in Portugal.

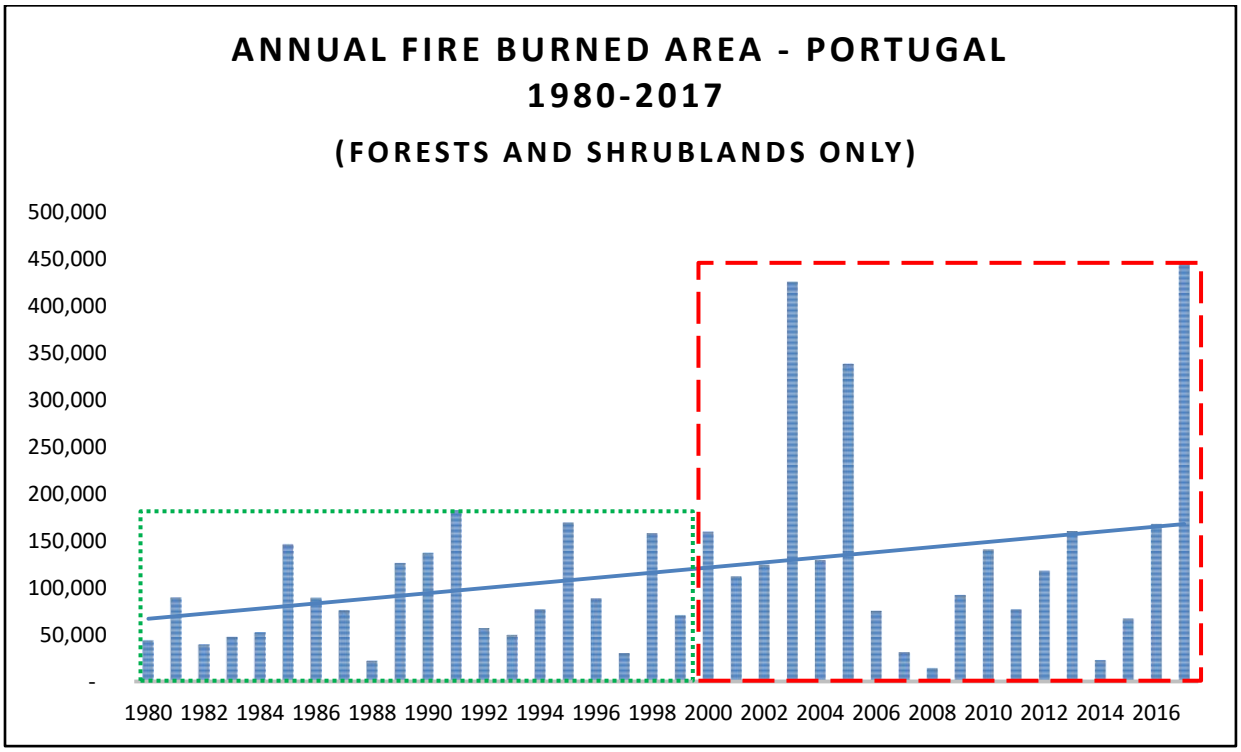


Figure 1 *Annual fire burned area in Portugal, 2001-2017, with linear trend line*
Data Source: ICNF

In 2008, Calado *et al.* recognized a trend in increasing burned area since the 1980's that demonstrates a pattern of "*large inter-annual variability"* (Calado *et al.*, 2008). It's this issue of large inter-annual variability that is potentially the most difficult characteristic to evaluate. A much greater range of burning conditions can be expected in the future as demonstrated by the wide variation in climate and weather episodes experienced by Portugal in recent decades.

Also of importance is where this is happening regionally, as not all regions demonstrate the same tendency. Figure 2 shows this more clearly. Note that the most significant inter-annual variability occurs in the North, Central and Algarve while the Alentejo and Lisbon regions have been comparatively stable over the last decade. Appendix A includes individual graphs and tables for each region.

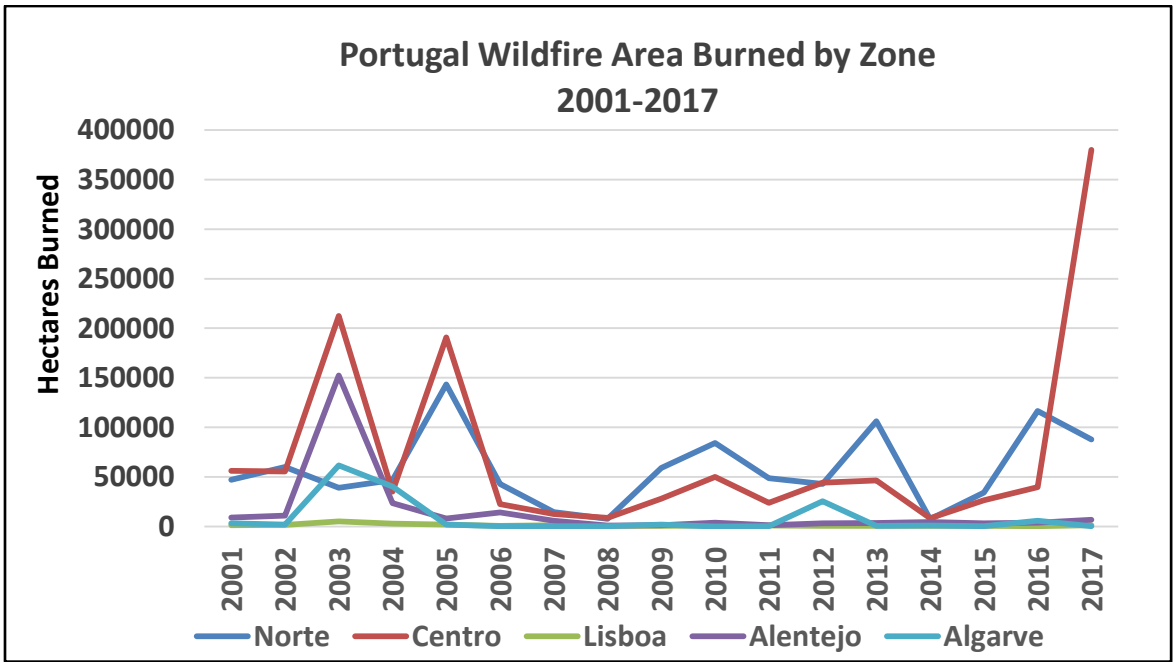


Figure 2 *Inter-annual variability in fire years by NUTS II regions.*
Data Source: ICNF- Appendix Tables A1-A5

Wildfire Risk in Large Inter-Annual Variability Fire Cycles

Pereira *et al.* have described this highly variable annual burn area pattern as the *"asymmetric nature of fire size distribution"* (Pereira *et al.*, 2004). This pattern of alternating years of "*higher highs*" (e.g. 2003 for area and 2005 for occurrence) and "*lower lows*" (e.g. 2007 for occurrence and 2008 for area) can place extreme stress on environmental systems and represents an increasing, twofold challenge for fire protection organizations. The first and most obvious is that some summers will experience an extended period of higher severity burning conditions often adding additional weeks on both the front and back end of the traditional July through September peak fire season. Since the hot and dry period is longer, it exerts greater moisture stress on vegetation for a longer period of time. This can result in much higher burning intensities than might otherwise occur. The effect of this extension of the traditional fire season can be seen in Figure 3. From 2001-2008 just 12% of the total area burned was outside of the July through September period. In just eight years, from 2009-2017, this tripled to 36%.

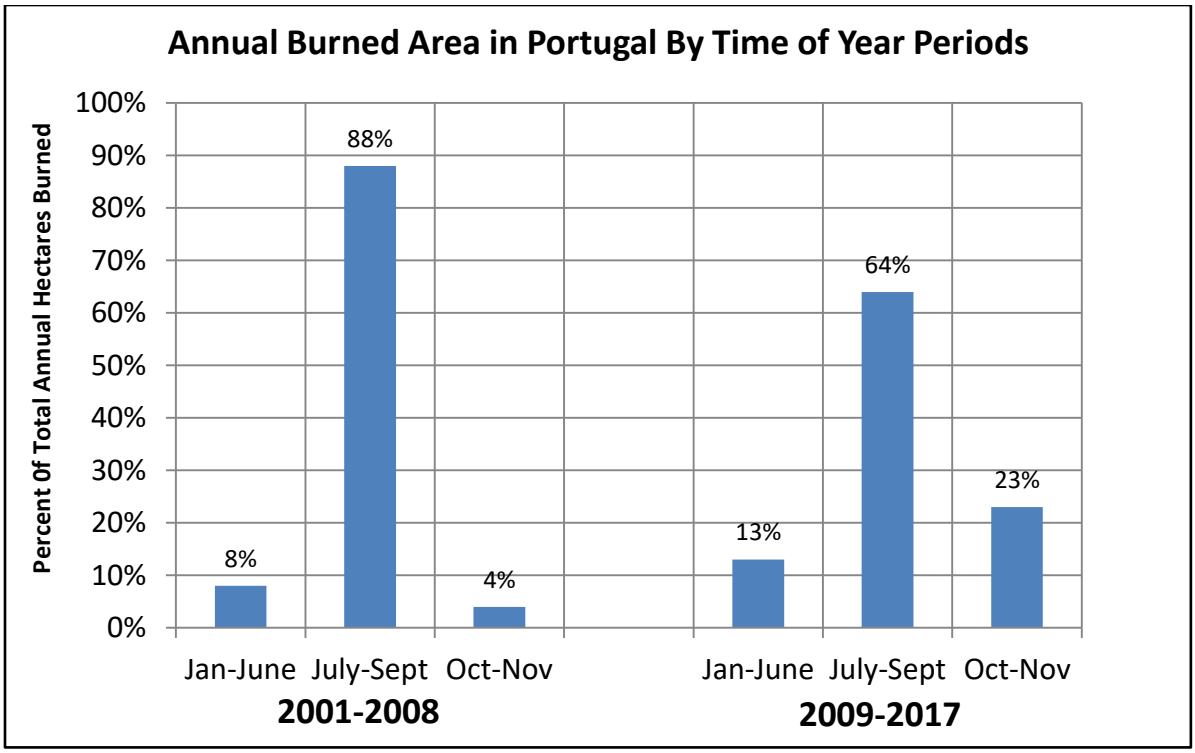


Figure 3 *Annual area burned by time of year periods for 2001-2008 and 2009-2017.*
Data Source: ICNF

The second, and not so obvious, challenge occurs during years that experience a cooler and moister summer. Occasional summers of low fire activity will continue to occur and when they do, it's very easy to get complacent. The summers of 2007 and 2008 are classic examples after which, in 2009, Portugal declared victory in successfully conquering the problem of catastrophic fire. They mistakenly attributed success in achieving very low annual burned areas largely to the increase in aerial firefighting assets, new policies and organizational reforms. While these improvements should have a positive effect, it's difficult to assess their true impact until a full cycle of inter-annual variability has occurred. History has now proven otherwise. The changes made were not of sufficient improvement to achieve the 100,000 ha maximum burned area goal during the hot and dry extended summers that followed, most notably that of 2017.

Cooler and moister summers offered by inter-annual variability should be viewed as a gift, offering substantial opportunities to make significant progress in reducing hazardous fuels through prescribed burning, mechanical and even manual means. Firefighting assets that would normally be heavily involved in initial attack response could be diverted to fuel reduction projects, until needed for firefighting. The challenge is in having enough areas with plans and preparations in place to take full advantage of these opportunities.

Projective thinking in risk management requires inserting into the assessment an even more extreme fire season, a worst-case scenario, in terms of what the environment might be over the next decade. Fire research has already been exploring factors which might best be characterized as driving forces in the new fire environment. While fire numbers in terms of total hectares burned and frequency of larger wildfires are significant in and of themselves, fire risk is likely to be compounded by the influences of climate change, fuel accumulation, and fire occurrence which must be considered in future risk estimates.

Climate Change Effects on Large Fire Occurrence and Severity

Climate studies now show a disturbing trend, particularly for Portugal and other Southern European countries. Work completed as part of the European Forestry Institute's larger study of wildfire issues projects that temperature levels (especially in summer) in Portugal will be hotter and precipitation levels lower than average (Moreno, 2009). Increase in temperatures is now firmly established as a trend and showing no signs of abating in the near future. As early as 2002, researchers were confirming significant increases in the minimum and maximum temperatures for the Iberian Peninsula (Miranda, 2002 and Pereira, 2004). More importantly, this trend was particularly noticeable in Spain and Portugal. Confirming this thesis, during 2017 Portugal experienced the driest September ever recorded and the hottest October ever recorded in 87 years of record keeping. The European Union Joint Research Center forecasts the situation to only get worse, particularly in the Iberian Peninsula (Figure 4).

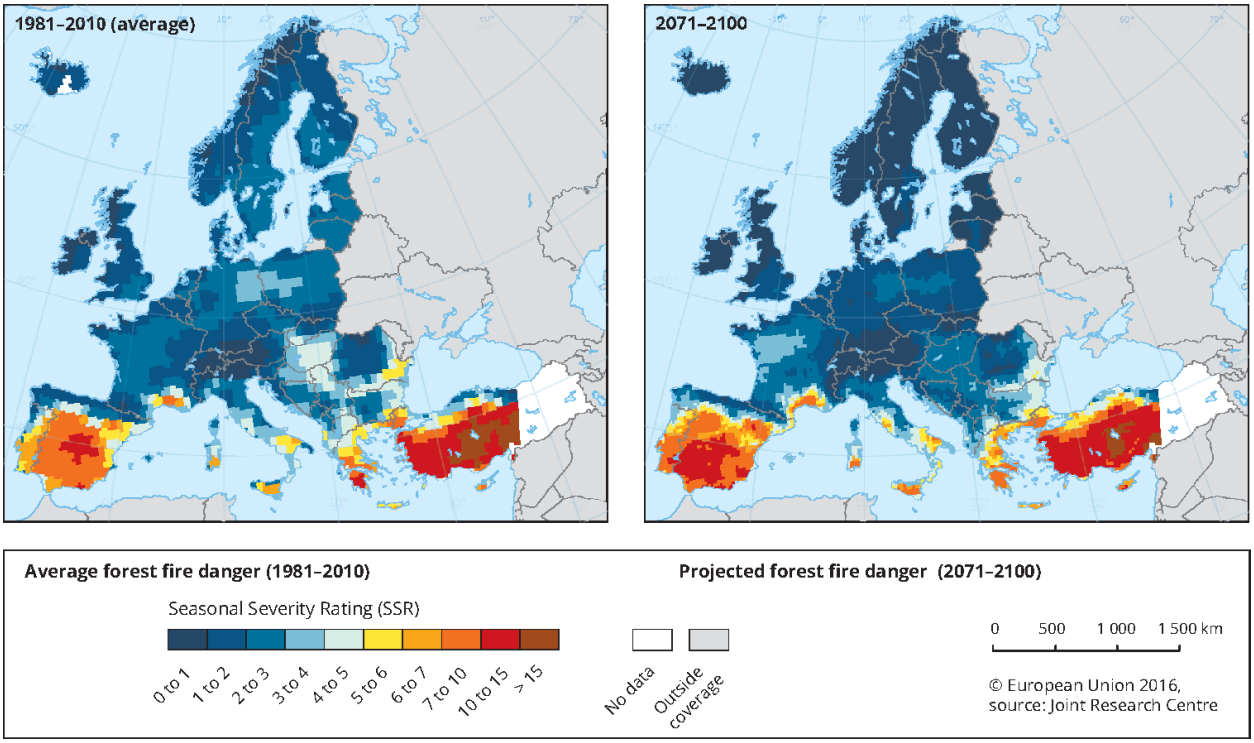


Figure 4 *Average (historical) and projected (future) forest fire danger in Europe*
Data Source: EU-JRC, 2016

In the 2006 National Forest Strategy, Portugal officially recognized global climate change, particularly the effects that are most influential on increasing the risk for large destructive forest fires. The strategy report projects for this century a significant rise in mean temeprature across all regions of Portugal. It also forecasts more heat waves (DGRF, 2007). There's also recognition that these major changes in climate and seasonal weather patterns will place additional environmental stress on vegetation which, in turn, would spur a new era of increasingly severe, larger and more damaging wildfires. As Moreno has concluded in the European Forest Institute study, in these landscapes which are already increasingly vulnerable to fire risk due to combined bio-mass stress and declining agricultural management: "*Climate change will very likely increase the length and severity of the fire season, as well as the extension of areas of risk. Extreme conditions are likely to increase in many areas and with it, the probability of large fires*" (Moreno, 2009).

Research has noted the factors contributing most to the increase in burned area are those related to increasing fuel load and continuity across large landscapes and increased human-caused ignitions (Catry *et al.*, 2007). However, more scientists are now focusing on global climate change and its effect on regional summer weather temperature and precipitation patterns as the catalyst that will turn fire potential into actual catastrophe: "*The latest data from the European Forest Fire Information System (EFFIS) suggests that nearly all wildfires are man-made, with very few resulting from natural phenomena like lightning. However, the hot and dry conditions induced by climate change result in more severe fires and a higher frequency of small fires growing to become uncontrollable"* (EU-JRC, 2016). The stage has been set for more frequent occurrences of catastrophic fire years as hotter and dryer weather conditions mount (Lourenço, 2008).

Climate change researchers have been quite specific about weather conditions they see as particularly favorable to increased wildfire. Pereira has identified two weather based situations that would lead to this: first, long term dry periods followed by lack of precipitation in late spring and second, a period of short term heat waves within longer periods of dry conditions (Pereira, 2004). Making matters worse, the outlook also foresees an increase in these kinds of summer weather events. Moreno has predicted an increasing risk cycle with high temperature variability, more frequent and intense heat waves, and lengthening dry spells and drought conditions (Moreno 2009). Either of these weather factors (droughts and heat waves) can have a marked effect on increasing burned area. The chance of both occurring simultaneously is statistically small. However, in 2017 it became a reality. On 15 October with long standing drought and record heat, dry strong winds from the south (Sahara Desert) from an approaching hurricane (Hurricane Ophelia) and over 500 ignitions, fires resulted in record breaking disaster.

For short periods of time, most notably during 2003, 2005, and 2017 burning conditions were so severe that fire protection system capability was clearly overwhelmed. Fire research has focused on these years not only because of the magnitude of area burned, but also because of uncharacteristic weather factors differentiating each year. In 2003 it was high Spring rainfall and episodic heat waves and in 2005 it was drought (Viegas, 2008). More recently, in 2017, it was a dreadful combination of drought, heat and wind from both thunderstorms (ITC Report, 2017) and offshore Hurricane Ophelia. These stand in contrast to other years where wet and milder summer conditions were such that it greatly minimized both the number of fire occurrences and the area burned.

Why are milder summers an important factor in this equation of increasingly larger burned areas? The answer may be in two parts. First, what doesn't burn in milder years accumulates becoming even more readily available to burn during future years with hot and dry summers. And second, milder summers also grow vegetation at an accelerated rate, due to less moisture stress, providing yet more fuel for future fires occurring in the next hot and dry summer. This concept that benign fire years are setting up more extreme fire years has not gone unnoticed. The Global Fire Monitoring Center, drawing on a number of sources of weather factors and fire records in Portugal, has warned of a looming strategy and resource disconnect: *"Nevertheless, fire suppression measures have reached to reduce total annual area burned in relatively mild fire seasons but a latent potential for catastrophic fire events under adverse weather conditions reveals insufficient structural reforms rather than it reflects an increase of large fires driven by climate change, as could be seen in the case of Portugal"* (Goldhammer and Krause, 2007).

Ironically, the years of record low burned area (e.g. 2007, 2008 and 2014) are as much an indicator of the effects of climate change as are the years of exceedingly high burned area. What's important to recognize though is the increasing unpredictability in annual burned area patterns that have developed in the last two decades. From 2001 to 2017, annual burned area totals varied from 18,245 hectares (2008) to over 475,000 hectares (2017); a 26-fold difference. That represents a huge range of potential annual fire activity. It begs the question at what level of annual fire suppression work load and

firefighting capability should fire protection services be funded and organized to successfully address? And, more importantly, can Portugal expect the near future to bring fire years more severe than 2017?

Structural Fire Risk Factors

Climate change may be the most heralded global danger affecting fire, but other significant changes have also been taking place over the last several decades that are having an ongoing detrimental effect on wildfire potential. The increase in burned area in Portugal has become the most noteworthy in all of Europe. While seasonal climate variations and the occurrence of severe weather events are important in the development of destructive wildfires, they're not the only relevant factors.

Since the 1990's, the consensus of land management research places major blame on the neglected state of Portugal's woodlands and forests. Researchers have noted the unique set of structural environmental conditions that have made Portugal so prone to wildfires. The fine scale geographic mosaic of less flammable vegetation patterns that once existed due to well-tended private and community agricultural plots are now overgrown with dense stands of highly flammable trees and shrubs. Marginally productive agricultural lands once converted to forest plantations are increasingly left unmanaged as too costly to maintain. Abandoned areas are overtaken by invasive shrubs and woody species making landscapes increasingly uniform in burning characteristics. As two researchers have noted: "…*in the Portuguese landscapes, lack of active management and suppression driven wildfire policies promote fuel accumulation (Collins et al., 2013) and bigger and recurrent fires set an important disturbance, jeopardizing forest and conservation goals*" (Oliveira *et al.*, 2017). Areas that once stopped fires now fuel increased fire intensity.

The growing fuel load problem is further exacerbated by a general lack of management. An estimated 80% of Portugal's forests are unmanaged, influenced by several factors including:

- Inadequate silviculture practices predominantly in eucalyptus and pine that result in large areas of overstocked, monoculture, single age class stands
- Aggressive natural revegetation of abandoned agricultural plots and recently disturbed sites such as burned areas and forest clearings for powerlines and roadways
- A lack of economic stimulus for promoting opportunities for larger scale biomass removal of understory, noncommercial vegetation and harvest residue for biofuel or electricity generation

Recently burned landscapes can provide areas of low flammability vegetation that may limit the size of some fires in the years that follow. However, this fuel reduction benefit is extremely temporary and, in the longer term and without significant intervention, will only serve to expand areas of flammable vegetation. Field visits to previously burned areas have confirmed this. Within five to ten years after burning, large fire scars should no longer be considered as barriers to fire spread. In many burned areas forests have been replaced by even more flammable shrubs and dog hair thickets of dense pine, eucalyptus and acacia reproduction. The fear is that the same areas could burn again soon, but in fewer days because fires will now spread even faster across this new landscape of continuous fuels.

While this changing face of landscape mosaics has been recognized for some time, the effects are now clearly associated with increasingly larger fires. Fuel continuity across large landscapes with steep slopes, difficult terrain and other fire exacerbating topography, increases susceptibility for larger and more destructive wildfires. In many areas of Portugal, the ingredients already exist for potentially disastrous large fires pending the next severe fire weather event. The increasing inter-annual occurrence of wet years that contribute to increased fuels, plus drought years that make fuels ever more flammable, are setting the stage for the next era of larger and more devastating fires. Ironically, it's these same conditions that worsen the forest insect and disease problems becoming prevalent in Portugal, including oak disease, pine wood nematode, eucalyptus weevil, and "pulguinha do carvalho".

But it's not just about how much and how continuous fuel is across the landscape. It's also where the fuel is located from a topographic positioning standpoint. Fires tend to spread faster up steep slopes. Wind tends to get channeled and amplified when encountering certain topographic features like river canyons and mountain ridges. Figure 5A displays the results of a recently developed methodology that maps wildfire susceptibility, the combined effect of vegetation and topography on fire potential. How well does it work? Figure 5B displays an overlay of the areas burned in 2017. Almost every area that's black on the Figure 5B map was classified as high or very high wildfire susceptibility preceding the fires on the Figure 5A map.

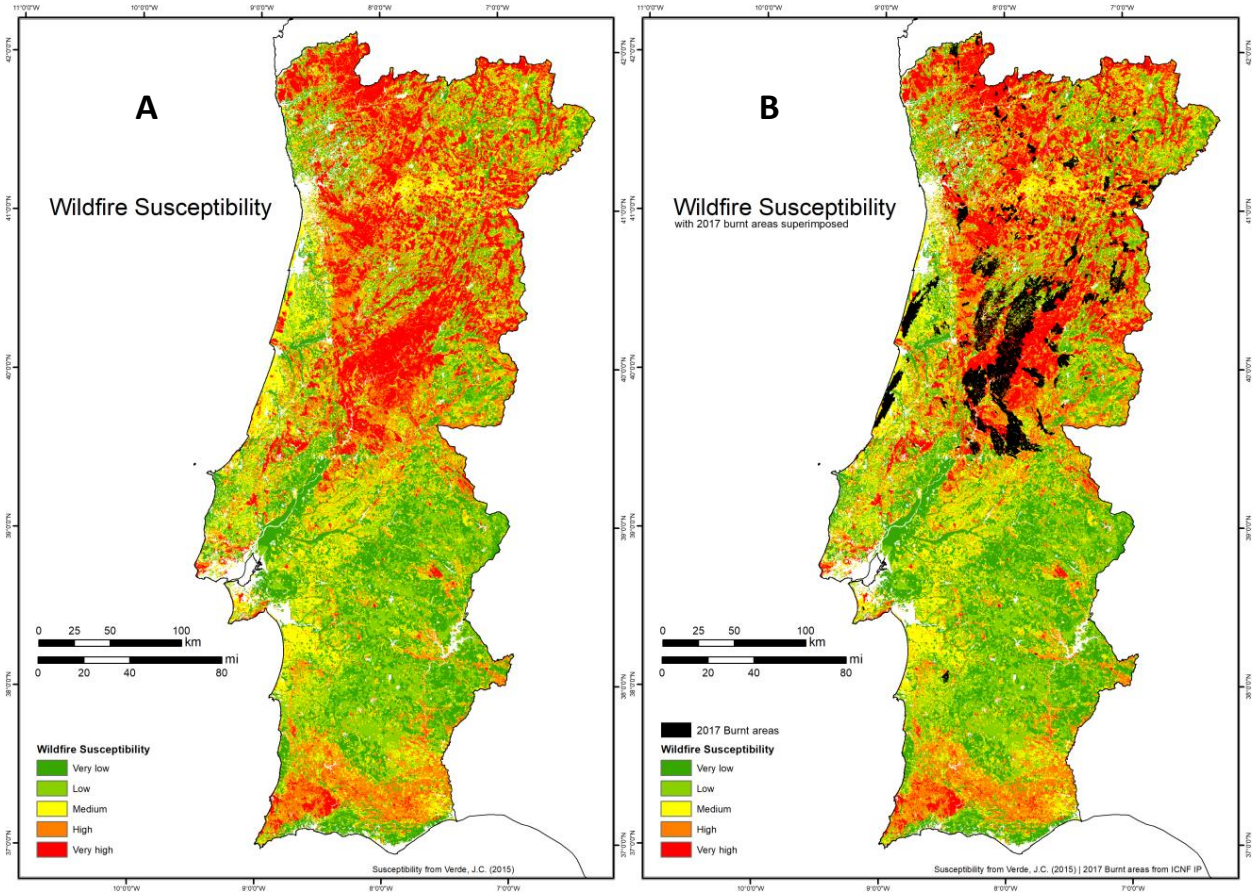


Figure 5 *Wildfire Susceptibility Maps (2015 vs 2017 Wildfire Burned Areas)*
Source: Verde and Zêzere, 2010

This mapping methodology has demonstrated a very high prediction rate; 30% of the susceptibility identifies 70% of what gets burned. At 40% of susceptible area, burned area identification increases to 83% (email communication with J. Verde 17/12/2017). Combining this information with drought conditions, weather forecasts and ignition density maps can provide incredibly valuable information for everything from prioritizing fuel treatment locations and assigning fire prevention patrols to positioning firefighting forces.

Human Risk Factors

Yet another contributing factor that cannot be ignored is the unusually high occurrence of fire starts in Portugal from human-caused ignitions which account for 98% of all fires. To say "the Portuguese people are the problem" is not an understatement. Portugal, when compared with Southern European countries having similar fuel and weather conditions, has a disproportionately high number of human-caused ignitions relative to population (Figure 6). Its Iberian Peninsula neighbor, Spain, is five times larger and has four times the population, yet has fewer human-caused ignitions. The good news is the annual number of ignitions in Portugal has been in a gradual downtrend since 2003—but there are still far too many ignitions in Portugal during moderate to severe periods of fire weather.

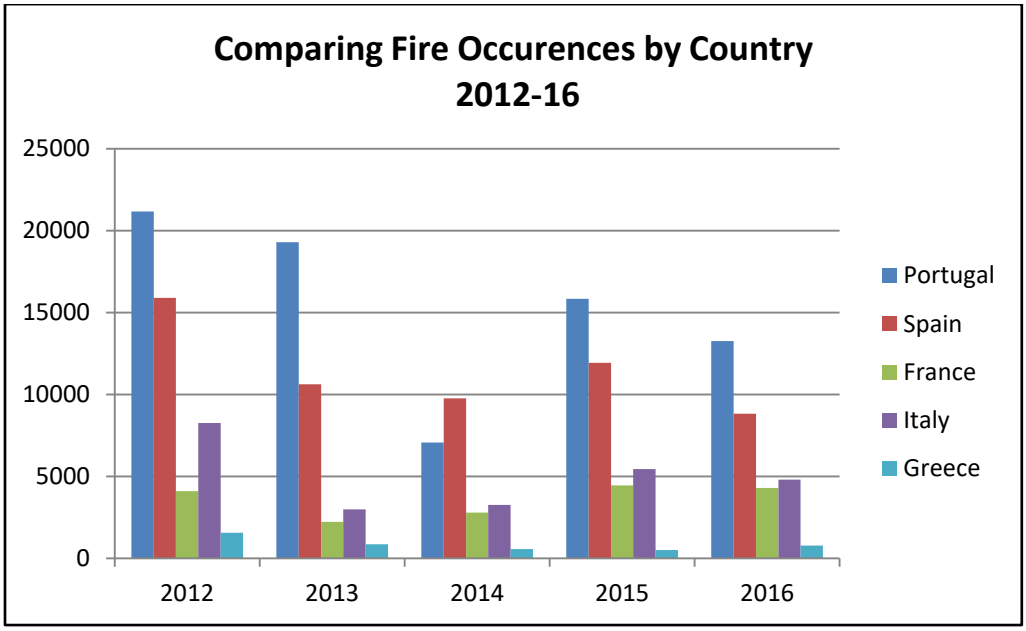


Figure 6 *Number of fire occurrences in Southern European countries 2012-2016*
Source: EFFIS data

It must first be noted that fire data by cause in Portugal is weak. Of the 423,756 occurrences recorded from 2001-2017, only 27% have a recorded cause. Roughly 59% of fires are never investigated and another 14% have insufficient evidence to make a cause determination (the cause is unknown). Most of these fires are from preventable causes such as pastoral and agricultural burning, accidental sparks from faulty equipment, indiscriminate use of fireworks, etc. Yet another completely preventable cause, rekindles, comes from firefighters.

From 2012 to 2016, the only period for which the European Forest Fire Information System (EFFIS) has data on rekindles as a specific cause, they account for 10% to 20% of ignitions annually when the cause is known (Figure 7). *"Rekindles and false alarms are phenomena that have a significant presence in the Portuguese forest fire management system and an important impact on suppression resources in particular and fire management resources in general"* (Pacheco *et al.*, 2013). Rekindles are fires that have been successfully suppressed but not completely extinguished. After firefighters leave, no one returns to inspect them. Then hours to days later, holdover embers ignite flames and the fire springs back to life, often resulting in huge losses. The horrific fire that burned around Oliveira do Hospital during October 2017, resulting in reportedly eight deaths and the damage or destruction of five timber industry mills, was determined to have been the rekindle of a fire that firefighters responded to several days earlier.

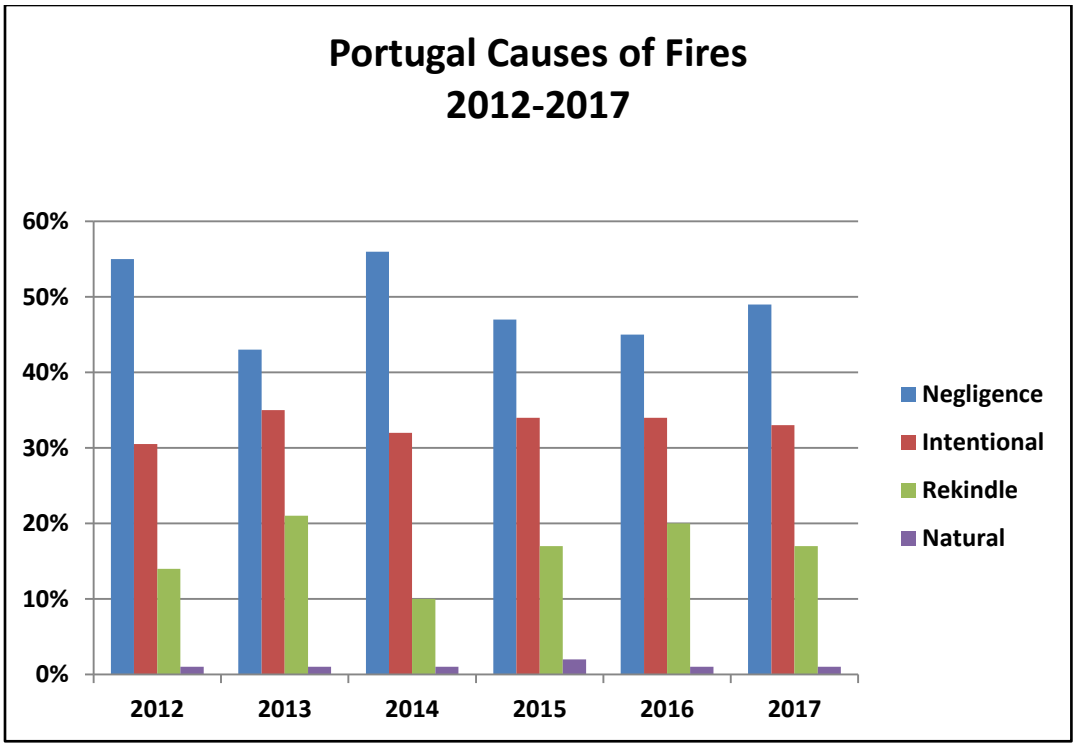


Figure 7 *Source of Portugal's fires where a cause is known 2012-2017*
Source: EFFIS data 2012-2016 and ICNF for 2017

As researchers have noted, there is high correlation between fire occurrence and population centers (Catry *et al.*, 2007). Most of these urban area ignitions result in little damage but do place a demand on the fire response system. Someone has to respond to every reported fire. On days when dozens to hundreds of fires are starting, every fire represents a potential danger and becomes important. In contrast, more remote forested and uncultivated shrub and grassland areas that represent about 46% of the country, host less than 15% of fire ignitions. However, it's often in these more remote locations that ignitions result in large fires (Moreira *et al.*, 2010). Detection is more challenging, first intervention response times are generally longer, and the terrain is more rugged and less accessible to ground firefighting forces and equipment. This consideration is especially important in areas where firefighters are not well trained or equipped in perimeter control tactics and large fire management.

Some have argued that the sheer number of human-caused ignitions that Portugal experiences is not an important factor in many areas during much of the year. While true at a surface glance, this attitude raises multiple concerns. First, excusing risky behaviors during wetter and cooler periods is promoting a tolerance for bad habits that can be ill afforded when the weather turns hotter, drier and windier. This goes for traditional activities like agriculture and forest activities, debris or trash burning, cooking lunch at a construction site, or indiscriminately shooting fireworks during a festival.

Second, every ignition, no matter how small, requires a response and every response has a cost. While the Corpos de Bombeiros (CB) brigades are a volunteer heavy force, they do get paid a small wage (46 euros/day) for responding to forest and shrub fires. And while the Intervention Group for Protection and Rescue (GIPS), Special Forces Firefighters (FEB) and Sapadores Florestais are paid a daily salary whether they're firefighting or doing fire prevention, there's still the additional cost of helicopter flight time and vehicle fuel. Then there's the lost opportunity cost. While responding to reported ignitions, some fuel reduction and fire prevention activities come to a halt. Possibly the biggest cost of all is having

too many fires at once on moderate to severe fire weather days. This can overwhelm fire brigades, allowing fires that might otherwise have been extinguished while small to grow much larger posing a threat to houses, commercial forests and other improvements. Obviously, there's a savings for every unwanted ignition that's prevented.

Portugal's Fire Risk History Since 2001

When combining the effects of climate change and associated weather, fuel and vegetation conditions across vast landscapes, and the propensity of ignitions, an almost incomprehensible range of outcomes is possible. Figure 8 provides a visual display of the spectrum of fire years that has occurred since 2000. The results are literally all over the chart. From the benign fire years of the lower left corner to the catastrophic fire years towards the upper right corner, the visual spread is startling. Also, notice that the annual hectares burned fall into five distinct groupings, which will be used later to evaluate future fire risk.

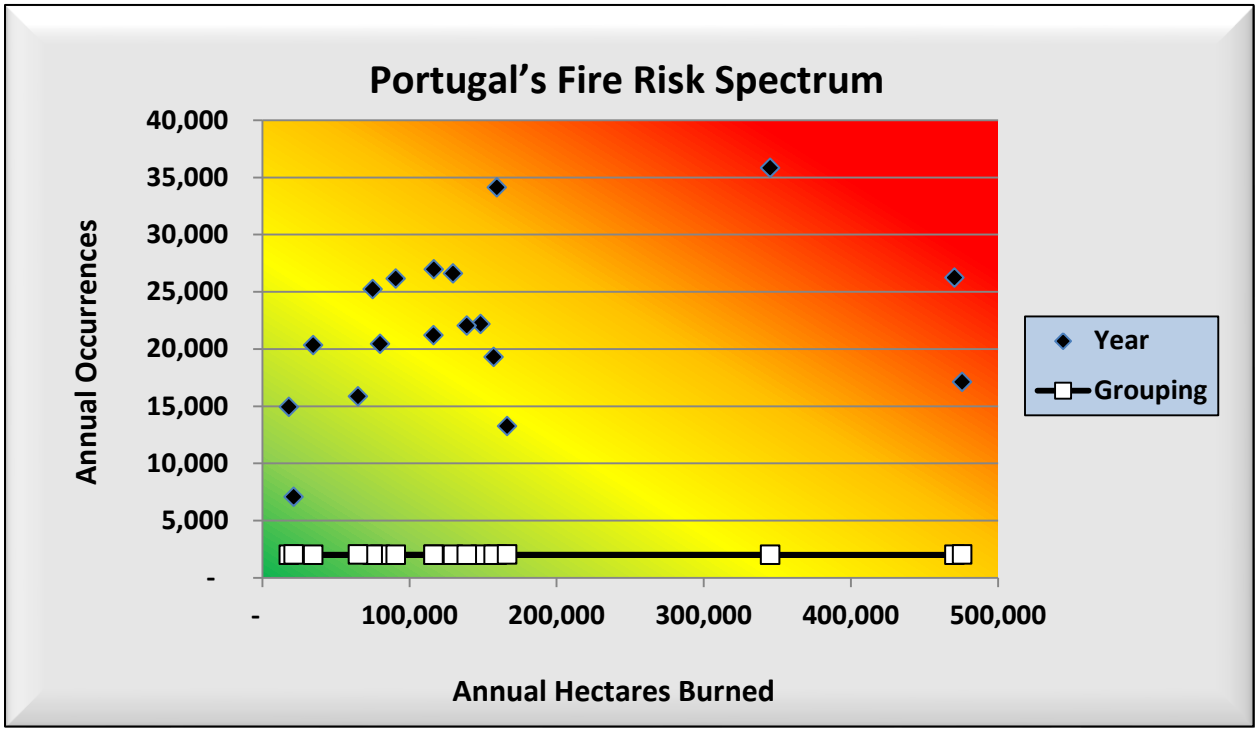


Figure 8 *Portugal's fire risk spectrum 2000-1017*

Planning a fire protection program for this range of possible annual outcomes can be an administrative nightmare. By staffing too heavily in a low fire year, you stand accused of wasting funds. By staffing too lightly in a high or extreme fire year, the results can be catastrophic. The solution could be in maintaining a base level fire management organization year-round and then adding seasonal workers to reinforce this structure in the most critical period. When not fighting fires, firefighters can be more heavily committed to fuel reduction and ignition prevention activities. Then, if the situation changes, they could shift to fire suppression.

Scenarios for the Next Decade of Fire Risk

Various risk factors reviewed in this assessment (climate and weather, fuels and vegetation condition, and fire occurrence) have been integrated into different fire scenarios for the next decade.

(Figure 9). Each scenario uses annual hectares burned for fire years from 2000-2017 as the baseline from which to forecast future change. The scenarios use 150,000 hectares as a midpoint, roughly approximating the mean annual burned area over this period.

Scenarios are only expressed in total annual burned area. Not included is consideration of the consequences in loss of human life, personal and industrial property, destruction of natural resources, and even legacy assets of the nation – such as the loss of the Pinhal de Leiria, a national forest of Portugal tracing back to the reign of Don Afonso III in the 13th Century where wildfires in October 2017, burned 86% of this national monument's 11,080 hectares of pines.

Fire Risk Scenarios	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Descriptor	**Low Fire Year**	**Moderate Fire Year**	**High Fire Year**	**Extreme Fire Year**	**Black Skies**
Annual hectares burned in thousands	0-50	50-100	100-200	200-500	Approaching 750
Number of times it occurred in 18 years (2000-2017)	3 in 18	4 in 18	8 in 18	3 in 18	0 in 18
Historical Risk Factor, (percent of actual occurrence)	17%	22%	44%	17%	0%
Weather/Climate adjustment factor	Reduced chance	Reduced Chance	Increased chance	Increased chance	Increased chance
Future Risk Factor	**12%**	**18%**	**45%**	**20%**	**5%**

Figure 9 *Integrating fire risk: scenarios projecting Portugal's future*

Four of the five scenarios are charted in terms of frequency of their occurrence since 2000. However, prudent strategic planning requires the creation of an even more catastrophic worst-case scenario with a larger burned area. Using a risk scenario model created for multiple disaster situations in short time intervals (Cragg, 2017) a new Black Skies scenario is included. It involves a fire year which would approach 750,000 hectares, approximately 10% of Portugal's total forests, shrub, and agriculture areas. This report builds on the original projection made in the 2009 Report that there would be a 500,000 hectare fire year within the next decade (Beighley and Hyde, 2009).

Brief explanations of the five fire risk scenarios:

Scenario 1 represents a low or benign fire year where burned area is more than 67% below the expected normal annual mean. This scenario is characterized by relatively wet and mild annual conditions. It has occurred only three times since 2000.

Scenario 2 is characterized by more historical weather conditions with few severe weather events resulting in a high rate of successful first intervention. Ranging from 50,000-100,000 hectares, it has occurred four times since 2000.

Scenario 3 typically experiences numerous severe fire weather events with short periods when fire fighting forces are occasionally insufficient to meet the demand. This is really the "new normal" for Portugal. Fire years of over 100,000 hectares occurred only six times in the 1980s and 90's, but have exceeded this level 11 times in the first 18 years of the new century.

Scenario 4 displays an extreme fire year scenario with numerous, more lengthy periods when fire fighting forces are overwhelmed by the number and size of fires, as was the case in 2003, 2005 and 2017. It should be noted that this probability score for extreme fire years (approaching 500,000 hectares) is somewhat lower than a recent study by Parente and Pereira (2016) who estimate the risk at 23%. If extreme fire years come in pairs over shorter duration, as they did in 2003 and 2005, it would point to an even higher probability of a companion extreme fire year to 2017 happening by 2020.

Scenario 5 outlines a fire year that has not yet been experienced in modern times. This prospect, labeled the Black Skies scenario, **would not only exceed 500,000 hectares but approach 750,000, burning nearly 10% of Portugal's forests, shrub, and agriculture areas**. A Black Skies scenario would involve multiple concurrent very large fires in several regions of the country. It would push national firefighting capabilities past the breaking point requiring massive international assistance for which Portugal is not prepared to effectively integrate with its own forces. In 2009, the prediction of a 500,000 hectare season was viewed as an unreasonable forecast. Burning 750,000 hectares is not really that much of a stretch. Had there been major fires in the Algarve or Alentejo similar to 2003 where they accounted for 150,000 hectares burned – 2017 would have been closer to 650,000 hectares. Indeed, a Black Skies Scenario, as included in this report at a 5% chance, is not so unbelievable. And, as the impacts of climate change mount, the probability for Scenario 5 will likely increase over time.

To complete the scenarios, the future risk factor displays a quantification of the shift in the expected occurrence of each risk scenario as anticipated over the next decade. Considering projections of future fire danger for the Iberian Peninsula (see Figure 4), high and extreme fire years are more likely to outweigh low and moderate years. Probabilities of the historical risk factor are adjusted accordingly to estimate the future risk factor.

Summing up Portugal's Future Fire Risk

Occasional years with lower fire occurrence and burned area will still occur, primarily due to moister, cooler climate and weather conditions. Portugal will need to use these years to get even more aggressive with fuel reduction activities, including prescribed burning, browsing and grazing by livestock, mechanical and manual means.

The probability of numerous large (>100 ha) to very large (>1,000 ha) fires occurring concurrently in multiple regions is increasing, even in more moderate fire years. Fire statistics may even have to be modified to create new, larger fire size classes moving the old interval of 1000 hectares up to 10,000. The risk of another extreme fire year (i.e. 2003, 2005 and 2017) continues to increase to a 20% probability. This growing probability is largely driven by further negative impacts of climate change, accumulating biomass, and an inability to significantly reduce ignitions. Looming in the shadows of another extreme fire year is the prospect of the Black Skies scenario exceeding any fire year Portugal has experienced in modern times.

Climate change also is increasingly likely to extend the fire season in some years beyond the traditional Bravo-Charlie-Delta period (15 May-30 Oct). The convention of concentrating fire resources in the prime summer season is rapidly becoming outmoded. One need only look to the devastating wildfires in California in November and December of 2017, to see that this is not just a phenomenon for Portugal.

Over the next decade, the risk of a potential fire year burning 600,000 to 750,000 hectares or more in Portugal must be given serious consideration. This would likely result from high to extreme fire year activity occurring simultaneously in multiple regions. The most recent report by the EU Joint Research Center also warns: *"The danger of forest fires will increase relative to the present, in particular around the Mediterranean. This suggests that effective adaptation strategies will be crucial to lessening the detrimental impacts of climate change on forest fires, the direct damage to European citizens, and the reductions in biomass, biodiversity, and provision of ecosystem services that they can cause"* (EU JRC 2017 Report 108974). Portugal clearly does not have sufficient expertise or firefighting forces for effective large fire management. Seamless integration of firefighting assistance that will be required from other European countries is not possible without adopting a universally recognized incident command system. To not have advance strategies in place to prepare for such an event would be inexcusable. Extreme fire years and Black Skies worst-case scenarios also point to the even greater need for fire planning, organizational restructuring, prevention, and fuels reduction strategies as well. It is to those issues that this report turns to in Parts II and III.

Bulldozer clearing a fuel break in a eucalyptus forest. Photo Credit: Vasco Campos

Part II

Wildfire Defense Planning and Institutions—Are Reforms Working?

Over the past several decades, Portugal has been the subject of several reviews by forest fire experts from many other countries, particularly the United States. Findings from these reviews have been relatively consistent, identifying four major areas needing improvement: (1) preventing unplanned human ignitions, (2) creating a structural fire defense system of fuel breaks and by reducing fuel load in critical areas, (3) improving firefighting capability to implement perimeter control tactics and large fire management strategies and, (4) restructuring Portugal's fire organization.

Portugal's Fire Plan (Plano Nacional de Defesa da Floresta Contra Incêndios)

In 2005 Portugal developed a technical strategy to implement all of these recommendations (Oliveira, 2005). The following year, a highly modified version of the technical report was moved forward as the strategic national plan for improving the forest fire problem. The major difference between the two versions is that the technical plan emphasized a prevention strategy, while the highly modified version promoted a strategy that increased suppression capability, primarily by adding helicopters and air tankers. In May 2006, the Plano Nacional de Defesa da Floresta Contra Incêndios (PNDFCI) was approved in the Council of Ministers and published with good intentions to move the recommendations to reality (RCM n.º 65/2006).

The PNDFCI worked well as long as milder summer weather conditions prevailed as in 2007, 2008, and 2014. However, during the more traditional hot and dry summers of 2010, 2012, 2013 and 2016, the results were not so impressive as these fire years exceeded the goal of 100,000 hectares burned. Since the PNDFCI was implemented, for short periods of time Portugal's forest fire protection system was clearly overwhelmed by both high numbers of daily occurrences, with many days experiencing hundreds of new ignitions, and in area burned, with many days exceeding 10,000 new hectares burned.

The Three Organizational Pillars of Portugal Fire Management

Since the devastating fires of 2003 and 2005, several attempts have been made to reform state entities to more effectively address the growing forest fire problem. Authorities and responsibilities have been juggled around in response to political pressures in what has been termed "successive restructuring". Some newly created entities had a very short life span before being summarily deconstructed. Others, having survived, were either reduced to a shadow of their former importance, or have grown in prominence, thriving through the constant upheavals brought by the reallocation of personnel, resources and budget. Portugal's fire protection organization currently works through three pillars:

- The Institute of Conservation of Nature and Forests (ICNF) is responsible for national policy for forests and the National Network of Protected Areas, coordinating structural prevention (fuel breaks and fuels treatment), aspects of public awareness and planning, public forest and conservation area infrastructure maintenance, data collection and analysis.
- The Republican National Guard (GNR) has tasked the Intervention Group for Protection and Rescue (GIPS) with conducting first intervention on wildfires and the Service for the Protection of Nature and the Environment (SEPNA) with coordinating operational prevention actions in terms of surveillance, detection and law enforcement.
- The Authority for National Civil Protection (ANPC) is responsible for fire response coordination and all firefighting activity, including administration and payment of firefighting contracts, aircraft fleet management and firefighting data and information collection.

Municipalities also have an important role. They manage the Technical Forest Offices (GTF) and many of the Sapadores Florestais teams. Sapadores Florestais teams are five-person hand crews that can also be sponsored by forest owners associations and ZIFs. Municipalities are also responsible for updating local fire management plans (Planos Municipais De Defesa da Floresta Contra Incêndios), many of which are more than a few years old, and some having never been approved (ICNF 2018). In addition to Portugal state firefighting organizations, non-government organizations and private companies provide significant additional firefighting forces. Forest owners associations and Alfocelca, the private firefighting company on contract to The Navigator Company and AltriFlorestal, provide an array of first intervention and fire prevention resources.

But the bulk of the ground firefighting force, the Corpos de Bombeiros (CB), comes from the Humanitarian Association of Volunteer Fireman (AHBV) that exists in almost every community. These associations provide local response capability in terms of civil protection and rural fire brigades, ambulance services, and a multitude of nonemergency community support services. They are considered the backbone of the Portuguese firefighting system by most citizens.

Civil Protection and Rural Fire

Over the last two decades various reviews of the Portuguese firefighting system have identified deficiencies in addressing forest fire protection, as opposed to civil fire protection. These include the lack of perimeter control means and expertise (hand crews, dozers, and supervisors), weak tactical airspace coordination, a disinterest in utilizing technical fire support at all coordination levels, and inadequate training specific to strategic fuel modification and prescribed fire planning and execution. Also, in a much less visible way, is the lack of influence and practical application of research science and emerging technologies in natural resource management, decision support and wildfire predictive services. The opportunities to correct these deficiencies have existed for several years, yet little progress has been realized. This suggests that a bolder approach is needed.

As recommended by the 2017 ITC Report, a new government entity that specializes in rural fire management, emphasizing ignition prevention, structural fuel reduction, and firefighting using perimeter control tactics and technical fire expertise, is required. Recently announced government reforms are leaning in this direction with the proposed creation of the Agency for the Integrated Management of Rural Fire (AGIF). It's important that this organization have authority at the same levels of government as the ANPC to ensure that new approaches and policies are receiving appropriate consideration. Critics argue that two parallel emergency response agencies, one responsible for civil protection firefighting (ANPC) and the other responsible for rural firefighting (AGIF), would only throw confusion into the system. However, this has not been the case in several other countries that have a much larger fire response capability. In the USA, Canada, and Australia emergency responders from multiple local, county, state and federal government agencies all work effectively together under the Incident Command System (ICS). There's no reason that a multitude of Portuguese fire authorities can't have similar success.

This new organization (AGIF or similar) should include an intermediate level of coordination and management on a NUTS II geographic basis while also providing field supervision for the Sapadores Florestais program and forest planning at the Intermunicipality Community (CIM) level. This would promote better utilization and prioritization of work between municipalities competing for funds and means. It would also ensure that fire prevention and fuel reduction work is a higher priority than other work needs of the municipalities. The GTFs should also be elevated to the CIM level to promote more consistent forest and fire management plans between municipalities, and provide technical fire expertise for executing prescribed burns and rural fire management support. While many in Portugal have the

knowledge, skills and experience to staff such an organization, there may initially be insufficient numbers to meet the need. An aggressive recruitment and training program would be a priority for AGIF.

Fire Budget Allocation and Accountability

While attempts were made to acquire annual expenditures for all fire programs, insufficient records are available. Even data displayed in the Independent Technical Commission Report (ITC) (See table below) was accumulated from multiple sources. As prevention costs have remained relatively the same, suppression costs increased by 18.5% over the 17-year period. Also note that almost three times as much is spent on suppression as is invested in prevention.

Period	2000-2006	2007-20012	2013-2016
Prevention Costs	24.0	23.6	25.0
Suppression Costs	65.9	69.5	78.1
Ratio Suppression to Prevention	2.75	2.94	3.12

Table 1 *Average annual costs for prevention and suppression in Portugal (millions of euros)*
Source: ITC Report 2017, pg. 37

The ITC Report also highlights that, over the same periods, the cost of air tankers and helicopters represents between 50%-65% of the total suppression cost. What becomes increasingly clear is that the majority of the operational effort, as opposed to the planning effort, has been applied to increasing fire suppression capability. It's even more pronounced when Afocelca assets are included. While fire response capability has clearly been the priority, is it enough to emphasize improvements on only a third of the solution? It's this imbalance in strategy that's problematic. The other two thirds of the strategic solution; preventing people from igniting alarming numbers of fires and reducing the fuel load that continues to grow unabated, have had far less funding and investment.

Also, the current organizational division of the Defense Against Forest Fires System between ANPC, ICNF and GNR (the three pillars) allows the system to be only partially accountable. A single state management unit, like an AGIF, is needed with responsibility for evaluating and improving rural fire management policy, coordinating rural fire protection programs among ANPC, ICNF and GNR, financial accountability, and annual reporting of rural fire management accomplishments. This management unit must have access to all financial records and databases related to fire programs and activities. Only then can progress be measured for rural fire management system improvements that have integrated program goals and performance objectives (See Appendix B for a sample program monitoring model).

Fire program effectiveness cannot be evaluated without having a complete picture of all expenditures, accomplishments and outcomes achieved. This includes activities at all governmental levels, including municipalities. Currently the information necessary to accomplish any relevant program evaluation is either fragmented between responsible entities, inconsistently measured, or is inseparably combined with other information irrelevant for this purpose. An example is the case of the GNR. Expenditures on SEPNA fire prevention and law enforcement programs are inseparable from the cost of all SEPNA services, which also cover a wider range of activities, making it impossible to identify fire specific costs. These same arguments also apply to rural fire data collection, database management and data reporting. A continuing program of integrated rural fire system improvements will be difficult, if not impossible, to achieve without a single state oversight entity.

Reconsidering National Priorities

Reducing total ignitions is critical to improving the effectiveness of Portugal's rural fire defense. More daily fires over large areas spread firefighting forces thin. This overtaxes the system and forces prioritizing first intervention and initial attack responses. Emergency response priorities are established by the ANPC as follows and appropriately put protecting human life first:

1. Life
2. Buildings and other infrastructure
3. National parks and conservation areas
4. General forests and shrub lands

Unfortunately, this prioritization has significant implications for the potential effectiveness of fire suppression in commercial forests and unclassified rural lands. What's best for the populace and communities may actually place Portugal's forests in higher jeopardy. When there are more fires than what the system can effectively respond to, forests and shrub lands will go without, or go with less than is needed to effectively stop fire perimeter spread. These situations occur most often when there are high numbers of ignitions and during severe burning conditions; those that cause fires to spread unchecked over vast areas. These priorities assume that all Portugal's forests and shrub lands outside of national parks and conservation areas are equally valued.

One suggestion that has merit is to give managed forests, which have documented investments, a higher emergency response priority than unmanaged forests with no investment. Two excellent examples are the ZIFs, in which the government has made an investment, and well-managed commercial forests which are of national economic importance, especially for rural areas. A restructuring of the above priorities in this way would also give incentive to landowners to better manage their forest in order to move to a higher fire protection priority. A change to emergency response priorities would be as follows:

What's a ZIF?

A Forest Intervention Zone (ZIF) is a territorial unit, where the main land use is forestry. This approach assembles and organizes small forest holders and creates a joint intervention for forest management and protection. Established by law in 2005, and frequently updated, each ZIF of private forest has to include at least a contiguous area of 750 ha, a minimum of 50 landowners and 100 forest plots, and has to be managed by a single body, usually a Forest Owners Association.

1. Life
2. Buildings and other infrastructure
3. National parks and conservation areas
4. Managed forests and agriculture land
5. Unmanaged forests and agriculture land

Managed forests and agriculture land could include those approved by the government as meeting a certifiable risk reduction standard and *unmanaged forests and agriculture land* would include all other lands not assigned to a higher priority group as follows:

Managed forests and agriculture land	*Unmanaged forests and agriculture land*
• ZIFs having existing government investment • Managed agriculture lands • Forests with a Sustainable Forest Management Certification from FSC or PEFC. • Managed forests meeting government risk reduction certification • Potential ZIFs still in the planning process	• All forests not meeting government risk reduction certification • Abandoned agricultural lands • All undeveloped land for which owners cannot be identified

The adoption of this change would require the government to establish a standard for risk reduction certification. There could be other uses for this new standard as well. It has been recommended that an increased value added tax be applied to wood products once harvested. Included would be a tax exemption or rebate (contribution on forest clearing) if the landowner adequately disposed of the post-harvest woody residues. Risk reduction certification could be used as the standard for evaluating whether or not sites qualify for this contribution.

Part III

Fuel Management, Firefighting and Wildfire Prevention —Toward A Balanced Strategy?

Forests and shrubland occupy about 67% of mainland Portuguese territory (ICNF 2017 *Forest Profile).* Of the 35% of area occupied by forests, only 3% are public land. Much of the forest is privately or communally owned, mostly in small parcels less than 1 hectare, and can't be used for farming or cultivated agricultural due to poor soils and geography. However, forests contribute greatly to the wealth and well-being of Portugal. Estimates of the total economic value for Portuguese forest ecosystems, considering market services (timber and non-timber forest products) and non-market services (recreation, landscape, carbon sequestration, watershed protection, protection of soil erosion and biodiversity), approach a billion euros: *"At least half of the economic value of forest ecosystems is due to non-market ecosystem services."* (Lopes and Cunha e Sá , 2014).

What's a Forest Worth?

Mortagua citizens view their forests as a bank, collecting interest over time. When asked how fast their eucalyptus forest grows, the answer is "about 4,000 euros/hour". The municipality has the lowest fire occurrence rate in the country. They're so protective of this investment citizens often call the CB Commander when they spot "strangers" driving around. Unfortunately, even with this level of care and attention, they suffered huge losses on 15 Oct 2017, as a fire starting in Lousã jumped a 300-meter-wide water reservoir and roared into town.

Structural Prevention Improvements

Based on the economic and environmental importance of Portuguese forests, implementing widespread structural prevention measures that increase their resiliency to damage from fire should be a national priority. Yet 80% of Portugal's forests are unmanaged, which means that little effort or investment is made to make them: (1) more resilient to damage by fire, insects and disease, (2) more ecologically sustainable or (3) more economically productive. It's like planting a vegetable garden then walking away until the end of the growing season and expecting a bountiful harvest. Like gardens, vineyards and fruit orchards, forests must be tended or managed to achieve specific outcomes. While completely fire-proofed forests aren't economically feasible, or practical, they can be managed in a condition that greatly improves their ability to survive fire.

Creating a reliable and sustainable forest defense against fire is not just about reducing ignitions and improving firefighting capability. More forests need to be managed in a way that improves their ability to resist and survive fire. This generally involves three main characteristics of forests:

- Species selection and silviculture methods
- Forest structural characteristics, including understory and fuel load and
- Landscape level mosaic patterns of differing age class and species diversity

A defensibly sustainable forest involves simultaneously managing all three characteristics. Examples include: (1) where soil and moisture conditions allow, replacing dense thickets of noncommercial pine, eucalyptus and acacia with widely-spaced, less flammable broadleaf species like oak or chestnut, (2) harvesting forests on a spatially specific schedule that results in a checkerboard landscape pattern of young plantations, immature trees, and yet to be harvested older trees, and (3) controlling the spread of undesirable invasive species that compete for nutrients, space and sunlight jeopardizing the health and vigor of desirable species thus increasing their susceptibility to fire.

Unfortunately, many forest owners and managers ignore or intentionally omit managing one or more of the three characteristics. This not only increases the landowners' fire risk, but their neighbors' risk as well.

Another opportunity to turn unmanaged forest into managed forest occurs when large areas are burned. In the past, with the exception of managed commercial forests, much of Portugal's burned area was left unattended. Vegetation response to fire can vary greatly from area to area. It depends on many factors like species specific ecological adaptations to fire damage (root crown sprouting, seed drop, exposure of buried seeds), site conditions (soil moisture, post fire soil erosion), burn intensity (ground or crown fire), time of year burned, etc. One thing is certain; vegetation will return whether it be from sprouting, seeding in from unburned edges or germination of seeds that lay dormant for years in the soil waiting to be exposed. What returns will likely be an unruly mix of what existed before the fire and what has drifted in on the wind after the fire. Left unmanaged, fire prone grasses, shrubs and trees will likely establish dominance most quickly and in less than a decade the area will be ready to burn again. Controlling competing vegetation, forest species and stocking is most effective and least expensive when done within a year or two of the area being burned. Wait much longer and the battle is lost.

Almost all fire risk reduction options require forest owners to make additional investments. Many choose not to incur these costs and would rather "roll the dice" and place their bets on luck to avoid fire losses before harvesting. Unfortunately, it seems Portugal has lots of gamblers in forest ownership. The problem is compounded when almost everyone chooses to make that same bet. The few landowners that make the investment to reduce fuel load often find they're a small island in a sea of very flammable forest. Forest owner's need a collective push in the right direction with financial or tax incentives that reward forest management practices which reduce fuel loads. The concept of a special value added tax on commercial forest transactions that can be recovered when the post-harvest areas are certified as having been cleaned of hazardous residue would fit this need, but only for forest plots that are managed and on a harvest schedule. For those forest and agriculture plots that are abandoned, or just ignored, a different solution is needed.

Determining ownership can be a challenge for many of these small and unmanaged plots, even for the government agencies charged with enforcing forest fire prevention laws. Many owners who may have inherited family property live outside the country and their contact information is unknown. In other cases, ownership information is registered but not made available. When unmanaged or abandoned plots of land become a serious fire risk the state should have laws in place to declare them a public hazard. Once posted as a publicly declared threat, the owner should be given reasonable time to bring the property into compliance. If the owner doesn't comply in the time allotted, land ownership is then forfeited to the state to be managed as public land. On the surface this sounds like a harsh measure, but the alternative could be much worse if these lands are left unmanaged. Publicly available property owner records would greatly assist in landowner notification and enforcement of forest fire prevention laws.

Forest Intervention Zones

Another significant obstacle to achieving a greater percentage of managed forests is the small size and diversity of ownership of most forest land, particularly in central and northern Portugal. While some legal mechanisms have been established to facilitate organizing the many small property owners to take collective action, the most promising is the Forest Intervention Zone (ZIF) (Figure 10).

Figure 10 *ZIF locations and extent*

By the end of 2017, 189 ZIFs had been approved ranging in size from 751 to 54,788 hectares and covering a total of over one million hectares nationwide. Almost 100 new ZIFs are in various stages of the planning and approval process covering an additional 400,000 plus hectares. On the surface the numbers look impressive but what are the actual results in terms of improving forest management and reducing fuel load?

Even though the ZIF program has been in effect for over ten years with the goal of improving forest management and reducing fuel load on small plot forests, no one is monitoring the outcome. It appears there are many ZIFs covering a lot of forest area but making little improvement to the overall forest situation. The lack of performance is primarily a result of the financing scheme which heavily funds ZIF planning and establishment but then requires landowners to complete and pay for structural fire prevention work before they can submit a request for partial government cost reimbursement. Some landowners just don't have the funds to pay the full cost of fuel treatment upfront while others don't think the amount of reimbursement is a sufficient incentive.

The ICNF, charged with managing this program, is not keeping records of what is actually being accomplished in terms of structural prevention. So far, it's a bit of a white elephant. Even with legal authorities in place, many things are still lacking for the ZIF program to be an effective contributor to better forest management, including:

1. The desire of individual landowners to do work on their land that's in the best interest of the collective
2. Landowner trust that the entity managing the ZIF will act in their benefit
3. Economic attractiveness of many forest products and services
4. Effective, progressive leadership at community, municipal, and district levels
5. Additional financial incentives (reduced taxes or increased subsidies) that recognize the public benefit of private landowners reducing their future harvest income by removing trees to create a fuel break or a mosaic of less flammable vegetation

Until these issues are resolved, ZIFs will probably not result in any meaningful fire risk reduction improvement.

Hazardous Fuel Removal and Disposal

Southern European countries, Portugal included, place a high value on fuel breaks as the method of choice for structural fire prevention**:** *"Firebreaks are the most widely used fuel management technique in Portugal, mostly in the mountainous areas, in the public lands and in the eucalypt plantations of the pulp and paper companies."* (Xanthopoulos, G 2006). The fuel break system largely consists of a network of primary and secondary linear clearings along ridges and strategic breaks in topography designed to provide locations for more effective firefighting. However, under severe burning conditions, fuel breaks alone will almost never stop a fire nor do they reduce fire damage in the areas between them (Gould, 2007). Fuel breaks also provide a strategic anchor point for instituting area-wide, landscape level prescribed fire treatments. Fire experts have long warned however that fuel breaks should not be seen as a single remedy and must be integrated into a broader based fire prevention effort aligned with an appropriate level of fire suppression capacity: *"Fire management strategies adapted to a changing climate should be integrated with forest management and strengthen fire prevention activities such as targeted fuel treatments and prescribed fires"* (EU-JRC 2017 Report 105864).

Portugal's primary fuel break system, once completed, is estimated to include 130,000 hectares. However, this roughly represents only a single average year of area burned by wildfire. The annual numbers of hectares burned using prescribed fire is also insignificant compared to those burned in wildfires. And while thousands of hectares of commercial forest are harvested each year, fuel reduction activities prior to plantation reestablishment are limited, perpetuating an increasing ground fuel hazard. These numbers are not adding up in Portugal's favor.

However, expertise and resources exist to plan and execute a much larger fuel treatment program. Most municipalities have technical forest engineers trained in fuel treatment design and prescribed fire planning. The Intervention Group for Protection and Rescue (GIPS), Special Forces Firefighters (FEB) and Sapadores Florestais teams are eager to participate in the live fire experiences that an increased prescribed fire program would make available. Increasing both mechanical and biological means could vastly accelerate production. Combining dozers and tractors with Sapadores Florestais teams would greatly improve efficiency. Increasing numbers of sheep and goat herds on fuel breaks would make short work of removing the annual regrowth of grass and shrubs.

Alto Minho TREX

Deserving of recognition, the Alto Minho TREX Prescribed Fire Training Exchange in the north is an outstanding example of the capacity building potential that already exists in Portugal. Prescribed Fire Training Exchanges provide experiential training through one- to two-week events that bring together diverse groups of practitioners from national and local agencies, NGOs, universities, private contractors and local landowners. TREX builds local capacity and provides new perspectives to professional fire workers, while completing treatments that help communities and ecosystems. The new National Program for Prescribed Burning will need more efforts such as this.

But fuel break construction, prescribed fire, commercial harvesting and grazing and browsing combined won't result in sufficient fuel removal. Many flammable invasive species that now choke forest understories have no commercial value and need removal. Increasingly, stands of eucalyptus go unharvested because the wood is not acceptable quality for pulp. Even now, these older stands of eucalyptus have the next crop of regeneration coming up underneath doubling the potential future fire hazard. There's a phenomenal amount of biomass growing in Portugal that, if not continually removed and disposed of, will fuel the next series of catastrophic fires.

An even more critical question that arises from this hazardous fuel removal discussion is how to dispose of what will likely be mountains of noncommercial woody debris. Open burning is one method but would have several undesirable effects such as unacceptable volumes of smoke and additional risk from potential fire escapes. Some success has been made in addressing this by constructing large, low-emission, biomass fueled electric generation stations scattered about the country. Stations in the north are working efficiently while others, further south, are not. The inefficient stations were built in locations too distant from the sources of biomass requiring excessive transport costs. And some are just too large and the biomass supply is insufficient in the surrounding area. Lessons learned from these experiences should be applied to develop a strategy that locates many smaller stations closer to biomass sources. Some say the electricity generating output could be increased three-fold if the system was efficiently designed and located.

A goal that Portugal should strive for is to conduct fuel hazard reduction on more area than is annually burned by fires. This is an aggressive approach, but without it, Portugal's forests, shrub lands and communities will continue to remain at high risk of damage by fire.

National Lookout Tower Network

From 2001-2017, Portugal averaged over 20,000 ignitions per year. With all these starts, early and accurate detection is critical. Most fires are reported by citizens calling them in on mobile phones. This makes sense as the majority of fires start within two kilometers of populated areas. But who reports fires that start deeper in more unpopulated rural locations, in areas most prone to very large fires? "*Large fires in Portugal occur mostly where population density is lower and forest and shrubland dominate land cover"* (Moreira *et al.*, 2010). During the same period from 2001-2017, only 8% of the initial fire reports came from the National Lookout Towers Network (NLTN). Nonetheless, in 2017 these towers were the first to report many of the most damaging fires—including nine very large fires that burned a total of 75,000 hectares.

It's clear that towers provide critical detection in some areas. However, with a network of roughly 230 towers in various stages of maintenance, are they all of equal importance? In 2007, a research project attempted to answer that question with this summary: "*…we concluded that its configuration (NLTN) is not optimized to current surveillance needs, having a significant percentage of sites which give a very low contribution to the network capabilities. The presented proposals can either increase greatly NLTN performance or reduce its costs*" (Almeida *et al.*, 2007). It seems doing either would be an improvement.

The Service for the Protection of Nature and the Environment (SEPNA) is charged with operating the lookout tower network, and it's an onerous assignment. Many of the towers are in remote, difficult to reach locations. And they require some agility to climb the steep ladder up the narrow tube to a tiny cabin that's very uncomfortable on a hot summer day. The undesirability of the location and working conditions is only complicated by a requirement that SEPNA hire personnel from the unemployment list. While some of those that staff the towers can be quite good, many are ill-equipped physically and mentally to handle long shifts in the uncomfortably tight quarters. Some that sign up last only days to weeks and often quit on receiving their first paycheck. Of all the elements that make up the Portuguese fire detection and surveillance system, this requires the most attention.

While other detection technology is being used in some areas, such as video cameras, their resolution is not sufficient to spot small white smoke plumes before they darken to a more destructive color. In the future this could be an alternative, but it's not good enough yet. Either way, an updated analysis should be conducted on NTLN site locations to determine which are most beneficial to maintain. Until camera detection technology can match the human eye, another approach to staffing the towers is needed. One suggestion that has merit is for the closest municipalities to take over this responsibility.

They could be managed and funded by the local GTF with hiring done locally. Those staffing the towers would most likely live in the municipality and have a better knowledge of geographic landmarks.

Improving Firefighter Performance, Pay and Career Opportunities

The backbone of any firefighting system isn't aircraft or vehicles, but firefighters. Unfortunately, numbers of professional and volunteer firefighters in Portugal have been dwindling in recent years (Figure 11). Total numbers peaked in 2006 at 42,208 and have experienced an almost steady decline to 28,308 in 2016, a major 33% drop in just 11 years. Portugal now has a third fewer firefighters than just a decade ago, even though the number of Humanitarian Association of Volunteer Fireman (AHBV) has remained relatively stable. Obviously, this is not a great time to experience a decline in the firefighter ranks. Why is this happening and what can be done to reverse the falling tide?

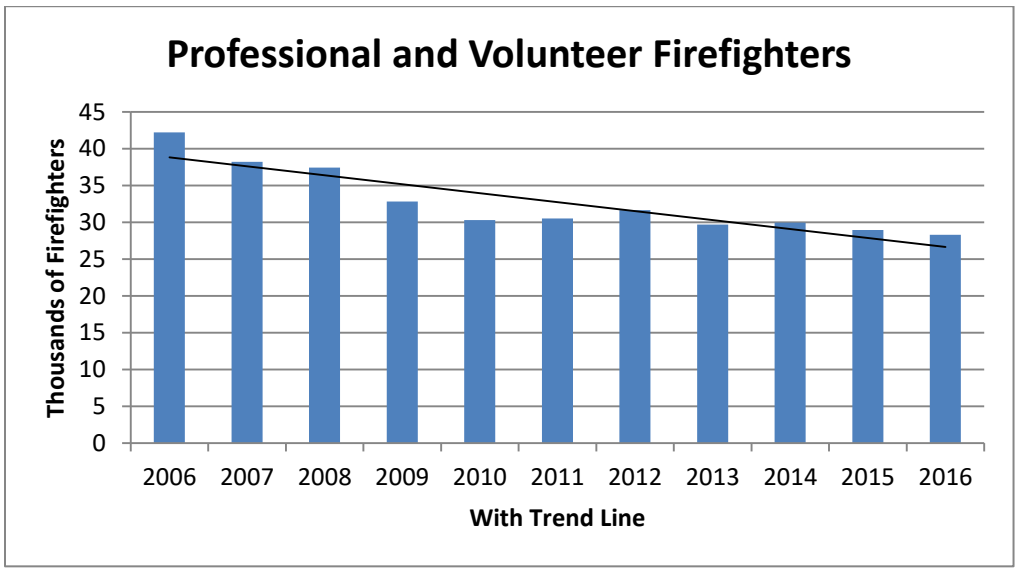


Figure 11 *Where have all the firefighters gone?*
Source: PORDATA 2016

The trend of fewer firefighters inversely parallels another trend in Portugal, the increasing average age of the population, which is expected to double from ages 26 to 52 in the period from 1950 to 2050 (Figure 12). A frequent topic of discussion when visiting CB fire stations is the increasing age of their firefighter ranks and that many young people are just not interested in participating. Firefighting is a physically demanding job for which a healthy, younger workforce is required. Before this report examines the limits of fire suppression capability in this new era of fire, the limits of firefighters must be discussed.

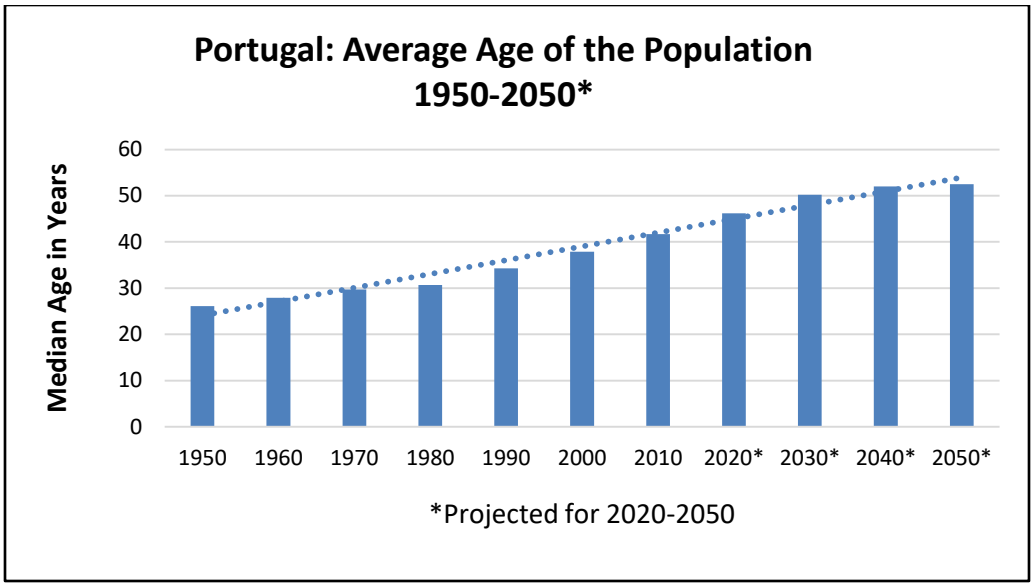


Figure 12 *The aging of Portugal's population (1950-2050)*
Source: United Nations Statista 2107

Of the firefighting organizations in Portugal, the Intervention Group for Protection and Rescue (GIPS) has the most attractive program for both recruitment and retention of firefighters. Other firefighting organizations should emulate this model. No one knows the physical demands of firefighting better than the GIPS, which is why they must past strenuous physical tests before even being considered for the job. All other professional firefighters, including the CB, Special Forces Firefighters (FEB) and Sapadores Florestais, should be required to pass basic level physical fitness requirements, and maintain a minimum standard level of physical capability while in the job.

While younger firefighters are more physically able, they're also far less experienced. So, the challenge is how to retain the older, more experienced generation in the system while recruiting a new and younger generation of firefighters. Fortunately, the GIPS can provide an example for this as well. They have other career options for older firefighters who can no longer meet the physical requirements or become interested in less physically demanding positions where the skills they learned in the GIPS are not lost, for example as SEPNA Officers.

With the government reforms issued on 27 October, 2017 (Presidência do Conselho de Ministros 2017) Portugal has an opportunity to correct firefighter recruitment and retention deficiencies currently plaguing the system. Older, more experienced firefighters can be moved into newly created, permanent positions for the purpose of supervising and training new brigades of firefighters in the FEB and Sapadores Florestais programs. Their expertise could also be used to coordinate with army officers in the patrol and final extinguishing of fires.

Also, higher wages are needed to attract younger people back to more rural areas. In raising the bar on entry level firefighter qualifications, the bar should also be raised on entry level pay. Currently many firefighters in Portugal are underpaid for the critical work they're expected to perform. And while a ten-week job during the summer months is adequate for college students, it certainly can't be considered a career opportunity. Firefighting should be treated as a professional career if a dependable and sustainable force of knowledgeable and experienced firefighters and fire managers is the desired outcome. Structural improvements to fire organizations should provide both career opportunities that attract younger recruits to firefighting jobs in rural areas, and career ladders to retain older, experienced firefighters in key leadership and training roles.

So where are more firefighters needed? It's generally in rural areas. But where is the younger, more physically fit population? The short answer is not in the rural areas. A metric commonly used to measure this changing population demographic is the Aging Index (see Figure 13); a ratio of how many old people (age 65 and older) there are for every 100 young people (age 14 and under). In the year 2000 the ratio for Portugal was 99 old people for every 100 young people, an even balance. By 2016 that ratio increased to 149 old people for every 100 young people, a 50% increase in just 17 years!

Figure 13 is a visual geographic representation of the relative distribution of younger and older generations by municipality. The darker the color, the more that older citizens outnumber younger citizens. Municipalities depicted in the two darkest colors are where this ratio is most tilted towards older people by at least 2 to 1 (a score of 210) to almost 8 to 1 (a score of 788). Unfortunately, these are the areas younger firefighters are needed most as they are also where many of the largest, most damaging fires occur.

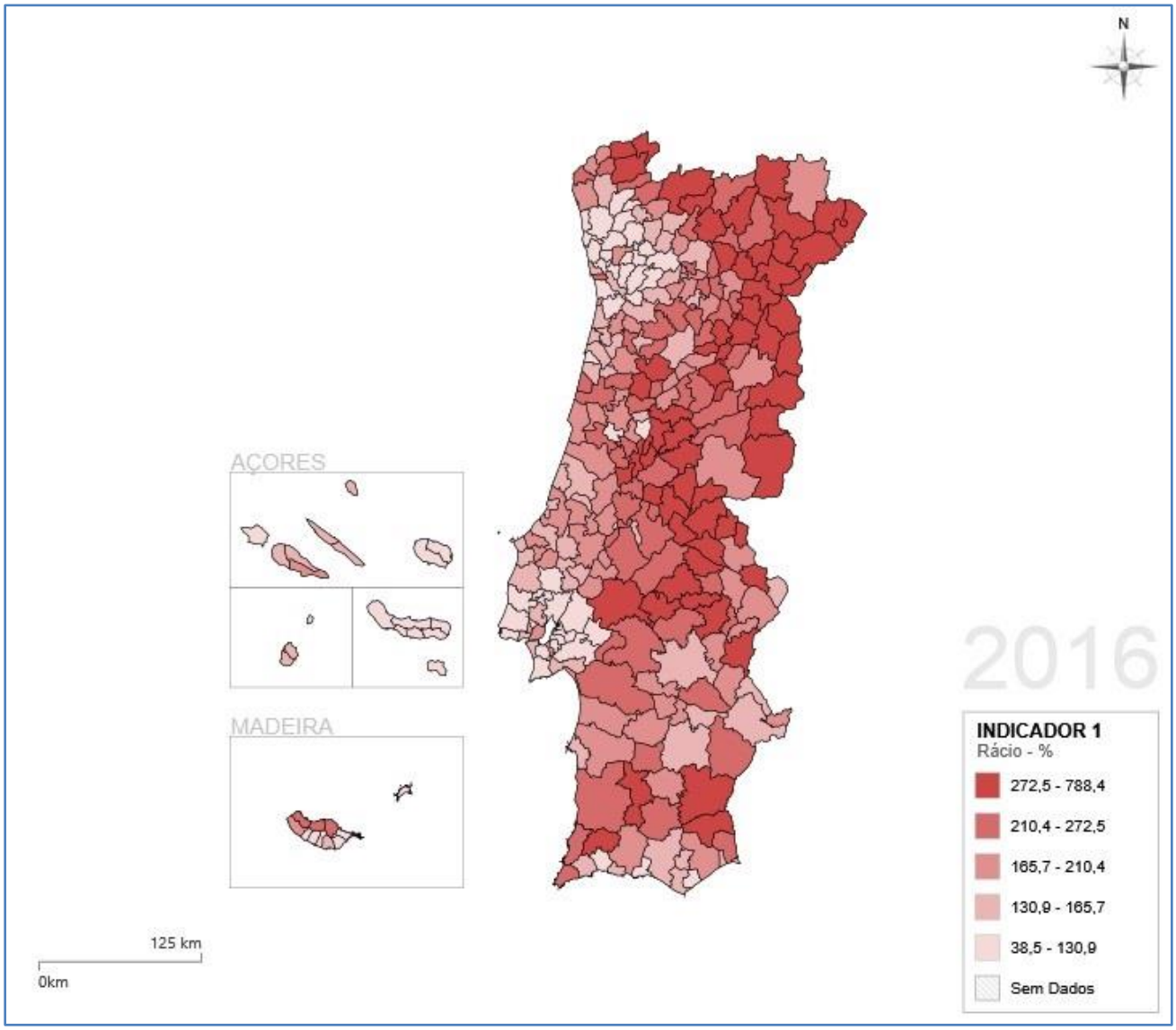


Figure 13 *2016 Aging Index by municipality*
Source: PORDATA

The Problem of Rekindles

As previously mentioned in this report, another aspect of the Portugal fire problem directly related to firefighters is the high number of rekindles. Rekindles average 16% of occurrences where a cause is known, with an annual range of 10-20%. This is not a new issue and was reported by fire experts as early as 2004 (Beighley and Quesinberry, 2004). Those very familiar with this problem say it can range as high as 30% in some areas. In some cases rekindles are not reported as such because it's considered a shame on the fire brigade. These are fires that should have been completely extinguished the first time, or at least checked daily and worked on until certified as extinguished. Recognizing that no system or human endeavor is perfect, getting this number down to less than 3% would be a significant accomplishment.

So why is this still such a huge problem after being identified more than a decade ago? Firefighters have reported that it boils down to two primary reasons. The first is a CB brigade culture that involves training, leadership, firefighter fitness and pay. Second, too many fires occurring daily forcing brigades to prematurely disengage the fire they're working on to respond to a newly reported fire that could pose a greater threat. This critique is focused primarily on CB brigades because they're involved in the majority of first interventions and are often the last to leave the fire. The responsibility of CB brigades as quoted from the DECIF: *"CBs carry out all actions that lead to an immediate intervention on the ground and to the rapid control and extinction of forest fires, permanently enhancing the performance of the device, as well as their aftermath and active surveillance operations after words, guaranteeing the consolidation of the extinction*" (DECIF 2017).

The culture of many CB brigades is to always work with hoses and water, stay on the roads, and avoid using hand tools. Some even consider using hand tools as "demeaning". While new recruits often receive training on using hand tools, brigade leaders seldom require hand tool use on fires. There's also a shortage of CB firefighters with the physical and mental capability for strenuous fireline construction, mostly because of poor pay for such demanding work. Many CB firefighters who stay in the volunteer program are older and not prepared for the increasing physical demands of the rural fire mission. This situation doesn't apply to all CB brigades but with rekindle percentages so high; it probably applies to a significant number.

In most cases, wildfires cannot be completely extinguished with water alone. Hand tools must be used to break up burning forest litter and duff and to stir in the moisture. It's physically demanding work that includes digging, chopping, scraping, and feeling the ground for lasting sources of heat. Only a mineral soil fireline can stop an undetected smoldering ember from creeping into fresh fuel. All firefighters should be thoroughly trained in effective mop-up and extinguishment procedures that brigade leaders must enforce.

Procedures must also be established for continued daily checking of fires until they're certifiably extinguished. This can also present a huge workload. On many days there can be hundreds of new fires that demand first intervention. And this daily pattern can continue unabated for weeks. During the more active periods of the fire year a dedicated workforce, separate from the first intervention brigades, will likely be needed to keep up with the fast pace of new fire occurrences. This presents a great opportunity for the Portuguese army to conduct integrated field operations. Working with experienced firefighter liaisons, platoons trained in heat detection techniques, equipped with maps of fire locations and gps devices, and armed with a hand tool and a back pump of water, can move efficiently through forests and rural areas checking fires, extinguishing hot spots and reporting back daily on results.

Limits to Firefighting Capability

Records clearly show that Portugal's fire response system can successfully detect, respond to, and extinguish hundreds of fires daily under benign burning conditions. However, when burning conditions become increasingly more severe, more fires become large. It's under these conditions, when many large fires dominate the landscape that most burned area occurs. From 2001-2017, less than 1% of the fires accounted for 80% of the total burned area. When weather and fuel conditions exist that promote large fire development, and the number of total daily fire occurrence increases beyond 100, the number of very large fires (>1,000 ha) increases significantly (Figure 14).

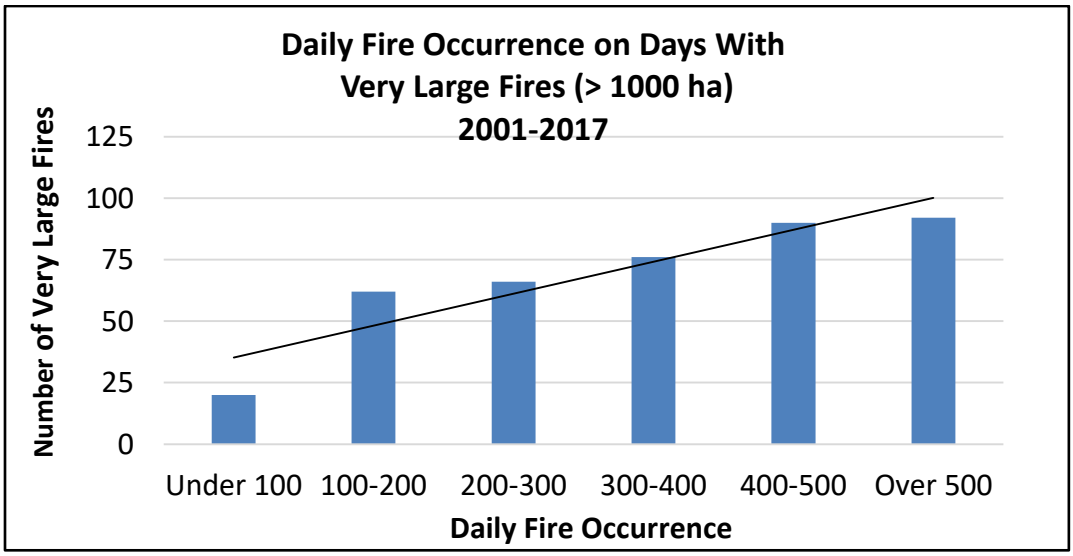


Figure 14 *Daily fire occurrence on days with very large fires (>1,000 ha)*
Source: ICNF data

As fires become more intense, and faster spreading, civil protection firefighting forces become less effective. As Fernandes *et al.* has noted: *"We found no evidence that allocating increasingly higher levels of fire suppression resources decreases the life span of extremely large fires"* and *"…extremely large fires likely expanded as long as the combined effects of weather, fuel and terrain overwhelmed the fire-control capacity, regardless of the available resources"* (Fernandes *et al.*, 2016). Under severe burning conditions firefighters are often forced to withdraw in consideration of their safety. In this situation, all efforts are directed at saving lives and houses while the fire continues to spread unimpeded, threatening more communities. Reduced visibility and increased air turbulence limit the use and effectiveness of firefighting aircraft. In extreme conditions, often the most prudent action is to evacuate areas in advance of the growing fire.

It's because of the limits of fire suppression forces under an increasing frequency of severe burning conditions, that future investments in forest fire protection may be better spent bolstering capabilities that promote a more strategic, less reactive approach. Again, from Fernandes et al: *"…our results suggest that further investment on large fire suppression should be focused on intelligence and organization rather than on resource availability. Improvement of large-fire management should integrate fire behavior analysis and expand fire-fighting options to enable effective perimeter control through more manual and mechanized fireline construction - versus line-holding with water, prevalent in Portugal"* (Fernandes *et al.*, 2016). While the movement of large wildfires may seem entirely unpredictable, their perimeter spread follows patterns that can often be projected hours in advance,

enabling fire commanders to choose locations that greatly improve their chances of success, and giving specialized hand crews and equipment sufficient time to construct fire lines and widen road clearings well before the fire front arrives.

Of course, for this farsighted approach to work, Portugal needs to acquire a sufficiently skilled force of technical fire specialists and meteorologists equipped with the latest remote weather monitoring and fire behavior prediction support tools. Also needed are a cadre of firefighters and commanders experienced in perimeter control strategy and tactics, a universally accepted Incident Command System and equipped with maps of fuel conditions, fuel break locations, plantation clearings, recent burn scars and rural road systems. This will require full participation by not only firefighting organizations, but also forest owners associations, ZIFs, the pulp and paper industry, utility companies, and municipalities. But even when all the pieces are in place, there's one more critical factor that must not be overlooked. Ignition prevention becomes of paramount importance when weather and fuel conditions support large fires - even more important than adding more firefighting forces. If on these days the number of occurrences could be minimized, far fewer large fires would result.

Reducing Ignitions

98% of fires in Portugal come from human sources. Portugal also experiences an unusually high number of ignitions relative to geographic size and population as compared with other Southern European countries with a similar climate. While it can be said regarding fire that the Portuguese are the problem, they're also the solution. But to become the solution, some attitudes and behaviors will have to change. Citizens, especially in rural areas, will have to become more vigilant, more vocal, and more engaged in fire prevention.

In the United States there's a saying regarding the threat of terrorism and public safety. "See something, say something". Created the day after the World Trade Center attack on September 11, 2001, *See Something, Say Something* became a citywide phrase. The NYC Metropolitan Transportation Authority adopted it to promote its new safety hotline in the wake of the attack. It's based on the premise that public safety officers can't be in all places at all times, so the public must become a major component of the surveillance system. What does this have to do with the fire problem in Portugal?

Fire has been a part of rural Portuguese tradition for centuries. It's used to clear and prepare agriculture fields, dispose of rubbish and debris, cook food in outdoor pits, promote new growth in pastoral areas, even to control snakes around the perimeter of houses. While these behaviors may not be risky during much of the year in cooler, wetter periods; they can become damaging, even deadly, when the weather changes for the worse. The government knows this, which is why they issue Critical Season burning restrictions when conditions become too risky for any kind of fire. However, not everyone complies. In fact, some try to evade detection by burning late at night when the smoke can't be seen. Some continue burning because they've been doing it for decades and are dismissive of government regulations. When citizens are asked if they would report a member of their community for illegal burning, many say "no, I see him every day; he is like a cousin, like family. It's not my job to enforce the rules." *See something, say something*, doesn't apply. But what if it could—and in a way that wouldn't alienate friends, family or neighbors? An anonymous fire reporting hotline telephone number is a possible solution for reporting negligent or suspect fire activities, without exposing the caller's identity.

If the public is expected to be engaged as part of the solution, they need accurate information about what's causing fires and how they can help. False information or rumors can adversely influence a fire prevention media campaign. It's not terrorists and it's not firefighting aircraft as many would have citizens believe. It's the Portuguese people who don't follow Critical Season burning restrictions, which indiscriminately shoot illegal fireworks, who fail to completely extinguish cooking and agriculture debris

and trash fires, who toss burning cigarettes in dry grass, who carelessly continue to use defective equipment. These are the real culprits.

Getting the right message to the right audience at the right time is one of many challenges to reducing ignitions. Social science and public communication specialists are skilled at tailoring messages to audiences of specific generations and demographics. Who does the target population believe and listen to most? Key opinion makers in each demographic should be solicited to participate in the message.

In Need of a New Fire Prevention Slogan

The previous campaign slogan *"Portugal without fire depends on everyone"* implies that the reader doesn't need to do anything because everyone else is taking care of it. The diffusion of responsibility over the entire population tends to minimize the importance of individual responsibility. Contrast it with the highly successful forest fire prevention campaign slogan *"ONLY YOU can prevent forest fires"* which makes the reader think that they alone have the ability, and therefore the responsibility, to solve the problem.

Early Warning of Fire Threats

At times, fire conditions can change quickly and be so severe that even the least likely ignition sources start fires. Not everyone stays abreast of daily fire weather forecasts, particularly in rural areas. A warning system is needed to alert citizens of critical fire weather developments. A combination of information and technology can help accomplish this. First, meteorologists need to know what weather conditions and trigger points are critical from an immediate fire threat standpoint (dry thunderstorms, high winds, excessively low humidity, etc.). These extreme fire conditions may only last for a day or two but their onset could literally happen overnight. In the US, the National Weather Service issues Red Flag Warnings and Fire Weather Watches to alert fire departments and the public of the possible onset of critical weather and dry conditions that could lead to rapid or dramatic increases in wildfire activity. Such alerts could have been issued when dry thunderstorms were developing over drought stricken central Portugal on 17 June, 2017. The premise is that if the public knows a significant weather event is imminent, they will take extra precautions to check that burned areas are cold, to avoid accidental ignitions, and to be vigilant about their neighborhoods and even think about the potential need for evacuation.

When fast spreading fires or other public emergencies materialize, a fool proof system is needed to get the alert out to those that need to know, without unnecessarily alarming those that don't. Since most citizens now have mobile phones, an approach using that technology could have the best results. In the US anyone can dial 911 from anywhere to report an emergency. Reverse 911 is a public safety communications technology used in Canada and the United States for emergency services to contact people in a defined geographic area. The reverse calling system uses telephone numbers and addresses which, when tied into geographic information systems, can be used to deliver emergency notifications to mobile phones in the alert zone. It's used to notify specific populations of potential tornados, flash floods, fires, severe thunderstorms, criminal activity, police actions, etc.; basically, any public threat that could quickly escalate in minutes to hours. Populations in areas of quickly escalating fire threat would get early notification giving citizens time to prepare or take action accordingly.

Pursuing a More Balanced and Sustainable Strategy

Unfortunately, there is no single game changing fix to the dilemma Portugal now finds itself in regarding the threat of catastrophic fire. Rather, the solution will demand dozens of strategic improvements made in the next several years and possibly over the next decade. It must be emphasized

that changes to the Portuguese fire system be made in a reasonable and sustainable way that encourages collaboration and maximum participation from all levels of government and the public.

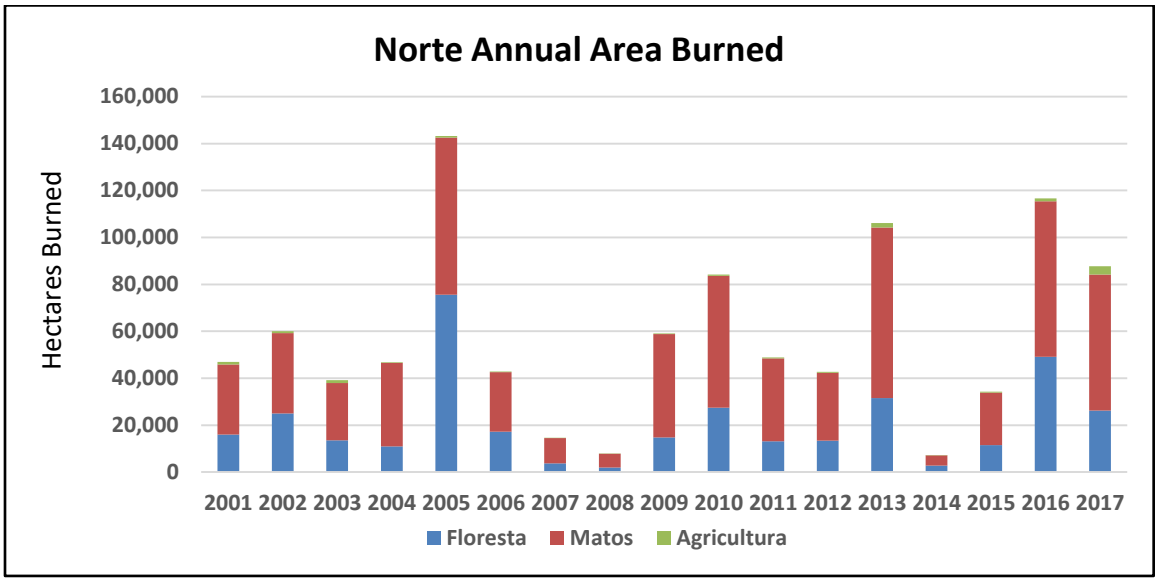
Some years, when Portugal is blessed with a mild, moist summer it will appear that the problem is solved. However, during other years, the heat and drought plagued years with numerous high wind episodes, fire fighting forces will be overwhelmed for short periods of time by fast spreading, intense firestorms. No matter which type of fire year Portugal experiences, it must stay focused on improving the underlying conditions that has put it at higher risk—expansive landscapes of highly flammable fuel and thousands of potential ignition sources.

Igniting prescribed fire in pine understory Photo Credit: Artur Costa

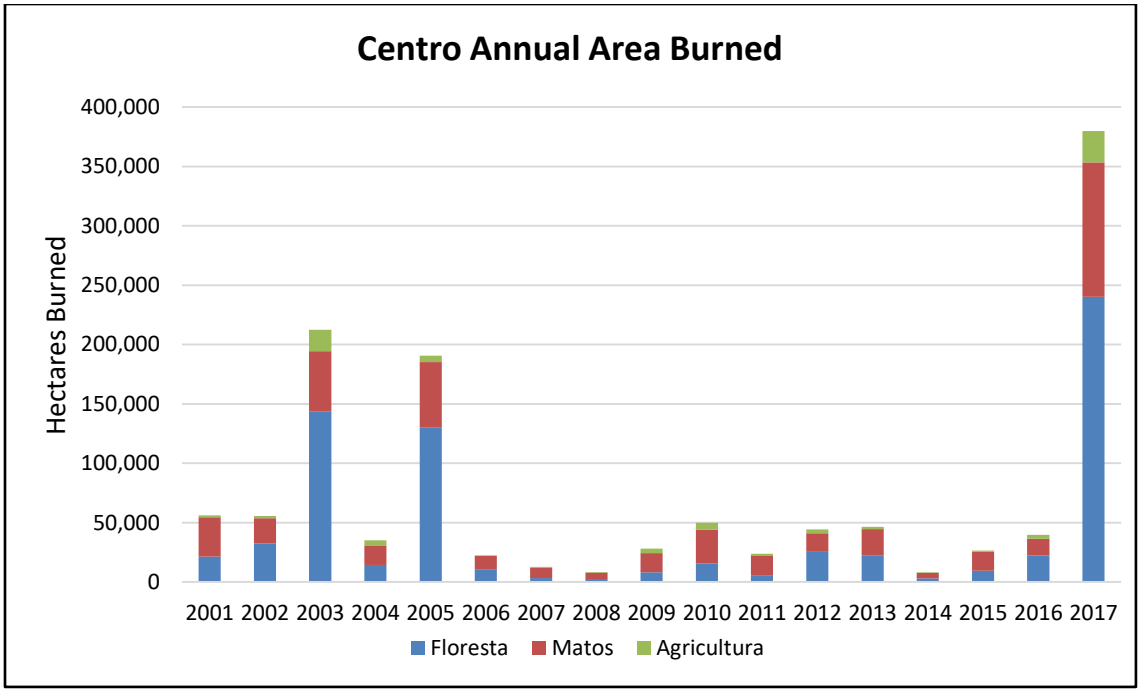
Acknowledgements

This report would not have been possible without the cooperation and support of The Navigator Company who provided travel support and accommodation in Portugal during the onsite interviews and data collection phase. The authors would like to thank those that made time available in their schedules for interviews and who provided data, shared research studies and other information. Special thanks go out to Manuel Rainha and Rui Almeida for scheduling interviews, providing translation and transportation services, and especially for many long and productive conversations.

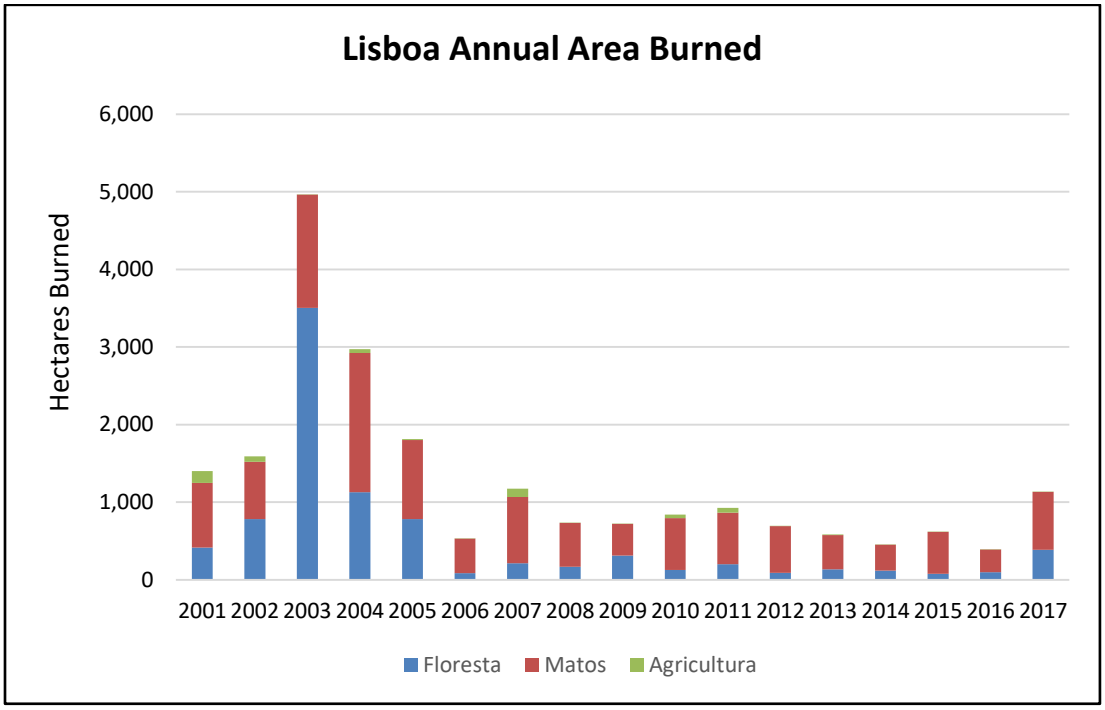
Appendix A Wildfire Area Burned by the Five Regions (NUTS II) and Number of Fires in Portugal by Size of Fire (2001-2017)



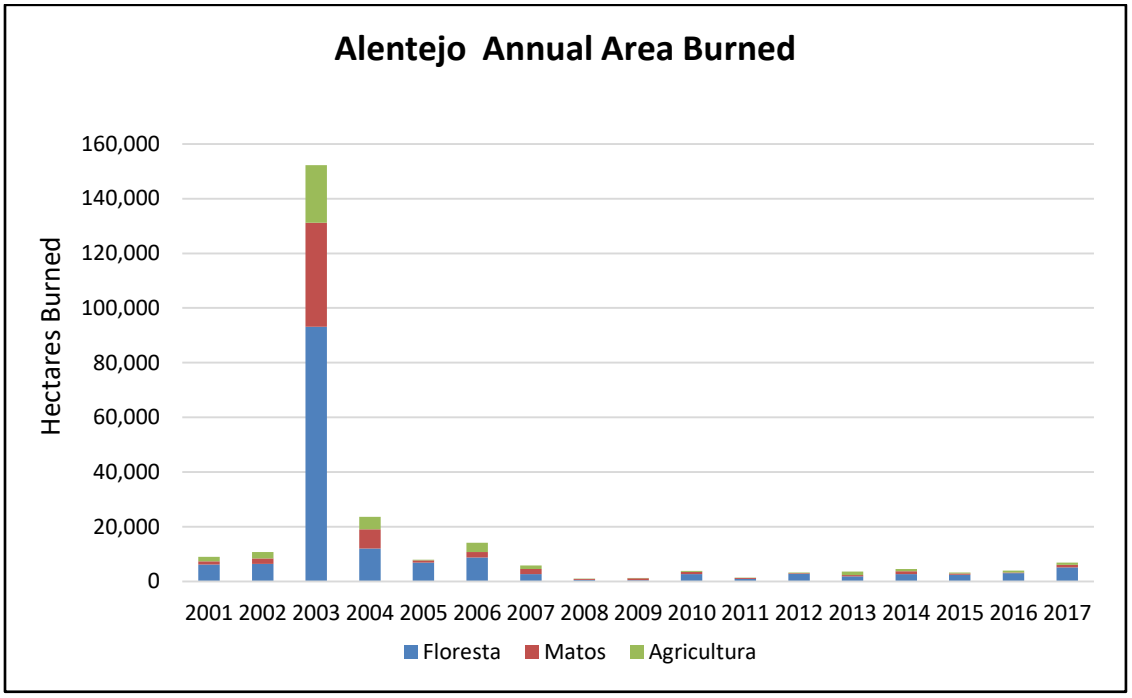
	Floresta	Matos	Agricultura	Total	Pct Flor.	Pct Matos	Pct Agric.
2001	16,035	29,852	1,077	46,964	34%	64%	2%
2002	25,002	34,140	876	60,018	42%	57%	1%
2003	13,467	24,455	1,194	39,117	34%	63%	3%
2004	10,935	35,612	194	46,741	23%	76%	0%
2005	75,621	66,902	742	143,264	53%	47%	1%
2006	17,206	25,390	224	42,821	40%	59%	1%
2007	3,691	10,805	143	14,639	25%	74%	1%
2008	1,961	5,790	42	7,793	25%	74%	1%
2009	14,726	44,043	256	59,025	25%	75%	0%
2010	27,461	56,217	514	84,192	33%	67%	1%
2011	13,147	35,230	416	48,793	27%	72%	1%
2012	13,428	28,836	477	42,741	31%	67%	1%
2013	31,505	72,643	1,968	106,116	30%	68%	2%
2014	2,691	4,400	225	7,315	37%	60%	3%
2015	11,454	22,406	414	34,274	33%	65%	1%
2016	49,050	66,337	1,240	116,626	42%	57%	1%
2017	26,201	57,919	3,646	87,766	30%	66%	4%
Totals	353,581	620,976	13,648	988,205	36%	63%	1%
Annual Mean	20,799	36,528	803	58,130			



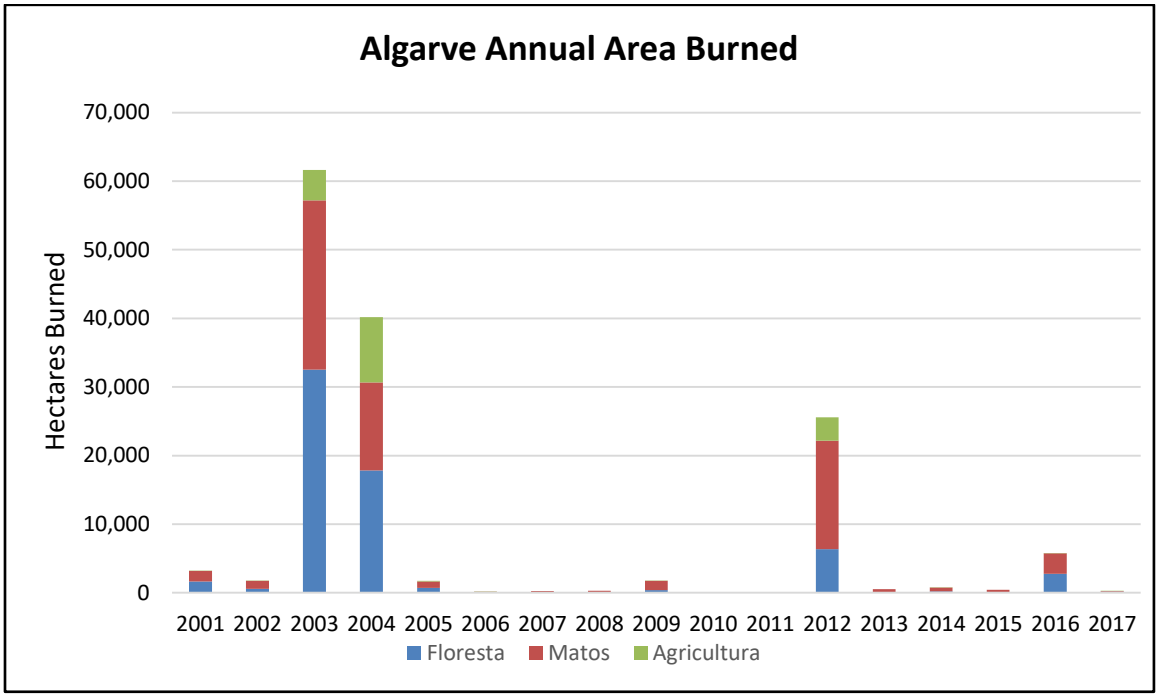
	Floresta	Matos	Agricultura	Total	Pct Flor.	Pct Matos	Pct Agric.
2001	21,331	33,274	1,494	56,100	38%	59%	3%
2002	32,435	21,225	1,907	55,566	58%	38%	3%
2003	143,403	51,082	18,052	212,536	67%	24%	8%
2004	14,293	16,513	4,229	35,034	41%	47%	12%
2005	129,889	55,482	5,273	190,644	68%	29%	3%
2006	10,262	11,691	497	22,449	46%	52%	2%
2007	3,230	8,987	483	12,700	25%	71%	4%
2008	2,615	5,205	720	8,540	31%	61%	8%
2009	8,262	16,160	3,691	28,113	29%	57%	13%
2010	15,782	28,358	5,952	50,092	32%	57%	12%
2011	5,753	16,174	2,013	23,940	24%	68%	8%
2012	25,392	15,729	3,199	44,320	57%	35%	7%
2013	22,110	22,580	1,832	46,522	48%	49%	4%
2014	2,990	4,782	448	8,221	36%	58%	5%
2015	9,571	15,935	992	26,498	36%	60%	4%
2016	22,522	13,851	3,439	39,813	57%	35%	9%
2017	240,148	113,315	26,427	379,890	63%	30%	7%
Total	*709,987*	*450,342*	*80,647*	*1,240,977*	*57%*	*36%*	*7%*
Annual Mean	*41,764*	*26,491*	*4,744*	*72,999*			



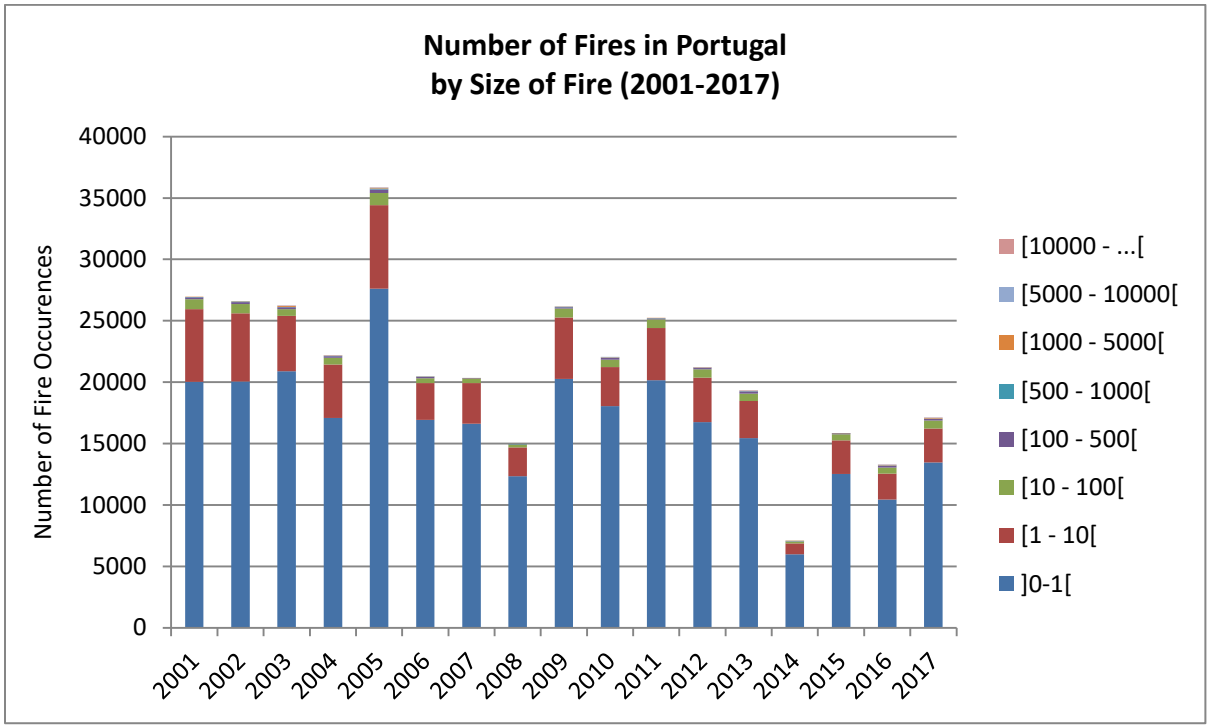
	Floresta	Matos	Agricultura	Total	Pct Flor.	Pct Matos	Pct Agric.
2001	416	833	151	1,400	30%	60%	11%
2002	780	741	70	1,591	49%	47%	4%
2003	3,505	1,457	3	4,965	71%	29%	0%
2004	1,130	1,794	49	2,973	38%	60%	2%
2005	781	1,019	12	1,811	43%	56%	1%
2006	83	446	3	532	16%	84%	1%
2007	213	852	108	1,172	18%	73%	9%
2008	167	567	3	737	23%	77%	0%
2009	313	408	1	722	43%	56%	0%
2010	126	666	46	839	15%	79%	6%
2011	202	661	61	924	22%	72%	7%
2012	87	603	5	696	13%	87%	1%
2013	134	443	6	582	23%	76%	1%
2014	119	335	3	456	26%	73%	1%
2015	78	539	1	618	13%	87%	0%
2016	98	292	0	391	25%	75%	0%
2017	387	747	1	1,135	34%	66%	0%
Totals	*8,618*	*12,405*	*523*	*21,546*	*40%*	*58%*	*2%*
Annual Mean	*507*	*730*	*31*	*1,267*			



	Floresta	Matos	Agricultura	Total	Pct Flor.	Pct Matos	Pct Agric.
2001	6,199	1,117	1,725	9,041	69%	12%	19%
2002	6,377	2,043	2,347	10,768	59%	19%	22%
2003	93,162	38,058	21,071	152,291	61%	25%	14%
2004	12,072	7,036	4,535	23,643	51%	30%	19%
2005	6,912	800	174	7,887	88%	10%	2%
2006	8,760	2,033	3,298	14,090	62%	14%	23%
2007	2,678	1,806	1,394	5,878	46%	31%	24%
2008	606	253	17	876	69%	29%	2%
2009	413	751	123	1,287	32%	58%	10%
2010	2,650	876	367	3,893	68%	23%	9%
2011	910	302	140	1,352	67%	22%	10%
2012	2,745	317	155	3,216	85%	10%	5%
2013	1,889	434	1,307	3,630	52%	12%	36%
2014	2,723	1,053	799	4,575	60%	23%	17%
2015	2,429	522	319	3,270	74%	16%	10%
2016	3,049	239	621	3,910	78%	6%	16%
2017	5,107	966	755	6,828	75%	14%	11%
Totals	*158,680*	*58,607*	*39,147*	*256,435*	*62%*	*23%*	*5%*
Annual Mean	*9,334*	*3,447*	*2,303*	*15,084*			



	Floresta	Matos	Agricultura	Total	Pct Flor.	Pct Matos	Pct Agric.
2001	1,632	1,545	56	3,233	50%	48%	2%
2002	567	1,164	83	1,814	31%	64%	5%
2003	32,515	24,673	4,465	61,654	53%	40%	7%
2004	17,839	12,834	9,489	40,162	44%	32%	24%
2005	713	953	79	1,745	41%	55%	5%
2006	6	173	1	180	3%	96%	1%
2007	3	255	0	258	1%	99%	0%
2008	109	191	0	300	36%	64%	0%
2009	379	1,362	44	1,785	21%	76%	2%
2010	27	78	0	104	26%	74%	0%
2011	19	100	0	119	16%	84%	0%
2012	6,360	15,823	3,409	25,591	25%	62%	13%
2013	18	510	0	528	3%	97%	0%
2014	199	557	9	764	26%	73%	1%
2015	6	420	0	426	1%	99%	0%
2016	2,767	2,966	36	5,769	48%	51%	1%
2017	142	107	6	255	56%	42%	3%
Totals	*63,301*	*63,711*	*17,678*	*144,689*	*44%*	*44%*	*12%*
Annual Mean-	*3,724*	*3,748*	*1,040*	*8,511*			



	Burned	Fire Sizes in Hectares		10-	100-	500-	1000-	5000-	Over	# Fires
	Area Total	Under 1	1 to 10	100	500	1000	5000	10,000	10,000	TOTAL
2001	116,738	20026	5931	805	148	14	23	0	0	26,947
2002	129,757	20046	5573	734	175	30	18	0	0	26,576
2003	470,563	20883	4503	557	149	45	59	14	9	26,219
2004	148,553	17088	4351	552	114	28	29	2	1	22,165
2005	345,351	27620	6796	980	284	79	58	5	1	35,823
2006	80,073	16936	2981	397	101	22	7	1	0	20,445
2007	34,647	16623	3314	338	35	3	3	0	0	20,316
2008	18,245	12332	2353	225	18	2	0	0	0	14,930
2009	90,932	20265	5008	727	111	15	9	1	0	26,136
2010	139,121	18038	3192	608	135	28	26	1	0	22,028
2011	75,129	20163	4254	684	97	18	6	0	0	25,222
2012	116,564	16739	3622	675	116	16	9	1	1	21,179
2013	157,378	15451	3018	603	162	30	27	1	1	19,293
2014	21,332	5990	885	162	26	1	3	0	0	7,067
2015	65,086	12522	2728	503	74	16	8	0	0	15,851
2016	166,509	10438	2108	504	151	31	21	3	1	13,257
2017	475,874	13460	2766	637	146	28	39	7	11	17,094

Appendix B Model for a Progress Report for Rural Fire Management System Improvements: Integrating Program Goals & Performance Objectives & Metrics

Three components of the rural fire program are included in this model covering Ignition Reduction, Structural Fuel Prevention and Fire Suppression. Each component is comprised of an example set of program goals for developing rural fire management capabilities or instituting reforms for a qualitative assessment. Linked to each set of goals are suggested quantitatively measurable performance objectives or metrics. This set of goals and indicators is incomplete and needs to be tailored to measure the elements deemed most important by the responsible government agency.

While this model takes a national perspective, it could be easily adapted to monitor goals and performance objectives at the regional and community levels as well. Also, additional components that are not covered in this appendix but could be developed include: Fire Program Management and Supervision, Fire Management Data & Analytics, Fire Communication and Technology, etc.

Ignition Reduction Program Goals	**Non existent**	**Incomplete/ Unsustainable**	**Complete/ Sustainable**
A program is in place to limit rekindles to less than 3% of fires with a known cause			
An objective of the DECIF is to limit daily ignitions to less than 100			
A system is in place to patrol all fires until they are certified as extinguished			
An anonymous public hotline is available for reporting negligent or suspect fire activities.			
A public education program is in place that features nationally respected celebrities and opinion makers.			
A Reverse 911 public warning system is in place			
Ignition Reduction Core Metrics		***Target***	***Current***
Percentage of fires with a known cause that are rekindles		<3%	17%
Number of days with >100 human caused ignitions nationally			
Percentage of fires certified as extinguished			
Percentage of anonymous hotline calls investigated with action taken			
Number of intentional ignitions during “Critical Season” declaration			
Percentage of fires with a known cause that are arson			

Structural Fuel Prevention Program Goals	***Non existent***	***Incomplete/ Unsustainable***	***Complete/ Sustainable***
A primary fuel break network exists?		X	
Fuel breaks are maintained in functional condition as annually certified by a Technical Forest Officer			
Prescribed fire use is safe, functional, widespread & ecologically beneficial to landscapes			
ZIFs have high member participation in taking collective fuel reduction actions			
Forest Residue Clearing Contributions are collected on commercial timber transactions to supplement the Permanent Forestry Fund			
Forest owners meet fire hazard reduction certification standard and state inspection requirements			
Property ownership records are posted online as public information.			
Forfeiture of abandoned property to state ownership is used for the creation of fuel breaks and reduced hazard landscape tiles (mosaic).			
Structural Fuel Prevention Core Metrics		***Target***	***Current***
Percentage of 130,000 ha primary fuel break system completed and maintained		100%	31%
Hectares prescribed burned with objectives met			
Hectares of fuel reduction accomplished in ZIFs meeting the minimum forest clearing standard			
Hectares of fuels reduction accomplished through commercial harvests meeting the minimum forest cleaning standard.			
Number of buildings surveyed for critical fuel clearance			
Percent of buildings surveyed found in compliance of critical fuel clearance			

Forest Fire Suppression Program Goals	***Non existent***	***Incomplete Unsustainable***	***Complete/ Sustainable***
Perimeter control tactics are executed on every wildfire		X	
Fire line construction means and expertise (hand crews, dozers and tractors) are acquired, trained and positioned			
Tactical aerial supervision means and expertise are acquired and trained			
A National Fire Weather Index (FWI) or similar is used to establish critical decision points for preparedness levels and Critical Season declarations.			
Technical fire specialists are assigned to national and regional coordination centers to provide predictive services.			
Critical watchtower detection sites are staffed with trained, dependable personnel			
First intervention and amplified attack firefighters pass a minimum physical testing requirement			
Incident Command System is used to integrate forest fire and civil protection objectives and means			
Forest Fire Suppression Core Metrics		***Target***	***Current***
Percentage of fires completely contained by a fireline		100%	
Percentage of firefighters trained in perimeter control strategy and tactics			
Percentage of firefighters trained in Incident Command System			
Percentage of firefighters meeting a minimum physical fitness standard			
Number of Technical Fire Specialists assigned to national and regional coordination centers to provide predictive services			
Percentage of large fires using more than 3 aircraft that are assigned an airborne tactical aerial supervisor			
Percentage of large fires (>100 ha) assigned an Incident Technical Fire Specialist			
Percentage of large fires (>100 ha) using ICS to effectively integrate rural and civil protection objectives and means			

Appendix C List of Individuals Interviewed

Municipalities
Carlos Trindade, Mafra Civil Protection and GTF
Paulo Bessa, Penafiel GTF
Jose' Goncalves, Valongo GTF
Miguel Rodrigues, Paredes GTF
Luis Filipe, Mortágua CB and GTF
Ricardo Bismark, Albergaria CB

Forest Associations
Vasco Campos, Caule
Sandra Pinto, Vale Sousa
Luis Sarabando, Baixo Vouga

Government of Portugal
Miguel Freitas, Secretary of Forests and Rural Development
Albino Tavares, ANPC
Miguel Cruz, ANPC
Joaquim Chambel, ANPC
Ribeiro Quelhas, GNR GIPS
Rui Almeida, ICNF
Joao Pinho, ICNF
Joao Moreira, ICNF
Nuno Moreira, IMPA
Tiago Oliviera, Mission Unit SGIFR
Joao Verde, Mission Unit SGIFR
Paulo Mateus, Mission Unit SGIFR
Carlos Dias, Polícia Judiciária

Academics
Paulo Fernandes, University of Trás-os-Montes and Alto Douro
José Miguel Cardoso Pereira, Instituto Superior de Agronomia
Patricia M. Alexandre, Instituto Superior de Agronomia
Carlos Da Camara, University of Lisbon
Domingos Xavier Viegas, University of Coimbra
Miguel Almeida, University of Coimbra
Joaquim Sande Silva, Polytechnic Institute of Coimbra

Private Companies
Manuel Rainha, The Navigator Company
Nuno Neto, The Navigator Company
Miguel Silveira, Altriflorestal
Orlando Ormazabal, Alfocelca
Antonio Salgueiro, Forest Engineering contractor

Non-Government Organizations
Abílio Pereira Pacheco, Institute for Systems and Computer Engineering of Porto
Domingos Patacho, Quercus - National Association for Nature Conservation

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Appendix E Authors

Mark Beighley

Mark Beighley is currently an independent consultant advising public and private sector clients in the areas of wildland fire risk assessment and response capability, strategic planning, and budget and cost analysis.

His U.S. federal government wildland fire management career spans 33 years, beginning as a firefighter in 1975 and ending as the Director of the Office of Wildland Fire (OWFC) in 2008, the highest ranking fire career executive in the Department of the Interior. As National Program Director, he coordinated fire budget and policy development for DOI land management agencies including the BLM, the National Park Service (NPS), the US Fish and Wildlife Service (FWS) and the Bureau of Indian Affairs (BIA).

Prior to serving as Director, OWFC, he held senior management positions within the U.S. Forest Service- as Assistant Director for Fire and Aviation Management and also Assistant Director for Forest Management. Before the Washington DC assignments, Mark was a Regional Fire Use Specialist, District Fire Management Officer, Battalion Chief and Fire Engine Captain.

Since retirement from federal service in 2008, his consulting projects have included:

- Management evaluation of the LANDFIRE fire risk mapping program for the USFS and DOI
- 2009 Quadrennial Fire Review and Report for The Brookings Institution
- Forensic audit and large fire cost review of the 2008 fires in Northern California for the USFS
- Serra da Lousã fuel break network assessment and report for the ICNF, Portugal

He studied at the University of California and has a Bachelor of Science degree from Eastern Oregon University. His contact email is Markbeighley@gmail.com

A.C. Hyde

Dr. Albert C. Hyde is currently a Visiting Professor with the Department of Public Administration at Northern Illinois University. From 1992 to 2009, he was the senior manager for public management consulting services operation of the Brookings Institution's Center for Public Policy Education in Washington D.C. During that period, he directed a series of major strategy projects with the U.S. Forest Service and the Department of the Interior's fire agencies in wildland fire management to include:

- The 2009 and 2005 Quadrennial Fire Reviews
- The 2007 and 2006 Large Fire Cost Reviews
- The 2004 Strategic Issues Panel for Wildfire Cost Containment
- The 2002 Blue Ribbon Panel on Aerial Fire Management Safety
- The 2000-01 Human Capital Study: "Where Have All The Firefighters Gone"

His Academic career includes being Chair of the Public Administration Department at the University of Pittsburgh, Director of the Public Administration Department at San Francisco State University and Director of the Human Resources Management Program at the University of Houston-Clear Lake, He was also a Professor and Scholar in Residence at the American University's in Washington D.C.

His PhD. degree in Political Science is from the State University of New York at Albany, where he also holds an M.P.A. degree in Public Budgeting and a Bachelor's Degree in Medieval History. His contact email is either Ahyde2@niu.edu or Achyde@aol.com.