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UNECE / FAO Team of Specialists
on Forest Fire

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(GMFC)

**Study of the Contemporary and Expected Future Wildland
Fire Problems in the UNECE Region**

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Introduction

The UNECE region has recently experienced a number of unprecedented large and disastrous wildfire episodes as accumulated consequence of socio-economic, land-use and climate changes. Some recent wildfire episodes also revealed an increasing vulnerability of society to direct and secondary effects of fire; e.g. the impacts of fire smoke pollution on human health and security. While there have been advances in fire management in some countries, there are still barriers preventing the sharing of scientific and technical knowledge and good practice between wildfire agencies in different states. These barriers have resulted in some wildfire agencies being unintentionally excluded from the technical information and advancements that they could utilize to develop greater national resilience and preparedness for large wildfire incidents. It is often the lack of resilience of a State to manage its own wildfire situation that results in the need for unplanned international emergency assistance.

Given the cross-boundary consequences of wildfires, e.g. transboundary transport of wildfire smoke pollutants, border-crossing wildfires and the wildfire threats to common global assets such as biodiversity, terrestrial carbon pools, atmosphere and climate on the one side, and the willingness of nations side to share expertise and resources in fire management on the other, UNECE member states could develop voluntary principles and procedures on cross-border cooperation and thus enhance economics, inter-operability and effectiveness in fire management between nations and regions.

In order to allow a coordinated, systematic approach for international cooperation in fire management, the Global Fire Monitoring Center (GFMC) through its coordinated international groups in 2010 began to prepare the convention of the “UNECE/FAO Regional Forum on Cross-boundary Fire Management”. While the scope of the Forum will focused on the Eurasian part of the region, the participation of member states of North America (Canada, U.S.A.) in the preparatory work and by attending the Forum ensure the consideration of expertise from countries that are comparatively advanced in fire management capacity and in the development of cross-border agreements and bilateral protocols and coordinated international operating procedures in fire management.

The main aim of the Forum is to elaborate recommendations to UNECE member states to build resilience of nations and communities within the UNECE region to wildfire emergencies and disasters by enhancing national and collective regional fire management capability through international cooperation.

In 2013 the Global Fire Monitoring Center (GFMC) was tasked with administering the UNECE project entitled *Safeguarding Sustainable Forest Management in the UNECE Region through International Cooperation in Fire Management*. This project will prepare the Forum. As part of the preparatory activities this ‘Study of the contemporary and expected future forest fire problems in the UNECE region that are newly arising from changes in land use, socio-economical conditions and climate’ was commissioned.

This study summarises the current state of affairs in key scientific fields associated with wildland fires and how individual member states and international cooperation has already responded to the increasing threat of wildland fires in the UNECE region. The focus has moved beyond purely forest fires to include ‘wildland’ or ‘vegetation’ fires. These terminologies differ from ‘forest fires’ and ‘wildfires’ in that by using them this study seeks to focus on all types of fire in the landscape – the only notable exception being structural fires. The reason for this is twofold. Firstly, fire in the environment is not confined to the land-use type of forests. Secondly, fire management needs to extend beyond the tired paradigm of a natural disaster that must only be stopped. Fire is an important natural and cultural phenomenon throughout the region – playing a vital role in maintaining ecosystem values and important practical and cultural roles in the highly anthropogenic landscapes of the region.

This study consists of five short chapters intended to paint a picture of the current state of affairs in the region. The study is not intended as an introduction to wildland fire science and management and a certain level of understanding is assumed amongst the member states’ representatives that will deal with it. Likewise this study does not provide an exhaustive list or analysis of issues in every member of the UNECE. Illustrative examples are instead provided with the presumption that the national

experts dealing with vegetation fires or forestry in the UNECE member states will be able to get a picture of the contemporary challenges at the regional scale.

The result complements the proposals distributed to member states by the project organisers for discussion at the project forum in Geneva on 28 and 29 November 2013 (Reports 2 and 3). Additional supporting documentation is provided in Report 4.

In combination, these documents will provide a compelling platform for discussing the regional challenges of wildland fire management as well as a very sound basis for achieving popular resolutions.

This study has been conducted from GFMC headquarters in Freiburg, Germany, and should be regarded as a living document. As part of the project member states have been requested to return a completed questionnaire to the project organisers detailing the ecological, scientific, political and social aspects of wildland fire management in their countries. Such information will build upon what has already been done to provide more powerful future analysis of vegetation fire in the UNECE region.

Executive Summary

The “UNECE/FAO Regional Forum on Cross-boundary Fire Management” is presented with this study of the current state of affairs and future challenges related to wildland fires in the region, as prepared by the Global Fire Monitoring Center (GFMC). When combined with the other documents presented at the forum, member states will be equipped the reasons that further cooperation in this region is desirable and the methods by which such cooperation may be achieved. The present study is divided into five chapters.

Climate Change

Projections of fire activity under conditions of global warming are made up of two components. Firstly, an outlook for the prevalence of fire-conducive weather conditions must be assembled from global climate projection models. Then, this must be applied to the current and predicted patterns of vegetation cover. Such complete models exist for Mediterranean Europe and most of North America, indicating that the coming decades will see substantial increases in the length and intensity of fire seasons, with a shift toward vegetation adapted to a more rapid and intense cycle of wildland fire.

Less complete models exist for Central and Eastern Europe and Eurasia. However, it is apparent from weather projections that hot and dry conditions currently experienced in the Mediterranean latitudes will, in the future, move to these areas. Also, mountainous areas are likely to begin to experience vegetation fire as a new disturbance factor.

The results from existing modeling processes return greatest uncertainty in the high latitudes of North America and Eurasia. This should be considered a vital area of further research due to the great potential for negative effects if fire begins to impact on this carbon dense and fire-sensitive part of the world.

Fire in the Wildland Urban Interface

The meeting point of the established ‘fire worlds’ of vegetation fires and structural fires is currently becoming recognized as an area requiring more scientific and policy attention. This is due to the fact that the vast majority of human and economic losses occur in this region combined with the fact that established fire management policies – from land management to firefighting – do not apply here.

Research is underway in an uncoordinated fashion in Mediterranean Europe and North America, but no comprehensive solutions have yet been achieved. In addition to this, the recognition that vegetation fire smoke may be contributing to thousands of casualties annually within the UNECE

region is cause for wildland fire managers to look beyond the existing paradigm of fire damages when looking for 'solutions' to limit the impact of fire on human populations.

Rural Exodus and Land Abandonment

While other parts of the world continue to battle with land-clearing and deforestation, large parts of the UNECE are experiencing a 're-wilding' of lands previously occupied by cultural institutions such as agriculture. In many regions this has consequences for vegetation fires because of the increased hazard posed by vegetation regenerating on abandoned lands and the declining rural population equipped to deal with this increased threat.

Rural decline and agricultural land abandonment is universally associated with changes in market conditions that make farming and rural life an unattractive option for the local community. In Western and Southern Europe and North America agricultural abandonment is being addressed to some degree by a range of policy measures designed to avoid its occurrence. On the other hand, in the post-communist countries of Eastern Europe and Eurasia, the economic turmoil that led to massive land abandonment has not been left far enough behind for countries in this region to make the same progress.

National Preparedness for Managing Wildland Fire

The management of wildland fire in the UNECE region must always be seen as the responsibility of individual member states. A number of models exist for dividing the responsibilities of fire management between the sectors that influence some facet of wildland fire (i.e. land management, emergency response etc.). However, in many cases a lack of coordination between these sectors results in inefficient and ineffective management of fire, with the result that a great deal of resources are used without producing substantial reduction in exposure of the population and its assets to fire.

A feature of comprehensive wildland fire management systems is effective inter-sectoral cooperation coordinated by a permanent, central body tasked with ensuring these cooperative agreements are achieved, functional and improved.

International Cooperation and Coordination

A logical step toward managing wildland fire as a landscape-scale disturbance is to approach it at the international scale. Fire does not heed to national boundaries any more than to ownership boundaries. As well as this, immense efficiency gains could be achieved; firstly by sharing of information and practiced techniques between countries and; secondly, by providing joint operational capability available to assist in fire emergencies abroad when not in use at home.

For the past 25 years a number of neighbourhood, regional and global efforts have been made to achieve more effective international cooperation. The UNECE member states have the opportunity to build upon these efforts for the benefit of individual countries and the region as a whole.

1. Climate Change and its Effect on Fire in the UNECE Region

Anthropogenic climate change is acting on vegetated ecosystems in a number of ways, including the steady creep of climatic factors that may alter the geographic range of certain plants – generally toward higher latitudes and altitudes (Moritz et al 2012). The impact of these changes on ecosystems is a subject of concern due to the fact that it is unlikely that species will be able to keep pace with the projected geographic changes in their ecological range, and even if some can, then the disparate pace of adaptation will lead to dramatic changes in the local composition of ecosystems, the loss of function and ultimately local or widespread extinction of species (Marlon et al 2009).

These concerns are particularly strong in areas where fire is currently a relevant disturbance factor, and it is widely predicted that in such cases incremental habitat changes will be overshadowed by drastic changes to the disturbance regime, effecting extensive and rapid changes to ecosystems as well as impacting human populations unprepared for dealing with an increase in incidence of wildland fire (Lindner et al 2010, Marlon et al 2009).

In the regions where wildland fire is projected to become more widespread, the mechanisms for a growing fire threat can be divided into two components. Firstly, rapid changes in local environmental conditions leads to increasing mortality of vegetation directly or as a result of stress complexes, providing ample fuel available for combustion (Marlon et al 2009, Krawchuk et al 2009). Secondly, changes to climatic conditions to increase the intensity and duration of severe wildfire weather is highly likely to result in more extensive spread of fires that otherwise would remain small (e.g. Liu et al 2010, Wotton & Stocks 2006). It is also relevant to note that intensified storm activity in many regions is projected to increase the incidence of lightning-ignited fires.

Projections of fire activity in a world with higher atmospheric Carbon Dioxide (CO₂) universally agree on the fact that drastic changes are in store for much of the UNECE region, and indeed, the world. Contrary to the accepted wisdom of previous decades, globally this means increased fire activity in some regions and decreased fire activity in other regions, depending on the interplay between important factors such as temperature, precipitation and likely developments in vegetation cover. For example, many tropical regions are anticipated to experience a reduction in the factors that promote wildland fire (Moritz et al 2012). While not all modelling processes return completely compatible results, there is growing momentum among relevant fire authorities across the UNECE region to both increase the accuracy of projections and begin taking real and practical steps toward understanding and mitigating the impact of climate change on fire regimes in order to reduce the impact upon populations and resources.

Models and Methods of Projection

There are several methods that have been used to estimate the prevalence of fire under future climate scenarios. None of these explicitly aim to determine when and where fires will take place in the future, but rather try to determine the existing relationship between certain environmental variables and fire prevalence and infer future fire prevalence based on projected estimations of these variables.

Climate and weather

In all cases anticipated climate and the weather patterns that may subsequently be expected are central to the projection process. Examples of this include the study by Moriando et al (2006) in which a spatially explicit projection of the Canadian Fire Weather Index (FWI) was created for the Mediterranean region. Similarly, the Keetch-Byram Drought Index (KBDI) was forecast at the global scale by Liu et al (2010). Both of these indices are presently widely used by fire managers in estimating periods of high fire danger and are used to help determine expected fire behaviour. To make predictions of these indices more valuable, most studies consult historical records to determine the historical relationship between these indices and fire activity (e.g. Moreno et al 2013, Girardin & Mudelsee 2008).

Vegetation

Vegetation dynamics are taken into account to varying degrees of complexity. In the study mentioned above, Moriando et al (2006) complemented FWI by using historical and current maps of forest cover in the European Mediterranean countries, however did not attempt to model climate induced forest development. Moritz et al (2012) used historic and current remotely-sensed calculations of Net Primary Production (NPP) in order to estimate fuel loads at a general scale. This step avoids the pitfall encountered by Liu et al (2010) of predicting extremely high fire prevalence in deserts and extremely low fire prevalence based purely on weather variables. However, for projections of fire activity in the distant future (2070-2100) Moritz et al (2012) also abandoned estimates of vegetation dynamics due to uncertainties in vegetation dynamics at the global scale at such time scales.

At a much finer scale, Schumacher and Bugmann (2006) used vegetation dynamics and further ecological variables such as species, vegetation type, slope, aspect and soil properties extensively to model fire activity in the European Alps. The focus on economically-marketable tree species allowed the authors to incorporate a wealth of existing industry data in projecting the likely growth, mortality and migration rates of individual species in response to projected climate changes and hence produce a highly detailed projection of fuel availability over time. Indeed in such a heterogeneous environment as Switzerland details were a requirement for developing a useful outcome.

In more recent years the concept of pyrogeography has begun to be used to describe the distribution of wildland fire more subtly by borrowing heavily from the field of ecology (Bowman et al 2013). Using this, Krawchuk et al (2009) use Global Circulation Models in combination with a breadth of variables affecting the occurrence of wildfire to create projections of wildfire at the global scale. The wide range of variables used in this approach may provide projections of fire with greater regional refinement by better considering the complex nature of interactions between environmental factors that influence wildland fire.

Regional Findings

Considering the breadth of results and uncertainties obtained from various projections, results for various regions in the UNECE region that are most recent and most in agreement are presented by region in the remainder of this chapter.

North America

Internationally, the region that has been the subject of the most scientific attention regarding this topic has been North America. This seems to be largely because both the United States and Canada are currently highly fire prone environments with a wildland fire problem that appears to be increasing rapidly. Climate change has been teased out as potentially a great contributor to this increasing problem, compounding the results of management and development.

Studies strongly indicate that although the wildland fire response to climate change will be far from uniform across North America, the overall trend will be toward a large increase in fire-conductive conditions, resulting in large increases in wildland fire frequency and area burned as this century progresses (Krawchuk et al 2009). Increased and intensified droughts are likely to trigger a chain of events including insect- and drought stress-induced mortality, wildfire and soil erosion (Vose et al 2012).

United States – mainland states

According to a recent study commissioned by the United States Department of Agriculture (USDA), the prevalence of wildfires will increase by at least 100% across the country, with some regions expected to encounter burned area increases of up to 500% of recent averages (Vose et al 2012). In most forested ecosystems of the United States, the projection of increased fire activity is related to tree mortality resulting from the tandem pressures of drought stress and insect attack. Regionally, this is driven also by invasive plants in the southern states and Hawaii, increased spring precipitation and

primary productivity in the southwest and extensive habitat displacement in the northwest (Vose et al 2012).

Liu et al (2010) came to similar conclusions for the mainland United States without specifically considering the extant and expected vegetation. The anticipated Keetch-Byram Drought Index (KBDI) indicates that areas currently experiencing periods of 'Moderate' and 'High' fire danger will experience these for longer – i.e. longer fire seasons. Assuming that a fire danger reaching 'Moderate' signifies the fire season, the fire season is expected to increase from six months to 12 months in the southwest United States and from four to seven months in the southeast.

In applying the principles of pyrogeography, Krawchuk et al (2009) project a marked increase across the United States and southern Canada in conditions conducive to wildland fire, particularly when taking into account the projected influence of climate change on vegetation dynamics.

Assessing multiple climate models and their impact on vegetation fire drivers, Moritz et al (2012) break down anticipated wildland fire activity by vegetation type. Their findings indicate that many vegetation types in the area covering the United States are widely predicted to experienced increased vegetation fires, primarily 'montane grasslands and shrublands', 'temperate coniferous forests' and 'temperate grasslands/savannas/shrublands'.

Northern temperate-boreal USA and Canada

Moving further north, the temperate and boreal forests of Canada and Alaska are predicted to experience a great deal more fire than currently under conditions of increased CO₂. A wide range of projection techniques have led various authors and government bodies to broadly similar conclusions (e.g. CFWS 2005, 2010). Girardin and Mudelsee (2008) established the historical and projected relationship between droughts and fire events and concluded that within the coming century, fire occurrence would be highly likely to surpass any patterns reconstructed from the past.

Projections published by Krawchuk et al (2009) and Moritz et al (2012) both show broadly similar trends, with northern North America among the regions with globally the highest agreement in the scale and timing of anticipated changes in fire weather.

In articles specific to Canada's forest resources, Flannigan et al (2009) and Wotton and Stocks (2006) predict an increase of between 50% and 125% before the end of the 21st century. This is due to the influence of a range of factors, including a fire season lengthened by 30 days, a greater chance of atmospheric blocking patterns associated with dry spells and an increase in the occurrence of lightning storms.

Peatlands / non-forest

Beyond the areas already experiencing extensive fire activity, fire conditions are also expected to threaten ecosystems not currently tolerant or adapted to fire. Peat and swamp ecosystems are predicted to dry out severely due to climatic changes, which may push them beyond the threshold that has historically limited extensive combustion (Flannigan et al 2009). The likelihood of this is still subject to debate, because models don't tend to agree as readily in these extreme northerly areas. It seems that while fire weather is very likely to become more conducive to burning, the uncertainty remains in how the vegetation may react to both climatic change and how similar it is likely to behave to more familiar forest fuels (Moritz et al 2012, Krawchuk et al 2009). The effect on these areas is, however, very important due to the extremely carbon-dense nature of peat landscapes and the unique way in which peat fuels can continue to burn for many weeks or even months (Flannigan et al 2009).

Russia

From one boreal landscape to another – by area the majority of boreal, tundra and peatland ecosystems are situated across Russia. These ecosystems were also found by Moritz et al (2012) to be region of greatest agreement between of climatic projection models. However, other studies don't consider latitudes above about 45°, and some studies that have considered this region return mixed results (e.g. Liu et al 2010, Lindner et al 2010).

Using the principles of pyrogeography to project fire occurrence indicates the likelihood of an increasing prevalence of wildland fire in a sweep of land from Mongolia to Ukraine and decreasing fire prevalence at higher latitudes – toward the tundra and peat landscapes (Krawchuk et al 2009). However, the same study predicts vast increases in fire weather at these very high latitudes (admittedly from a low starting point), which would indicate that again the models have difficulty determining the course of the vegetation element. Also, both Moritz et al (2012) and Flannigan et al (2009) note that peat, Taiga and Tundra landscapes are poorly understood in their present fire ecology, let alone that predicted by modelling processes. Referring again to the issues of high carbon density and fragility of these landscapes, future studies are recommended to avoid overlooking the issue of fire in extreme northern environments

Throughout this region steppe landscapes form a conspicuous gap in the literature, probably because they are not generally seen as important either for wood production, grazing or carbon storage. However, the vast areas of steppe stretching from eastern Russia to Eastern Europe are highly active fire landscapes bordering on the forests, peatlands and communities that are otherwise considered important. While not specifically referring to wildfire, the steppe regions of Ukraine and Belarus are expected to experience more severe drought in decades to come, which may lead to increased fire activity (Krawchuk et al 2009).

Europe

Mediterranean

The Mediterranean countries of the UNECE already suffer from severe wildland fire challenges and this is likely to increase in coming years due to extended dry periods and extended and intensified heat waves (Moreno et al 2013, Moreira et al 2011, Lindner et al 2010). Liu et al (2010) expect the average annual fire danger to increase from 'Low' to 'Moderate' according to the Keetch-Byram Drought Index and the fire season to extend to six months. Moriando et al (2006) and Krawchuk et al (2009) anticipate France and northern Spain will experience the most dramatic increases in conditions conducive to rapidly spreading fires.

Inland areas of Mediterranean countries are expected to experience a much more dramatic rise in temperatures, dry periods and subsequently fires in the next few decades. However, following this period, the increased mortality of extant species and intensified droughts are expected to seriously limit plant primary production, and thus limit the fuel available to fan extensive wildfires (Moreno et al 2013, Beniston et al 2007).

Alpine / montane areas

Due to the fact that alpine and montane areas are geographically entwined in the Mediterranean zone, a number of authors have included these fire-inactive areas along with their priority study areas. While not generally the focus of these studies, the findings for these areas are quite telling for the true nature of the development of fire in parallel with climate change. The Pyrenees, European Alps and other temperate mountainous environments are currently considered to be almost void of fire activity (Lindner et al 2010 and Schumacher and Bergmann 2006). However, studies have shown that these regions are highly likely to experience wildland fire as a novel disturbance in decades to come, with potentially drastic impacts on ecosystem function (Moriando et al 2006).

Central and Eastern Europe

While non-Mediterranean Europe is conspicuously absent as a subject of wildfire research, there are some conclusions that can be drawn from the literature that does exist. Moritz et al (2012) found that most models agree that landscape types dominant from European Russia to the British Isles, including 'temperate coniferous forests', 'temperate grasslands' and 'montane environments' will experience a great increase in fire activity in decades to come. Likewise, a visual inspection of the global map created by Krawchuk et al (2009) indicates that central and Eastern Europe will actually become 'hotspots' of future fire activity (Figure 1).

Clues toward the future fire scenario in this region can be pieced together from the evidence provided by Moreno et al (2013), Moreira et al (2011) and Moriondo et al (2006). All these authors and many more predict future fire activity by using the likelihood of periods of hot and dry weather as a proxy for future fire activity. Few projections are informed by ignition sources and vegetation is not always included either.

In a study not specifically related to wildfires, Beniston et al (2007) intend to summarise the effect of climate change on extreme weather situations in Europe. The focus is strongly centred on heat waves with the direct impact of heat on the human population as the incentive for research. The findings indicate that there will be a dramatic shift in European climate in such a way that the summer climatic zones will move 400-500km north. It is anticipated, for example, that France and Hungary will experience as many days and spells over 30°C as Sicily and southern Spain experience today. The diagrams published by Beniston et al (2007) indicates that Eastern Europe, including Poland, Belarus, Ukraine and Romania, is a region that will experience a particularly dramatic increase in heat wave number, frequency and intensity. Figure 2 is an example of this published data. In relation to studies linking fire activity with extreme heat and drought events, there appears to be enough evidence to start seriously considering wildland fire linked to climate change as a real threat in central and northern Europe.

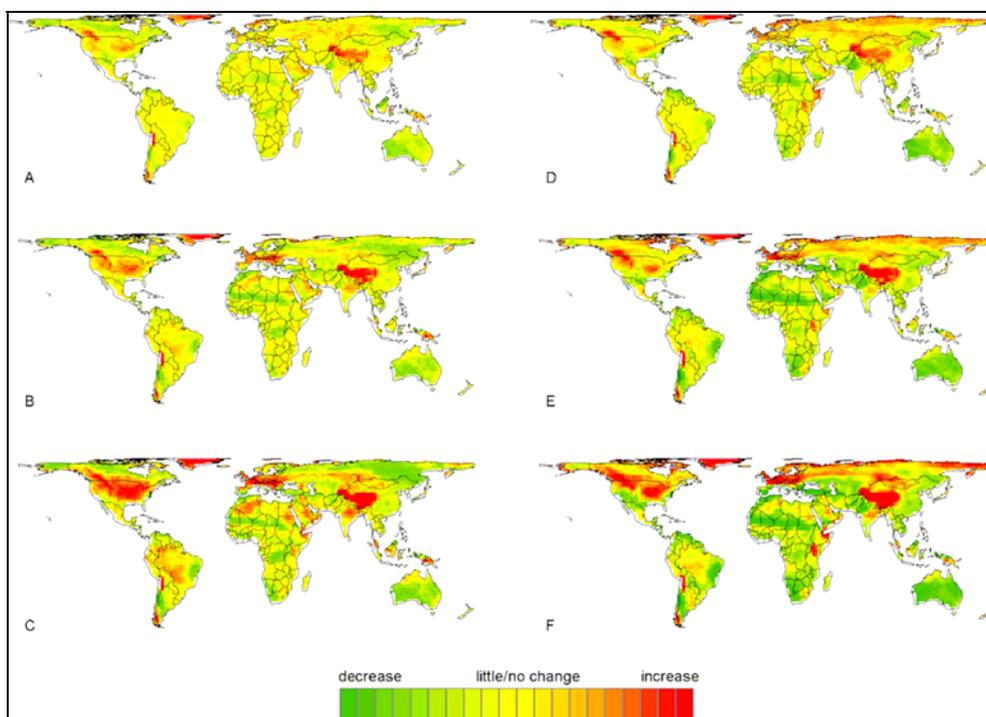
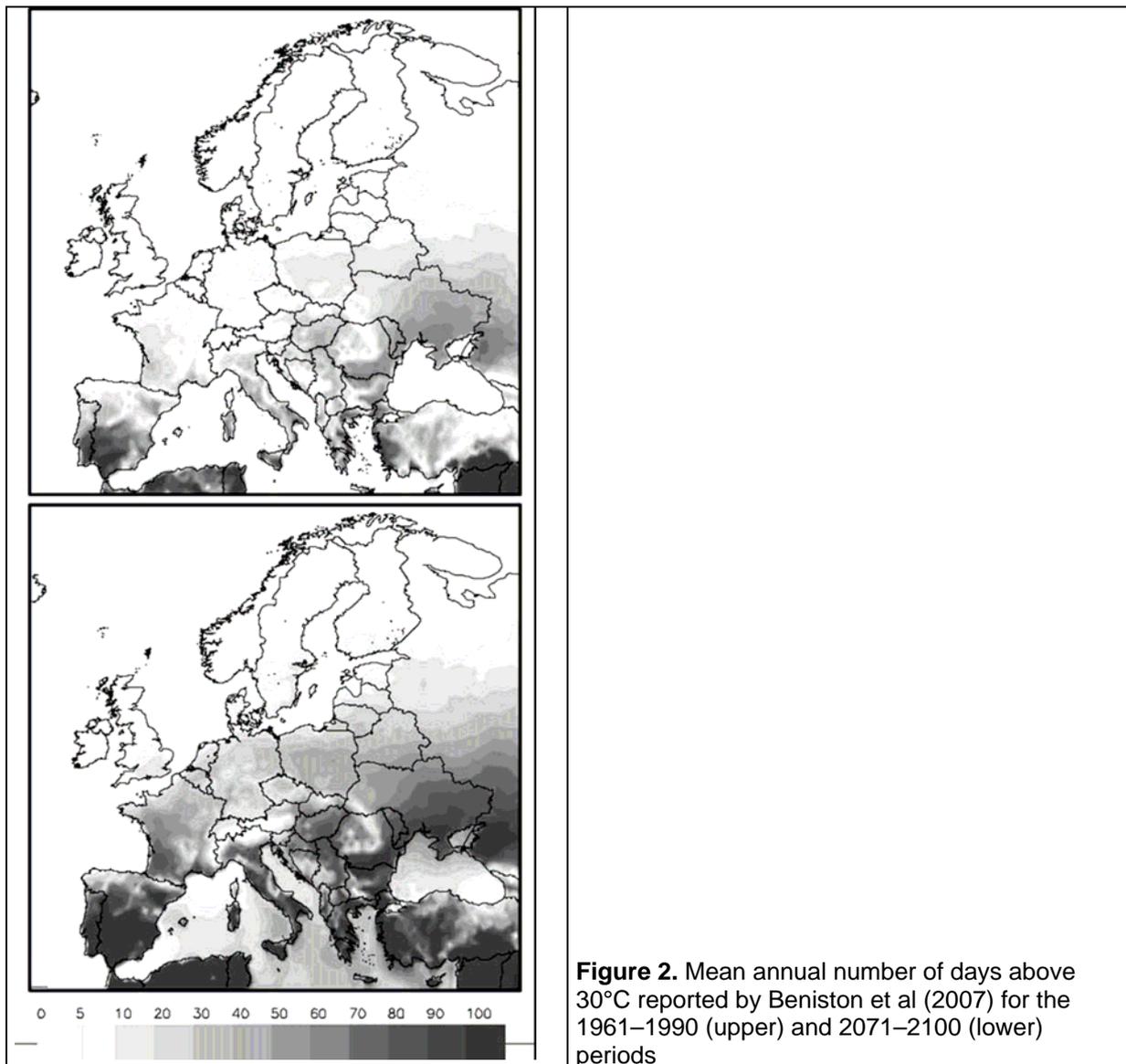


Figure 1. Changes in the global distribution of fire-prone pixels under the A2 (mid high) emissions scenario. An increase from current conditions (red) is indicated by a PD greater than unity, little or no change (yellow) is indicated by a PD around unit, and a decrease (green) is indicated by a PD less than unity. Panels show the mean PD for the ensemble of ten FIRENPP (A–C) and FIREnoNPP (D–F) sub-models. Climate projections include 2010–2039 (A, D), 2040–2069 (B, E) and 2070–2099 (C, F). Source: Krawchuk et al. (2009).



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2. Fires at the Wildland-Urban Interface

The cost, and by extension, the relevance of wildland fire to human populations is measured firstly in the lives lost and damaged by wildfire, and secondly by the economic impact of fire on individuals, communities and nations. This anthropocentric perspective view of fire is partly justified by the relative ease with which such losses can be measured in comparison to perceived damages to natural landscapes and ecosystem values or services.

Large fires burning through vegetated landscapes do result in tangible economic damages, particularly when merchantable timber is lost or watersheds are severely damaged, but the greatest costs resulting from wildfires occur when fire crosses the brink between vegetated lands and those occupied by people. The houses and infrastructure, not to mention the physical and mental health of inhabitants, are the costs that remain evident to us and are the primary inspiration for all attempts to limit the extent of wildfires.

The term 'Wildland-Urban Interface' (WUI) is one that refers generally to the point at which natural (or at least vegetated) landscapes meet the built environment. In practice this has generally been refined to mean the residential environment to exclude managed vegetation and other commercial activities (Lampin-Maillet et al 2010, Radeloff et al 2005). The term is related to a range of environmental science disciplines, but in practice has been almost exclusively used in relation to wildland fire for many years now (Lampin-Maillet et al 2009).

The presence of an interface between people and vegetation stems from different influences in different contexts. In large parts of Western Europe and North America the freedom to build a dream home amongst natural surroundings is strongly appealing, and the resources are widely available to the middle classes to enable this, even to the point that large tracts of WUI lands are holiday homes built for only seasonal occupation (Syphard et al 2007, Butler 1976).

In some regions, such as southern France, the decline and subdivision of agricultural lands to create a mix of urban development and regenerating fields has dramatically changed landscapes that were previously characterised by a sharp contrast between the urban and agricultural environments (Herrero-Corral et al 2012, Moreira et al 2011, Lampin-Maillet et al 2010). In stark contrast, a high proportion of the population living directly from the land through small-scale agriculture keeps huge numbers of people living in areas that could be classified as WUI in Southern and Eastern Europe and across Eurasia (Moreira et al 2011).

Identification of the WUI as a particular field of fire research only occurred in the late 1990s, although it had been identified as a problem landscape type in California as early as 1976. Until the mid-2000s fire in the WUI remained a 'shadow' between the established worlds of forest fires and urban fires. In the words of Butler (1976);

"There is no compelling reason why foresters should be required to study the ASTM (American Society for Testing and Materials) tests for fire resistance of timber beams... By the same token, the fire engineer who is active in the application of fire codes to building materials will find very little use for a detailed knowledge of the packing ratio on fire spread in pine needle duff."

Thus for many years effort was targeted toward the general measures that could be taken by residents to protect themselves against a future forest fire. Campaigns such as FireWise (USA) and FireSmart (Canada) were developed to provide residents with the information they require in order to address the risk of fire impacting upon themselves and their property by creating a defensible space directly around their homes (Gorte 2013). However, due to the fact that anything less than total compliance severely decreases the effectiveness of such actions, as well as the difficulty of enforcing legally-binding regulations, such programs are considered to be of limited success. Heavy losses have continued to occur despite increasing uptake of home defence activities (Gorte 2013).

These continuing losses, combined with the higher cost of preventing and suppressing WUI fires and the prediction that WUI areas will proliferate in coming years drives continued research into WUI fires (Gorte 2013, Maranghides et al 2012). More specific research questions aim to eventually feed in to concrete standards guiding individuals, municipalities and urban planners (Herrero-Corral 2011,

Pellegrino et al 2013). Internationally, the research efforts are minimally coordinated, with various teams targeting different elements of the problem as well as approaching comparable issues using different methods.

In the European sphere, dramatic losses of life and property in a number of fire events in the early-2000s resulted in heightened interest in Wildland/Urban wildfire – a great deal of which was presented at the *Wildland-Urban Area Fire Risk Management (WARM)* international workshop in Greece, 2003 (Xanthopoulos 2003). Later, a number of projects dealt with this topic by collaborating through the Fire Paradox Project to adapt and develop WUI-mapping methods for regional contexts (Lampin-Maillet et al 2010a).

In a recent government-commissioned report, the United States National Institute of Standards and Technology (NIST) identified four main streams of research demanded by scientists and policy makers related to fire in the WUI (Pellegrino et al 2013). Namely these are; exposure quantification, development of fire-resistant materials and design, suppression response and post-fire data recovery. While the global WUI fire science community does not uniformly use these particular titles, the bulk of recent research can be categorised using these themes.

Exposure quantification

The Wildland-Urban Interface is often discussed as if it is a clearly defined region in which suburbs meet forests. However, the situation is not quite so simple due to the endless variety of housing and vegetation arrangements and types which must be combined with topographic and climatic data in order to construct a spatially explicit WUI hazard index (e.g. Lampin-Maillet et al 2010a, Syphard et al 2007).

US American publications for both California and the entire country use a system comprised of two levels of WUI – *interface* and *intermix* WUI. Each is defined using a classification system that combines housing and vegetation density and connectedness with the distances between these identifiable ‘patches’ (Syphard et al 2007, Radeloff et al 2005).

In France, the existence of municipal laws governing the clearing distances required by residents was used as guidance for developing the scientific definitions (Lampin-Maillet et al 2010, 2010a). On top of that, input was sought from urban fire experts in relation to the maximum number of structures and the distance between these structures that could effectively be tackled by typical responding firefighting teams. This resulted in a classification scheme of up to 12 different ‘vegetation x urbanisation’ categories based on four levels of housing arrangement and three levels of vegetation aggregation (Lampin-Maillet et al 2009, 2010).

Retro-examination of the housing densities that were divided into the various ‘levels’ of WUI confirmed that the higher overall housing density and lack of vast, uninhabited areas in France compared to the United States justified the development of a regionally-specific classification scheme that was different to existing schema used in the American context (Lampin-Maillet et al 2009).

Results from studies in France have been developed to form the basis of commercial software known as *WUImap*, which is able to use cadastral, aerial photo and vegetation data to automatically classify WUI types (Cemagref 2010). Current efforts are being made to extend WUI mapping beyond the static vegetation and urban variables influencing the models described here. Addition of dynamic climate and weather data would allow more meaningful prevention and preparedness activities to be carried out with the greatest spatial and temporal effectiveness. A rudimentary description of this by Lampin-Maillet et al (2010a) suggests using the Canadian FWI scheme in order to achieve this.

Studies in Spain have taken this one step further. As well as modifying the *WUImap* classification scheme to better suit the local conditions according to expert opinion, the Spanish scheme combines each ‘vegetation x urbanisation’ category with fire ignition and burned area data in order to identify 7 distinct and dominant ‘scenarios’ of WUI in the study region west of Madrid. Taking the classification to this step allows the science and management communities to identify the specific weaknesses of particular areas without the burden of highly specific classification (Herrero-Corral et al 2012).

It is yet to be seen whether a universal definition for WUI is possible or desirable, as the situations in which WUI exists vary hugely. It is likely that the scientific community will continue to converge toward a general system for classifying Wildland Urban Interfaces while refining local variations on the system in order to account for dominant local development and landscape trends.

To the present day, only the USA has an actual estimate of what proportion of the entire country falls under the banner of WUI. Using the two definitions of WUI (*interface* and *intermix* WUI), Radeloff et al (2005) found that 9.4% of the land area and 38.5% of the population of the lower 48 US American states lie in WUI areas. According to Gorte (2013), this area represents only 16% of private land that is within fires reach of forested land and is readily available for further development – indicating that massive expansion of the WUI is possible.

Among the European cases, the region between Aix en Provence and Marseilles was found to be comprised of 30% WUI by land area, including 56% of residential structures (Lampin-Maillet et al 2010). The Herrero-Corral (2011) study west of Madrid went down a different road. In this case the entire region was classified as some form of WUI, thus highlighting that this scientific field is not at the point where direct comparisons are particularly informative.

An insightful result from WUI / wildfire studies is the ability to distinguish between different forms of WUI to identify the residential patterns that coincide with heightened fire prevalence or hazard. This thread is developed by Syphard et al (2007) in a detailed study of California, which included the recorded prevalence of fire within the different types of WUI. The study found that intermediate-density WUI experiences more fires and greater burned area than either remote areas or high-density WUI. This is due to the fact that humans are most often the cause of wildland fires – in this case resulting in a feedback in which human settlements are the greatest villain and victim of wildfire damages.

Comparable conclusions have been reached in French and Spanish studies such as Lampin-Maillet et al (2010) and Herrero-Corral et al (2012). In the French Riviera as well as near Madrid, intermediate levels of urbanisation recorded the highest incidence of fire and often the highest burned area. This reinforces the findings from California that the gradient of urbanisation intensity results in a peak of fire activity at an intermediate population density, where there are high ignitions due to human activity, low chances of early fire detection, slow response of fire suppression forces and highly connected vegetation – allowing unhindered fire spread (Moreira et al 2011).

Despite the higher prevalence of fire in areas of intermediate population density, it was universally found that the greatest threat to individuals is posed to remote dwellings due to the lack detection and suppression infrastructure and the much higher burden placed upon the resident to maintain a defensible space of a certain distance around the property (Lampin-Maillet et al 2010, Syphard et al 2007).

An approach that has not seen development in the UNECE countries is one that forms that basis of WUI mapping techniques in Australia. This focuses purely on large-scale losses of property during extremely damaging fire events, such as in Victoria 2009 and Hobart 1967 (Chen & McAneney 2010). The results of this show a fairly consistent reduction in the likelihood of damage with increasing distance from the vegetated edge, regardless of vegetation type or housing arrangement (Chen & McAneney 2010). In some parts of North America and the Mediterranean it may be suitable to focus specifically on these extreme events, but this is probably not necessary for most parts of the UNECE.

Fire resistant materials and design

In the eyes of some authors, the true Wildland-Urban Interface cannot be found on a map, but rather on the blueprints of the buildings within the range of flying embers from nearby vegetation (Manzello 2013, Manzello & Foote 2012, Butler 1976). From this perspective WUI fire must be broken down and “...*pragmatically viewed as a structure ignition problem*” (Manzello 2013). This perspective is based on a typical sequence of events in devastating WUI fires identified by Manzello (2013) and Chen & McAneney (2010) whereby a vegetation fire spreads to the few poorly-prepared properties in an area, subsequently overwhelming the urban firefighters on the scene. Fire is then able to spread to the less vulnerable structures due to prolonged flame or ember contact.

Although post-fire evidence is fundamentally lacking for burnt structures, the design, materials and exposure to flames and embers are factors that require much more detailed analysis to identify the specific risk factors a building is exposed to (Maranghides et al 2012). Maranghides et al (2012) point to factors that have proven to be highly influential in their study areas in Texas, such as the presence of Buffalo Grass around the structure, and a type of construction known as 'pier and beam', which allows dead vegetation to blow under a house – providing ample fuel directly contacting the flammable structure.

As well as identifying such weaknesses, research by Manzello & Foote (2012) led to the conclusion that real-life ember and flame attack can be reliably simulated with existing wildfire research infrastructure, indicating that rigorous and standardised building material and geometry assessment is well within our reach.

Dating back to 1976, Butler described building characteristics as fundamental to WUI research – a conclusion also reached by an expert panel of scientists, planners and insurers reported by Pellegrino et al (2013). Recognition of fire-prone zones is becoming increasingly prevalent, with initiatives such as the Fire Prevention Fee in California (CAL FIRE 2013) and requisite cleared areas in France (Lampin-Maillet et al 2010). However there is rarely a coherent link between the zoning of a region and the fire-preventative measures and standards that residents must adhere to (Pellegrino et al 2013).

Development of this scientific field could lead to recommendations that would enable residents to invest in the most effective risk-reduction strategies for their property and allow legislators, developers and insurers to develop standards which must be adhered to before development rights or insurance can be granted. These types of actions must be grounded with a scientific background and could prove hugely effective in limiting the damage caused by WUI fires and the costs associated with fighting them (Gorte 2013, Pellegrino et al 2013).

Suppression Response

The WUI is widely recognised as a 'shadow' between the established fire spheres of forests and buildings, and as such, the emergency response capability to wildfires affecting the WUI remains divided between these camps. Pellegrino et al (2013) conclude that the limited capability merely points to the fact that specialised tactics in these landscapes are lacking. The only suggestion tabled is that individual fire crews be expanded to be able to deal with more buildings simultaneously to stop the building-to-building fire spread that results in the most widespread damage once a fire has entered an urban area. This can easily be seen to draw parallels with the findings of Manzello & Foote (2012), which indicate that multiple structural fires lead to an overwhelmed urban firefighting force.

Post-fire data recovery

Theoretically, the heart of efforts to understand the specific vulnerabilities of the Wildland-Urban Interface is the consistent gathering of information in the post-fire environment. However, this is a field which has thus far been largely lacking due to the more immediately demanding tasks of assessing the damage and mitigating the human toll taken by damaging wildfire events (Maranghides et al 2012). A further constraint to collecting useable data after a fire is the inherent lack of evidence of the 'before' state of affairs, especially the fine details of building and vegetation types and the state of maintenance of each. These fine details are highly informative because the state of maintenance of vegetation and buildings are vitally important to their fire resistant properties (Manzello 2013).

The Australian example mentioned previously gets around a lack of on-the-ground data collection by comparing readily available aerial photographs, although this only gives a certain amount of detail (Chen & McAneney 2010). On the other hand, thorough post-fire evaluation allowed Manzello & Foote (2012) and Maranghides et al (2013) to develop empirical data relating to, respectively, the characteristics of ember showers and common features of houses that are or are not destroyed in wildfires.

Fire Smoke and Human Health

The human cost of wildfires is usually counted in the casualties falling victim to the flames, heat or smoke of a fire at close-quarters. In these cases it is obvious that the direct impact of fire has led to injury or death. However, at a much broader scale, a high number of people impacted upon smoke from all types of vegetation fires are not generally considered as direct victims of wildland fire damage.

It has been known for many decades that smoke and other fine particles are deadly given sufficient exposure. Regulations for vehicle emissions, home heating and tobacco consumption across the world are proof of this knowledge. Vegetation fire smoke is no different. It contains large quantities of the small particles (<2.5µm) which enter deep into the lungs, causing and aggravating respiratory and cardio illness. As well as the acute effects of these compounds, consistent exposure to vegetation fire smoke can lead to chronic illness and eventually premature death (Schwela et al 1999, NRDC 2013).

Wildland fire smoke pollution episodes across South East Asia in 1997/8 instigated the World Health Organisation (WHO) to assemble a task force and draft the *Health Guidelines for Vegetation Fire Events* (Schwela et al 1999). This document urges governments to recognise the fact that smoke episodes are a very real public health issue, with responsibility for limiting the damage falling on a range of sectors, including land managers and law enforcement, agencies dealing with public information and, naturally, the health system. Guidelines are provided for strategies that may be employed in each of these areas.

However, the true scope of the issue remains an area of great uncertainty. Single fire events in Greece (1998), California (2003) and European Russia (2010) have resulted in estimates based on a number of averaged casualty metrics. Results report locally-elevated death tolls of, respectively, 50-90%, 69, and 'hundreds' in these cases (Statheropoulos 2013, Knowlten et al 2011, Goldammer 2010).

The dispersed nature of wildland fire smoke and the fact that it may be one of many concurrent contributors to poor health lead to such uncertainty. In a recent attempt to account fully for long-term, though acute, exposure to smoke episodes Johnston et al (2012) report that around 339 000 deaths annually can be attributed largely to the effects of 'landscape fire smoke', with many more health problems contributing to the human and economic costs.

The vast majority of these modelled fatalities occur in Sub-Saharan Africa and South East Asia, and the number is currently impossible to verify. However, given the potential scope of the issue and its infant stage of research, it is an issue that must be addressed in one way or another by the UNECE region and the global community.

Conclusions

The recognition of the Wildland-Urban Interface as the epicentre of wildfire catastrophes in anthropocentric terms has developed in the last 15 years and is fast becoming a highly recognised scientific and social topic, particularly in light of increasing damages and casualties resulting from wildfire events. The scientific and policy communities are beginning to undertake real dialogue in order to identify the bounds of our knowledge on various aspects of WUI fire and strive to find the most effective means of damage and cost reduction.

The greatest future challenges will be for municipal, state and federal governments and the insurance industry to communicate the results of this dialogue to WUI communities in order to raise awareness of the true costs and risks of living in fire-prone WUI areas. This must result in greater regulation of the development and maintenance of WUI communities if emergency services are to have any hope of reducing the currently unacceptable risk for the public posed by wildfire on the urban fringes.

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3. Rural Exodus

Contrary to land-clearing and deforesting trends in many parts of the world, large tracts of the UNECE region are experiencing land-use change that is moving in the direction of increasing vegetation cover and density, particularly by changing the nature of agricultural lands.

In most cases forested land was converted to agriculture over the past centuries, so abandonment is followed by a succession toward higher biomass environments such as shrublands and eventually forests (Moreira et al 2011).

Increased biomass naturally leads to increased fire hazard, especially in the early succession period following abandonment due to the abundance of fine, connected fuel types. At a landscape scale abandonment is often associated with a vegetation homogenising effect, which enables ignitions to grow to large fires more readily than in the heterogeneous agricultural landscape that has been succeeded. This is more of an issue in regions where fire is already prevalent, but cannot be ignored in other regions due to the likelihood that fire will become more prevalent in many parts of the UNECE region (see Chapter 1).

Few case studies specifically make the link between agricultural abandonment and fire, but their findings can reasonably lead to inferences for regions where agricultural abandonment is of interest for social and economic reasons. In southern European Russia, the cessation of grazing in grasslands shortly after the dissolution of the Soviet Union is linked with an increase in fire prevalence (Dubinin et al 2011). These results can reasonably be assumed to hold true across bioclimatically similar regions of Ukraine, Kazakhstan and Mongolia. Likewise, the observed changes in fire regime closely associated with abandonment trends noted by Lloret et al (2003) and Pérez et al (2003) in Spain, Mouillot et al (2005) in Corsica and Moreira et al (2001) in Portugal can be expected to hold true for other parts of the Mediterranean that are experiencing abandonment which has not been the subject of specific wildland fire research.

The fundamental driver of agricultural abandonment is socioeconomic change leading individual farmers to actively choose less intense forms of land management, eventuating in practically unused land. Land of poor agricultural quality and land isolated from economic centres and transit routes bear the most obvious signs of neglect as farmers tend to focus on more economically favourable lands when continuing to work all lands becomes impractical or unviable. This is true across the entire UNECE region with regional variations expressed as products of the particular history and landscape in which they exist. In some instances favourable landscape factors have allowed regions to weather substantial socio-economic changes with a relatively intact agricultural land base. However, on the other hand, extensive land abandonment does not tend to occur in the *absence* of socioeconomic instigation.

The specific governance factor that has been found to be most influential in leading to land abandonment is the agricultural market environment. The agricultural market environment, including available subsidies and credit for boosting production as well as access to markets to sell to, is a very strong determinant of the profitability of specific farming practices, and it is widely found that the farming community responds quickly to changes therein.

Beyond this, there are several other factors that play important parts in land abandonment depending on the particular circumstances of the region.

Patterns of tenure, such as land parcel size and spatial arrangement and particularly the right of land sale, also play an important role in helping or hindering the farming community in finding workable solutions to get the most out of their land. Also, relatively static biophysical factors such as simple isolation and the suitability of land for agricultural production based on temperature, precipitation and soil quality play decisive roles in some contexts.

The decline of human capital in rural areas is a phenomenon that can be identified as both a cause and effect of rural economic decline. Increasingly attractive alternatives off the land draw the young and ambitious away from rural areas to cities and abroad. This depletion has led to increasing disadvantage for these regions, in which hope for revival becomes ever fainter.

As well as contributing to the dwindling economic virility of rural regions, a declining and aging population has a direct effect on the ability of the local population to prevent, prepare for and defend property against wildfire. Increased fire risk due to overgrown agricultural land is met by a decreased ability for local populations to deal with it – this situation of complimentary dangers is common across the UNECE region.

Regional patterns will be discussed here, including some degree of prognosis of land abandonment trends in the UNECE region. A compilation of published land abandonment data in UNECE countries is provided in Table 1.

Eurasia

The largest and fastest mass transition of land ownership in modern history occurred throughout the early years of the 1990s in the countries that had, until that time, made up the Soviet Union. Adding to the 145 million hectares of mostly farmland transferred from public to private ownership in the Soviet States, regime change and continued instability in Eastern and South Eastern Europe throughout the 1990s added more land to that moving from public to private hands (Dudwick et al 2005).

Generally speaking, under the various regional shades of communism, vegetated land was almost exclusively publicly managed and was wholly allocated to uses such as agriculture and timber production. The agricultural sector was held in high esteem and received highly favourable conditions such as subsidies and credit for fertilisers and machinery and guaranteed markets for all that could be produced. The pursuit of ideals and protection from more productive foreign competition encouraged the industry to expand the land base and employment share in agriculture. Although gross production was quite impressive, these actions had the effect of maintaining an agricultural sector characterised by low land and labour efficiency by western standards of the time (e.g. Prishchepov et al 2012, Lerman 2009, Kuemmerle et al 2006).

The rapid change of the political and economic systems and the subsequent vacuum of guidance and funding effectively took the rug from underneath the entire regional agricultural economy. Agricultural production collapsed across the region. Stabilisation of the agricultural economy has, in most cases, now been achieved, resulting in a once-again productive sector. However, in no case has this been without a period of economic turmoil mirrored by dramatically reduced productivity figures, which themselves are indicative of rural decline and land abandonment (e.g. Hostert et al 2011, Lerman 2009, Kuemmerle et al 2009, Ioffe 2005).

Transfer of land tenure to those most interested in continuing agricultural practices has played an important part in facilitating rural self-determination. However, different strategies in reallocating agricultural land equitably have, at times, not facilitated this, resulting in land with absent owners, or land that cannot be effectively transferred to those that may wish to use it. In such cases abandonment has occurred (e.g. Prishchepov et al 2012, Sikor et al 2008).

In many parts of this region simple isolation of farming lands from markets and even transport routes is on scale barely comprehensible in other parts of the world. Population density and road density and quality often prove important determinants of rural vitality and subsequently, agricultural abandonment. In addition, some parts of this region were very marginal for agricultural production even under the highly protectionist policy environment of the socialist regimes. Once this system collapsed it became all but impossible to maintain this artificially inflated system (Prishchepov et al 2013, Ioffe 2005, De Beurs & Henebry 2004).

The decline of human capital in rural areas of the former soviet states has been particularly severe by international standards. The abrupt and intense change in the opportunities in cities and abroad led to massive rural exodus, which has then continued thanks to the depressing impact of the first to flee. Such a downward spiral has been very difficult to control in some areas (e.g. Sikor et al 2008, Ioffe 2005, Dudwick et al 2005).

This section will present the variety of situations stretching from Eastern Europe eastward across Eurasia by considering land abandonment in relation to its most influential drivers, using examples from the region. Beyond the examples mentioned in the text, a summary table of countries in the region for which some data is available is provided in Table 1.

Agricultural Markets

Concerted efforts by some governments to emulate existing well-supported capitalist agricultural markets have occurred with varying degrees of success in nurturing dynamic and profitable agricultural industries. In these cases abandonment has still occurred, but rather as part of a planned exit from agriculture rather than a by-product of increasing carelessness and hopelessness.

The obvious cases include those countries that have reformed as part of the process for relatively early accession into the European Union (EU). In relation to agricultural markets, these Eastern European countries, including Poland, Hungary, the Slovak and Czech Republics and the Baltic States (Latvia, Lithuania and Estonia), have benefited in recent years from the highly supportive agricultural policies of the European Union. Combined with the fact that these countries were not as thoroughly socialist as the truly soviet states, this has enabled a relatively smooth transition to a modern, mechanised, subsidised, low employment intensity agricultural sector (Dudwick et al 2005). However, agricultural abandonment has occurred with little regard for the exact nature of reform, ranging from very low rates in the Czech, Hungary and Slovakia and up to 42% of pre-1990 farmland in Latvia (Prishchepov et al 2012, Kuemmerle et al 2006).

Although a smooth transition to a new, stable agricultural economy does not necessarily prevent widespread agricultural abandonment, a rocky transition does tend to compound the initial disruption caused by regime change. Incomplete agricultural market reform by the governments in countries such as Bulgaria, Ukraine, Kazakhstan, and Moldova has inhibited the ability for private enterprise to flourish. A lack of commitment to reforms and repeated interventions reminiscent of the soviet era have resulted in large, inefficient farms continuing to struggle on the edge of survival by simultaneously intensifying production on the best land and abandoning the worst (Baumann et al 2011, Kuemmerle et al 2011, Dudwick et al 2005).

Land ownership patterns

A number of studies have pointed to the various trajectories of land ownership as a driver of land abandonment (Kuemmerle et al 2009, Sikor et al 2008, Lerman 2009, 2008). While this can in no case be identified as the sole reason, in certain circumstances it has very likely played an important role.

In most cases, land ownership rights were transferred to local people in a way intended to be as equitable as possible. In cases where the pre-collectivisation owners were known and land ownership at that earlier time had been reasonably equitable, restitution of land was often attempted. However, due to the decades-long gap of ownership and the vastly different agricultural economy of the 1990s to the, say, 1940s, many 'new' owners had no interest in farming and often did not even know where their land was located (Prishchepov et al 2012, Kuemmerle et al 2009, Kuemmerle et al 2006). Poland and Latvia are very good examples of this, resulting in levels of agricultural abandonment between 14% in Poland and 42% in Latvia (Kuemmerle et al 2006, Prishchepov et al 2012). In these cases vegetation often became increasingly fragmented as small, household-farm-sized patches have overgrown.

Where the previous owners were not known, or the pre-collectivisation land distribution had been unfair (e.g. rich landowners employing many peasants) land was distributed by other means. This generally resulted in the large, mechanised farms being divided into a multitude of tiny patches, with each member of the collective receiving a number of small patches in different areas to avoid the disadvantage of being allocated only poor land due to slope or soil characteristics. While well-intentioned, such distribution resulted in severely decreased efficiencies of farming small patches and travelling between these postage-stamp fields. Notable cases include Romania and Albania, where such land distribution combined with other factors eventuated in the abandonment of the more

impractical land parcels (Kuemmerle et al 2009, Müller & Munroe 2008, Sikor et al 2008). The character of land abandonment in these areas was one of large patch size because areas unsuitable for agriculture were generally abandoned by all the farmers with a patch of land there.

In some cases the opposite situation has caused problems of its own. In Russia, Ukraine and Kazakhstan collective members were sometimes given equal shares of the collective and all its land. However, management continued in the old manner, and being unable to break up the land base through sale, a situation was created in which the large and cumbersome farms continued to attempt to survive with old practices in a vastly deteriorated economic climate. Abandonment was a major result on large swathes of land (Lerman 2009, Kuemmerle et al 2006, Dudwick et al 2005).

A problem that has been widespread in the post-soviet world was that in many cases no effective land market existed for some time after the political transition and land distribution. In some cases this was a result of disorganised reforms, but in other cases it was a tool to prevent speculators buying up large tracts of land and sitting on it waiting for a market to develop. The dual effects of this were to stymie the efforts of entrepreneurial farmers to expand their operations as well as robbing those not interested in farming of the potential income that could be derived from selling their land. Even if land could be sold, markets were immature and prices very low, so many non-farmers held on to their land as some kind of safety net. Again, the result of this was an under-utilisation of land throughout the 1990s, which has continued due to the difficulty of returning land to agricultural production (Prishchepov et al 2013, Prishchepov et al 2012, Müller & Munroe 2008).

Isolation / Poor Agricultural conditions

Characteristics that are particularly distinguishing of large parts of Russia and Kazakhstan are isolation and poor agricultural conditions. Huge tracts of these countries have very low population density and very distant markets for agricultural products. This is compounded by the degraded state of transport infrastructure, making agricultural products increasingly uncompetitive. Huge grassland areas of northern Kazakhstan and southern European Russia have reduced their livestock densities to virtually nil, resulting in revival of the native grass species. Around five years after abandonment wildfires returned to the region after decades of absence, which in this case is a return to a more natural state of affairs (Dubinin et al 2011, Dubinin et al 2010, Lerman 2008, Dudwick et al 2005, De Beurs & Henebry 2004).

Compounding isolation in some areas, the difficult growing conditions across Eurasia meant that agriculture was, in many cases, only viable with the massive state support for the agricultural sector. Ioffe (2005) notes that the most promising agricultural regions in Russia would be considered marginal agricultural land in the United States. Without access to ample fertilizers and intense labour these regions became unproductive, uncompetitive and largely abandoned (Ioffe & Nefedova 2004, Ioffe 1991).

Human Capital

The dramatic rise in opportunities during the transition period did not affect all parts of this region equally. Rural areas were far less attractive for those wanting to profit in money and experience than cities and western countries. The outflow of particularly the young and the motivated resulted in what Sikor et al (2008) refer to as 'orphaned pensioners' when studying the effects of a population reduction of up to 70% in rural Albania through the 1990s. The reduced population reduced the necessity for cultivating land as extensively as before, as well as the capacity to do so (Kuemmerle et al 2009, Müller & Munroe 2008).

Russia

The key factors influencing and driving land abandonment in the post-soviet sphere are to be found in spades in the Russian Federation. The central force of the USSR possessed the greatest area by far of agricultural land and had transitioned most completely to a collectivised style of agricultural economy in the decades since the *New Economic Policy* was abolished in 1928.

The area of agricultural land peaked in the Russian Soviet Federative Socialist Republic in 1978 and started to decline slowly throughout the 1980s as intensification, rather than expansion became the means for increasing agricultural production (Ioffe & Nefedova 2004). Farming enterprises were universally very large and subject to state regulation as well as receiving heavy state subsidies (Ioffe 1991).

In the 1980s, annual subsidies for fertilizers and machinery etcetera reached \$60 billion (adjusted to 2005 prices), which allowed the maintenance of extensive, high employment farming despite the difficulties presented by severe conditions and isolation. Between 1991 and 1998 this state support disappeared almost completely. In 1998 annual subsidies reached a low point of \$1 billion adjusted to 2005 prices. As a comparison, Russian farmers were receiving average subsidies of just \$12.50 per hectare and year while US American farmers were receiving \$200 and European Union farmers \$800. Combined with sudden exposure to international markets, Russian farms became highly unprofitable (Ioffe 2005).

Such a hurdle only adds to the difficult conditions inherent to the Russian landscape. Even in European Russia – home to the highly productive Central Chernozem Region and 75% of Russia's arable land – generally poor soils, long winters and low precipitation combine to give a bioclimatic potential far below that of competing regions in Europe and North America. Remoteness is also an integral factor in discussions of Russia, and applies justifiably to European Russia as well as Siberia and the Far East. Markets and the population are highly dispersed and trade routes in poor condition. In the Soviet era remote producers were given particularly favourable trade conditions in order to maintain a presence in the landscape. In the absence of such conditions remote areas have suffered more than most, with profitable producers only found now in rings around major population centres (Prishchepov et al 2013, Ioffe & Nefedova 2004, Ioffe & Nefedova 2001).

Although the market conditions changed dramatically, farmland continued to be managed as large collectives (now 'enterprises') after 1991 (Lerman 2009). By 2005 it was estimated that 95% of these farms were in levels of debt beyond any chance of being repaid. Crop output dropped to 56% of 1990 levels by 1998, and between 20 and 40 million hectares became abandoned by 2004 (Ioffe 2005).

According to Ioffe and Nefedova (2004), farms generally become chronically unprofitable when population density falls below 10/km² and the retired population makes up more than 40% of the total population. Such demise comes sooner for remote areas and areas with particularly poor environmental conditions. According to this observed pattern, 52% of farmland in European Russia is at high risk of abandonment in the coming years – this is approximately double that which has already been abandoned and would have a profound impact on the lives of the 32% of European Russians living in the identified regions.

Western and Southern Europe

Shared history

Land abandonment across Europe has followed some general trends over time largely due to relatively synchronised development over the past 200 years, developing from the 'starting point' of extensive subsistence agriculture followed by the industrial revolution, the agricultural revolution and finally the unified policies of the European Union *Common Agricultural Policy* (EU CAP). Still, the fundamental rule holds true – that patterns of land abandonment are reflective of broader socioeconomic factors of the time (Verburg et al 2006, Busch 2006). Again, localised factors of markets, land tenure, land suitability and isolation play roles of various importance depending on the local circumstances.

Beginning from the mid 19th century, European societies were profoundly transformed by the Industrial Revolution. Of the estimates that exist, rural population density and cultivated land area in some European regions peaked in the mid eighteenth century (Olarieta et al 2008, Tailleurfumier & Piégay 2003). The changing nature of industry and trade and associated political transformations took

many people off the land to urban areas. Simultaneously, greater efficiencies of industrialised agriculture began to reduce the amount of land required under crops and grazing.

The real dramatic transformation of European agriculture occurred as mechanisation, chemical inputs and greater appreciation of agricultural sciences drove the technological revolution in agriculture from around 1950. The rapid increase in labour costs relative to the cost of machinery and chemicals pushed farming toward intensified production utilising minimal human labour (Lorent et al 2008, Strijker 2005). Marginal land and land unsuitable for mechanised practices was first to suffer from neglect while higher total yields than before were possible from more concentrated farming practices (Mottet et al 2006).

This trend was fortified for many years by the *Common Agricultural Policy* of the European Union by strongly supporting agricultural technology and its transfer by subsidising agricultural products primarily based on gross yield. The effect of this was for farmers to 'intensify or perish' – those without favourable land generally perished and their land became overgrown (Mottet et al 2006, Strijker 2005, MacDonald et al 2000).

In 2003 the CAP was overhauled to lower the prices paid for crops and rather provide income support to farmers regardless of their gross productivity. This move was, in fact, partly inspired by growing concern about the abandonment of rural lands and its close association with rural community decline and rural exodus. As part of the newly invoked *Single Farm Payment* (SFP) it is even specified that land may not fall out of use, but may transition to less intensive uses that spread the environmental impact of the farm over a broader area. Since this rule began to apply there has been a notable drop in intensive cereal crop cultivation in favour of uses such as woodland and bioenergy crops (Tranter et al 2007, van Meijl et al 2006).

Characteristics of abandoned land

There are certain characteristics of land that has been abandoned in recent decades that are ubiquitous across Europe. Of these, the biophysical factors include isolated areas and areas of poor productivity and accessibility – especially mountainous areas. Socioeconomic factors include aging rural population, small farm size and farmers that benefit from several income streams such as small business or other local work.

Biophysical factors

Generally speaking, the effect of the above-mentioned abandonment drivers has been to intensify agricultural production on lands which are already more productive and those that are more accessible. Abandonment has been noted particularly on poor or rocky soils and lands with poor vehicular access – notably terraced vineyards – by Olarieta et al (2008) in north eastern Spain, Lloret et al (2002) in eastern Spain, Debussche et al (1999) in the French Riviera, Mottet et al (2006) in the French Pyrenees and Falcucci et al (2007) in Italy.

In mountainous regions all these factors tend to coincide and are compounded by isolation. Being highly unsuitable for modern, intensive agriculture, these steep, rocky and high-altitude regions were sometimes traditionally used for very small scale cultivation, although livestock grazing has always been far more common. The labour-intensive nature of keeping animals in such an environment has proven unable to compete economically with intensive livestock rearing, despite assistance from the CAP under the *Less Favoured Areas* legislation intended to provide extra help to farmers working in severe environments (Gehrig-Fasel et al 2007, MacDonald et al 2000). Many mountainous regions across Europe are experiencing land use change whereby pastures are overtaken by shrubland and forest. Examples are described by Peroni et al (2000) in Italy, Pérez et al (2003) in Spain, Taillefumier & Piegay (2003) in the subalpine France and by MacDonald et al (2000) and Moreira et al (2011) at the European scale.

Socioeconomic factors

Socioeconomic factors linked by various studies tend to echo similar themes when dissecting agricultural abandonment in Europe. The relatively low attractiveness of farming as an occupation has

led to an increasing average age of lead farmers across the continent. From Denmark (Kristensen et al 2004) to Spain (Hill et al 2008, Romero-Calcerrada & Perry 2004) and Greece (Brouwer et al 1997) it is found that the overwhelming trend is for farmland to be run by those over the age of 60. This has been the case for some time now and has hence seen a lot of people already drop out of the agricultural business as they approach an appropriate retirement age.

However, not all farmers last so long in the industry, and it has been found that those farmers with several streams of income – the ‘jack-of-all-trades’ type folks – tend to leave farming to pursue more profitable occupations (MacDonald et al 2000, Brouwer et al 1997). Linked to this is the fact that *small* farms, employing only a handful of people, are particularly likely to break up and sell the best of their land while allowing the rest to grow over. Several authors suggest that small farms are at particular risk of abandonment, possibly linked to the fact that small farms do not qualify for assistance under the Less Favoured Areas programme (the minimum size threshold varies from 0.5 – 3ha, depending on country and region). Southern Europe – from Portugal to Greece – has a far higher proportion of farms falling below this threshold that are hence more vulnerable to economic pressure (Brouwer et al 1997).

Interplay with wildland fire

Southern Europe is of particular concern because of the existing prevalence of fire in the landscape. Many studies have linked landscape-scale trends of increasing biomass volume and homogeneity with increasing prevalence of wildfires, with *large* fires becoming particularly problematic (e.g. Moreira et al 2011, Moreira & Russo 2007, Vega-Garcia & Chuvieco 2006, Lloret et al 2003, 2002). The characteristic succession of abandoned agricultural land to shrubland is repeatedly identified as the major cause of increasing fire occurrence. As well as replacing pastures and crops, fire-adapted, early-succession shrub species have been found to be replacing forests following large fire occurrence (Mouillot et al 2005, Pérez et al 2003, Lloret et al 2002). The effect of this on a broad scale is a vast increase in the area and connectedness of a highly flammable vegetation type. Teamed with fairly constant human ignition sources, this can lead to much larger and more intense fires when the weather conditions allow it (Viedma et al 2006, Pérez et al 2003, Moreira et al 2001).

While the above is particularly true for abandoned land that is not subject to some kind of management plan, converting abandoned lands to another productive use is not necessarily a solution. Afforestation projects are often seen as an attractive alternative to abandoning lands or, alternatively, to the ‘greening’ of landscapes (Van Doorn & Bakker 2007, Viedma et al 2006, Moreira et al 2001). This may negate some of the negative economic results of moving away from agriculture, but if forests of highly flammable nature such as *Pinus* and *Eucalyptus* are not managed specifically for fire, they could themselves become a serious fire hazard. This is particularly true across the Mediterranean, where fast-growing exotic species have been widely planted since the 1970s (Moreira et al 2011, Lloret et al 2003). An extreme example is that of Israel, where rapid expansion of forest cover has been linked with massively destructive fire events such as that of 2010 (Carmel & Cadmon 1999).

North America

Generally speaking, the same universal drivers of agricultural abandonment as Europe have made their influences in North America. However, a key difference seems to be that at the time of the industrial and agricultural revolutions, large parts of this region were under the continuing influence of agricultural expansion and settlement. This is particularly notable in Canada, where unproductive or poor-access land was very rarely converted from its indigenous state to cultivation because its poor qualities were apparent and the settlers only used the best land in what they thought was *terra nullius* (Villani 2012, Hofmann et al 2005, Parson 1999). As a consequence Canada can be largely written out of discussions about agricultural land abandonment.

This phenomenon is less pronounced in the United States, but can be noted in the West and Midwest, which underwent European settlement much later than the east coast. Total agricultural land area in the United States peaked around 1949, but this total figure hides the fact that in the northeast,

farmland area started to decline already in 1880 and in the southeast around 1930, while farmland west of the Mississippi continued to expand until the 1970s (Waisanen & Bliss 2002). Also, the decline has been much more dramatic in the east, while the west basically stabilised close to its peak area (Brown et al 2005). Overall, the area of farmland has continued to fall to the current day since the high point in 1949 (Nickerson et al 2011).

Northeast

The pattern of agricultural abandonment in the north eastern states of the USA can be paralleled with that of Western Europe, albeit with local variations. Being settled by Europeans prior to the industrial revolution, farmland took on a character similar to traditional European agriculture limited by mechanisation and transport possibilities. The early decline of north eastern agriculture after the peak in 1880 was directly linked to rail access opening up more productive farmland further west to the large markets in the populated eastern states. Small farm plots and rapid population expansion dictated a pattern where large areas fell out of production to urbanisation and farm amalgamation (Nickerson et al 2011, Waisanen & Bliss 2002, Hart 1968).

Southeast

Cultivated later than the north east, south eastern agriculture developed at a time when the realities of industrialised society were apparent. However, extensive abandonment of land occurred as a result of the cotton industry's collapse in the early 20th century, which was largely due to Boll Weevil outbreaks. Not idle for long, the great proportion of this land has been replanted with *Pinus* species for timber production. This has created a fire risk inherent to large-scale forests, but a risk which is relatively known to the managers of the land (Brown et al 2005, Waisanen & Bliss 2002).

Guided by Policy

In neither UNECE country of North America is there official recognition or discussion of a heightened fire risk associated with abandoned land. However, there is strong movement to limit the true abandonment of land in favour of a more controlled retreat from intensive land uses where necessary.

In 1981 it was already recognised in the United States that the land base under agricultural use included a certain amount of surplus and that this surplus may contribute to some kind of degradation if left unchecked (USDA 2013). The response to this came in the form of the *Farmland Protection Policy Act*, which aimed to account for, and limit, the amount of agricultural land being abandoned and developed (USDA 2013, 2011). Later, in 1985, the *Conservation Reserve Program* added to this by providing a mechanism for farmers to gain a low income for registering land as 'idle cropland', which set the foundation for a central repository of this information which could be used to monitor the extent of agricultural land use trends and guide policy related to this (USDA 2009, Lubowski et al 2006). In the same period other government interventions into the agricultural market, such as increasing the level of crop insurance support and transitioning subsidies from yield-based to income support, aimed to stabilise the agricultural industry to take away the economic shocks that tend to cause farmers to leave the industry and their land (Nickerson et al 2011). From the slow decline in agricultural area it can be assumed that these policies have had the effect of minimising the economic turbulence experienced by farmers and the amount of land being abandoned. Nonetheless, from 2002 to 2007, 27 million acres changed classification from 'pasture cropland' to 'pasture' according to the United States Department of Agriculture, leaving the smallest area of cropland recorded since 1945 (Nickerson et al 2011). This change indicates that a continuing decline of cultivated land is taking place.

Conclusions

The conclusions that can be drawn from the information available point to the fact that economic reasons – particularly rapid changes – are universally the trigger for agricultural abandonment. Other local factors such as the agricultural potential of a certain site and the nature of the local population are highly influential in determining *which* land becomes abandoned and *how rapid* this process is. In economies where land abandonment has been recognised as undesirable, government intervention

has been able to provide a supportive environment which allows farmers to choose more freely whether to stay or go. The lesson from this is that the farming community is highly dynamic and resilient. This should be useful knowledge when more countries recognise a need for revival of rural communities – the farming population is not afraid of reinventing itself.

Whether by coincidence or not, the regions which already face the greatest threat from wildfire due to climate and vegetation also seem to face the highest likelihood of agricultural abandonment.

The effect of the fall of the USSR on the region of Eastern Europe and Eurasia has been profound in many ways. The agricultural sector has certainly not been immune and the shock of transitioning from a largely state-supported economy to one of the most unforgiving type of capitalism. This transition has provided the instigation for many former farmers to try their luck elsewhere. Fire in this region is periodically a massive threat, and one that has become more potent in a landscape with higher fuel loads and better connected fuels.

Southern European countries are supposed to benefit from the stabilising forces of the European Union *Common Agricultural Policy*, but the patterns of ownership in this region don't allow the full benefits from this relationship to be realised. Fire in southern Europe is a constant threat, and much of the vegetation making its way into former farmland is well adapted to living with the kind of fires that people prefer to live without.

Table 1. Abandoned land estimates for countries of the UNECE. The figure provided is the decline (as a percentage) of land that was being used at the beginning of the study for agriculture. In some cases an area of decline was reported. Projections are not included.

Country, Region	Estimate	Notes	Source
Albania	28%	1988-2003	Müller & Munroe (2008), Sikor et al (2008)
Belarus	1) 8% 2) 13% 3) 38%	1) 1980-2004 2) 1990-2000, 2 regions – north east and north west 3) 1992-1999, Southern region	1) Lerman (2009) 2) Prishchepov et al (2012) 3) Hostert et al 2011
Bulgaria	widespread	Post-1991	Dudwick et al (2005)
Canada, east	Decrease	Until 2001	Hofmann et al (2005), Parson (1999)
Canada, west	Increase	Until 2001	Hofmann et al (2005), Parson (1999)
Canada, total	3.1%	1951-1991	Parson (1999)
Czech Republic	12%	1991-2008, north west region	Baumann et al (2011)
Estonia	30%	1991-1993	Kuemmerle et al 2006
France	1) 82% 2) 95% 3) 7%	1) 1828-1991, south east region 2) 1774-1997, central Corsica 3) 1950-2003, Pyrenees	1) Taillefumier & Piegay (2003) 2) Mouillot et al 2003 3) Mottet et al 2006
Georgia	6%	1980-2004	Lerman (2009)
Italy	1) 883km ² 2) 26% 3) 100%	1) 'Current' for 1990-2006, Sardinia 2) 1960-2000, entire country 3) 1950-2000, Apennines' mountains	1) Ricotta et al (2012) 2) Falcucci et al (2007) 3) Peroni et al (2000)
Kazakhstan	1) 60% 2) wide-spread 3) 38%	1) 1980-2004, mostly grazing pasture 2) Post-1991 3) 1990-2000, cropland area	1) Lerman (2009) 2) Dudwick et al (2005) 3) De Beurs & Henebry (2004)
Kyrgyzstan	55%	1980-2004	Lerman (2009)
Latvia	42%	1990-2000, south east region	Prishchepov et al (2012)
Lithuania	28%	1990-2000, eastern region	Prishchepov et al (2012)
Moldova	5%	1980-2004	Lerman (2009)

Table 1. (continued)

Poland	14%	1990-2000, northern region	Prishchepov et al (2012)
Portugal	1) 29% 2) 10-18% 3) 29%	1) 1989-2004, Iberian Peninsula, area following 'rural exodus' trend 2) 1985-2000, small study in Alentejo 3) 1958-1995	1) Hill et al (2008) 2) Van Doorn & Bakker (2007) 3) Moreira et al (2001)
Romania	21%	1990-2000, southern Carpathians	Kuemmerle et al (2009)
Russia, Euro.	1) 31% 2) 90% 3) 31%	1) 1990-2000 – eastern Kaliningrad, sections of northern Euro. Russia 2) 1985-2007, livestock numbers 3) 1990-2000, parts of Smolensk, Kaluga, Tula, Rjazan, Vladimir	1) Prishchepov et al (2012) 2) Dubinin et al (2010) 3) Prishchepov et al (2013)
Russia, total	1) 12% 2) 20-30 million hectares 3) 40 million ha	1) 1980-2004 2) 1990-2005 3) 1990-2010	1) Lerman (2009) 2) Ioffe (2005) 3) Prishchepov et al (2012)
Spain	1) 6317 ha 2) 29% 3) 21% 4) 13%	1) 1956-1993, Tivissa, Catalonia 2) 1989-2004, Iberian Peninsula, area following 'rural exodus' trend 3) 1860-1999, Vallès, Catalonia 4) 1984-1999, central region	1) Lloret et al (2003) 2) Hill et al (2008) 3) Olarieta et al (2008) 4) Romero-Calcerrada & Perry (2004)
Switzerland	1-4%	1985-1997, High alpine areas	Gehrig-Fasel et al (2007)
Turkmenistan	2%	1980-2004	Lerman (2009)
Ukraine	1) 11% 2) 30% 3) 63%	1) 1980-2004 2) 1986-2008, western region 3) 1992-1999, northern region	1) Lerman (2009) 2) Baumann et al (2011) 3) Hostert et al (2011)
USA, east	1) 22%	1) 1950-2000	1) Brown et al (2005)
USA, total	1) 11% 2) 22%	1) 1950-2000 2) 1982-2007 (48 states)	1) Brown et al (2005) 2) USDA (2009)
Uzbekistan	24%	1980-2004	Lerman (2009)

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4. National Fire Management

The management of fire in the environment is currently most strongly associated with firefighting efforts to suppress forest fires. However, contemporary fire management must necessarily look beyond this and involve a broad range of public and private sectoral interests. The broadening of fire management beyond forests and suppression receives varying, but generally increasing, degrees of traction in UNECE member states. This is partly reflected in the evolution of terminology associated with wildland fire management. For example, the term 'wildland fire' in itself signifies a move away from considering only forests (forest fire) and uncontrolled fires (wildfire) to include all types of burning in any part of the vegetated landscape while correctly continuing to exclude structural fires.

The *Fire Management Voluntary Guidelines* (FAO 2006) outline the fact that, from a legal perspective, wildland fire must be considered in some way by a number of sectors, such as land management, health, rural development and the criminal justice system. This runs parallel to the private interests such as lives, homes, businesses and their associated insurances that are involved.

The general field of wildland fire management is touched upon in so many sectors for good reason. Fire not only affects different lands and their user groups in different ways, but the long-range effects, the health and property damaging potential of wildfire and the contrasting strategies between managing planned fire and uncontrolled fire result in a wide and complex range of stakeholder interests related to vegetation fire (Montiel & Herrero 2010).

Ultimately the management of wildland fire must be governed by legislating for all stages of the wildland fire process. The responsibilities must be divided rationally according to each agency's geographic and thematic jurisdiction as well as their respective abilities to influence, regulate and police fire-related activities (Montiel & Herrero 2010, Morgera & Cirelli 2009).

A typically straightforward example of responsibility assignment can be found across the UNECE region in the fact that the relevant Forestry agency is generally responsible for forest fuel management and fuel breaks within forests. Poland practices this kind of model, with the *Forest Fire Protection Department* working permanently with the *Poland National Forest Service* on all aspects of fire prevention, preparedness and response (IBLES 2002, 2012). In contrast, since 1998 the *Greek Forest Service* has been relieved of its fire management duties by the *Greek Fire Service* (Xanthopoulos 2000).

On the other hand, the responsibility of fire suppression may depend on where a particular fire started, and then become complicated by what it may potentially burn. Perhaps the greatest area of blurred responsibility lines is in post-fire investigation and imposition of reparations and sanctions. A fire that started in, for example, agricultural land and crossed into forests and urban areas while being fought by as many as five different agencies will result in a nightmare of compensation considerations for costs associated with losses and firefighting activities (Morgera & Cirelli 2009).

This kind of situation is common in the case that each agency approaches wildland fire in isolation and only from their perspective. The result is often that the country ends up with a jumble of ad-hoc wildland fire-related legislation scattered among the breadth and depth of government, with cooperation agreements drafted bilaterally only when deemed necessary.

Wildland Fire Management Strategy

One way of approaching this situation is through the development of a national level Wildland Fire Management Plan or Strategy. The overall aims and requirements of wildland fire management in a country can be drawn together at the national level and responsibilities delegated to the most appropriate agency. For example, Portugal is working from a *National Fire Plan*, which delegates and coordinates responsibilities such as fuel management, fire suppression and wildfire monitoring and assessment (European Commission 2012). However this is not the norm, as most countries in the UNECE tend to rely on the existing relationships developed between agencies, as discussed below.

As well as the sectoral breadth of relevant agencies, the process of identifying appropriate wildland fire responsibilities should address the question of to which level of government certain responsibilities should be allocated (Montiel & Herrero 2010). In most cases the national-level agencies are considered best equipped to provide general planning and preparedness guidance for landscape management on one hand and large-scale support to emergency coordination on the other - for example the role played by the United States Forest Service (Everett 2002).

Ground-level preventative actions and most preparedness activities need to be guided by bodies much closer to the ground level. In a move in this direction, since 2007 Russia has delegated all responsibility for forest management, including fire prevention, to the federal forest districts while maintaining central control of emergency response through EMERCOM. While at a conceptual level this should be a positive move, lack of preparedness at the regional level to take over such responsibility meant that the fire prevention and suppression capabilities were initially reduced after the change (Goldammer et al 2013).

Interagency cooperation

A challenge inherent to wildland fire management alluded to above is the need for coordination between sometimes vastly different sectoral interests. The web of isolated and ad-hoc agreements between various agencies serves the usual purposes of each and allows them to cooperate reasonably effectively in the circumstances that those agencies typically face but may actually lie dormant for long periods. However, in extraordinary circumstances such as emergency wildfire response, these relationships are required to work under intense pressure with potentially grave consequences resulting from misunderstandings (Montiel and Herrero 2010, Montiel et al 2010).

In saying this, it is also apparent that the 'response' phase of wildland fire management is generally the pinnacle of interagency cooperation, with any existing flaws receiving amplification due to their consequences. Areas of responsibility such as fuel management or ignition prevention do not enjoy high levels of cooperation between agencies (FAO 2006).

In many UNECE countries the cooperation that exists between agencies responding to wildfires is maintained by annual meetings held to agree on such matters as geographic areas of responsibility, incident management arrangement and hierarchy and cost-sharing agreements. Outside of these particular meetings, most agencies work independently until a complex fire event occurs. This arrangement is notable and proudly proclaimed by many countries reporting to the European Commission Joint Research Center in their annual *Forest Fires in Europe* report (e.g. European Commission 2012).

Many of these arrangements are very positive and progressive in their aims to approach fire from the perspectives of multiple land managers or multiple responding agencies. However, to move beyond sporadic, emergency-only cooperation and improve wildland fire management as a whole – including prevention, preparedness and post-fire assessment – some countries have taken the step to establish a permanent interagency body charged with coordinating and harmonising wildfire-related activities between agencies and levels of government.

While the exact model differs between countries depending on the existing allocation of responsibilities, bodies such as the U.S. American *National Interagency Fire Center* (NIFC), the *Canadian Interagency Forest Fire Center* (CIFFC), the Portuguese *Integrated System for Relief and Protection Operations* (SIOPS) and the localised inter-agency task forces operating in Ireland since 2012 provide examples of permanent, multi-sectoral approaches to wildland fire management (Nugent 2012).

Such agencies actively seek inter-agency collaboration with the aim of reducing the number of gaps, overlaps and conflicts between agencies responsible for various aspects of wildland fire. The resulting harmonised strategy increases the effectiveness of each agency in their own work as well as their coordination efforts so that fewer casualties, fewer material losses, better environmental outcomes and cost savings are the eventual result.

The establishment of an organisation such as this grows from a collective realisation that multilateral negotiations will be more effective than bilateral negotiations in serving the goals mentioned above. In

recent years a number of UNECE member states have been undertaking this process such as Armenia, Azerbaijan, Georgia, Ukraine and Greece. This process has been kicked off by the organisation of 'national round table' meetings in which relevant stakeholders share their views and concerns. From that point it is possible to begin harmonising policy and other actions within and between sectors (Goldammer 2011, OSCE 2012).

Beyond the general theme of interagency cooperation and specifically the effectiveness of suppression operations and coordination there are a number of particular aspects of wildland fire management which require special attention in some parts of the UNECE region. The remainder of this chapter will discuss some of the aspects of high importance within the UNECE region.

Specialised Training and Equipment

In some UNECE countries on-the-ground management of vegetation fires is handled by dedicated teams for whom wildland fire is the primary task and qualification. Such forces are present in a small number of countries such as the United States and Spain and provide potent fire suppression capabilities. In a far greater number of cases members of forest management or emergency services such as *Fire and Rescue Services* (United Kingdom), the *Forest Service* (Italy) and *Volunteer Fire Brigades* (Austria) are able to access some degree of specific vegetation fire training in addition to their usual emergency response capabilities. In areas where wildfires are a common occurrence, regular exposure to wildland fire operations can also make these forces highly effective. Finally, a number of UNECE member states do not provide any meaningful forest or vegetation fire training to the forces that are expected to respond to these incidents, whether this is the urban fire service, the forest service or the military (European Commission 2012, Montiel et al 2010).

The lack of emphasis on vegetation fires in the last two of these groups is generally due to the fact that vegetation fires pose a low perceived risk because history has shown that they are a rare occurrence. Records do show that some regions, particularly northern Europe, experience severe wildfires only on rare occasions – perhaps even decades apart. This region is predicted to experience increased wildland fire activity in the future, and may be dangerously underprepared (Montiel & Herrero 2010). The lack of specific and practiced skills results in poor response strategies which drive up the cost of suppression hugely and leave the window open for the fire to spread, cause damage and flare up if weather permits (Montiel et al 2010).

Vegetation fires differ from other natural and human disasters in the key aspect that they can be combated during the event. Earthquakes and landslides cannot be stopped or 'diverted' to any great degree, so disaster management in those cases is more focussed on infrastructure standards intended to minimise damage before the event and response capacity to manage the cleanup and deal with affected communities after the event. Within the realm of fire, vegetation fires also differ in key ways from structural fires as they are a mobile disturbance influenced heavily by factors that have little impact on structural fires, such as weather, terrain and the nature of the fuel.

A mixed bag of countries institutionalises wildland fire competence by providing specific publications and obliging a certain proportion of their emergency responders to be trained in wildland fire suppression techniques. As well as the typical North American and Mediterranean examples, others are striving to put themselves ahead of the problems that are currently faced and those that are likely to await them in the future (Montiel & Herrero 2010). As well as enhancing human capital, some countries are choosing to invest in more appropriate equipment for suppression of vegetation fires. In 2011 Latvia invested heavily in off-road pickup trucks and heavy tankers fitted with hand tools, pumps and hoses better suited to vegetation fire suppression. European support is available for enhancing wildfire preparedness through appropriate training and equipment. Since 2008 Lithuania has been accessing EU funding to set up a semi-automated forest fire detection system (European Commission 2012).

An important international effort aimed at disseminating reliable and standardised wildland fire competency information is *EuroFire* – a project carried out under the auspices of the European Union Leonardo da Vinci Programme. Initially published in English, French and German, these competency

standards provide an understanding of the fundamentals of wildland fire as well as practical techniques for its suppression, which are assessed through a competency-based training framework. As part of the European Qualifications' Framework they also serve as a template that can be edited and implemented at the national level and as such have already been translated in Russian, Georgian, Armenian and Azerbaijani. Translations for use in Greece, Ukraine and FYR Macedonia are currently being prepared (GFMC 2013a).

Fire History

One of the fundamental tools that allow effective and holistic wildland fire management is a reliable knowledge of when fire is likely to happen and under what conditions. Systematically kept records of fire statistics feed into the entire system of fire management by quantifying the nature of fire in the local environment. From this information the concept of a 'fire season' can be established, which is the foundation upon which a chain of actions can be built to enhance the preparedness of a certain country for the fires that it is likely to experience.

Many member states of the UNECE record some details of vegetation fires, although in most cases in an incomplete way. Recording burnt area seems to be mostly an initiative of forestry agencies as they try to estimate their 'losses' due to fire and other disturbances. The majority of countries included in the European Commission Joint Research Center (JRC) *Forest fires in Europe 2011* mention that most vegetation fires start in agricultural landscapes before crossing into other land use types (European Commission 2012). This important factor is widely recognised, though not systematically recorded. This is partly a result of the existing sectoral approach to wildland fire management, but the result is that the true nature of fire in the environment is not well understood. To gain such an understanding, all fire incidents in the landscape should be recorded, including their ignition source, the fuel affected (and to what intensity), the time of year and the weather conditions at the time of ignition and propagation (Montiel & Herrero 2010).

Going back to the concept of a 'fire season', one of the main reasons that this is so important is that it can guide reasoned actions for pre-season prevention activities and in-season preparedness activities, providing structure to the basic understanding of fire management. Such actions start with intensifying fire detection strategies, conducting awareness campaigns, daily updated fire activity reports and fire weather forecast and may extend to seasonally reinforcing fire suppression employment (among other examples, these strategies are employed, respectively by Sweden, Hungary, Poland and Greece) (European Commission 2012, Montiel & Herrero 2010, IBLES 2002).

At the European level, the European Forest Fire Information Service (EFFIS) has been compiling the *European Fire Database* since 1980. A number of European countries contribute their national statistics to this database but the figures reported are only for forested lands, so only tell part of the story (European Commission 2012). Also, the database is bound to nationally-produced statistics, which has been found to be of dubious accuracy in some cases, with remote Russia serving as a prime example. The large size and low population density of Russia means that they have long used a variety of methods to detect vegetation fires and collect forest fire data. However, the official annual burned area reported internally and to the international community has been found by Goldammer et al (2013) to be a massive underestimate of the true figure.

Fire Danger Ratings and Early Warning

Following closely from the topic of fire history, the development of a system of forecasting fire risk in real time is one of the major tools that can be developed directly as a result of understanding the historical nature of fire in a particular region of interest. This necessarily involves the cooperation of multiple sectors – most importantly meteorology agencies (Montiel & Herrero 2010).

The most basic form of early warning system is one that unites climatic factors to give a relative approximation of the potential severity of a fire event if it were to occur in fuel that could carry it. Temperature, humidity and recent and expected rainfall are factors that feed into such an index. The Canadian Fire Weather Index (FWI) operates along these lines by drawing the connections from

these weather factors to their effect on fuel moisture content and finally to likely fire behaviour. As well as being used in Canada, a number of countries in Europe, such as Hungary, use the Canadian FWI internally (GFMC 2013b). It is also the basis for European fire danger projections from EFFIS (European Commission 2012).

Other UNECE member states have developed internal fire danger rating systems which can be likened to the Canadian FWI. Russia and Poland have similar systems which are updated daily during the declared fire season, and Switzerland has developed a system which fits into their natural hazard rating system used otherwise for storms and avalanches (European Commission 2012). As an example of a very specific fire danger rating system, European alpine countries have developed an alpine fire danger rating system as part of the ALP-FFIRS project (ALP-FFIRS 2013).

At a global scale, the Global Observation of Forest and Land Cover Dynamics (GOFD-GOLD) provides an online tool which links the FWI to fires detected as presently active by satellite observations. The combination of these provides a more realistic projection of where fire activity is more likely to worsen (GOFD-GOLD).

Use of Fire in the Environment

The intentional, or at least tolerable, use of fire in the landscape serves a number of different purposes. In ecosystems that have evolved with natural fires such as the 'Light Taiga' forest types of Central and Western Asia fire may be used (or tolerated) to facilitate floral and faunal processes requiring the unique combination of disturbance and post-combustion chemicals that fire provides (Valendik et al 2013, Lazaro & Montiel 2010).

Beyond this, cultural uses of fire include artificial landscape management for biodiversity or cultural purposes (such as maintaining open lands in the absence of grazing), or more immediately practical reasons, such as waste disposal, crop residue disposal or hazard reduction. Throughout most of the UNECE, cultural fire in the landscape is subject to an outright ban because it is presumed, often correctly, that most destructive fires start from these sources. It has also become intolerable, particularly for land management agencies, to undertake burning which impacts upon the population through perceived heightened fire risk, smoke pollution and for a variety of other reasons (Lazaro & Montiel 2010).

Some European Union countries and the United States are able to police such burn bans and more importantly, have provided alternatives to burning – particularly in the agricultural sector. However, over vast tracts of the UNECE land masses this is not the case. The continued necessity of burning from land users' perspectives combined with arbitrary sanctions for those who get caught has resulted in fire becoming an uncontrolled force in the landscape as citizens start fires clandestinely and disappear to avoid the law. If land management fires were legal, the fire could be kept under the eye of the landholder so they could serve the desired purpose in the target area without impacting upon neighbours. However, under current conditions such fires often spread beyond the intended boundaries of the target area. Again, this fact is widely recognised by countries reporting to the EU Joint Research Center but is not examined further. In some member states a system of fire permits and assisted burning does exist but is currently either too inflexible or too expensive to make it an attractive option (Lazaro & Montiel 2010, Moore et al 2002). In a number of UNECE member states, including Sweden, Denmark and Norway, there is no mention of legal uses of fire, which leaves its use in something of a grey area (Lazaro & Montiel 2010).

The category of human-ignited fire that has started to grow in acceptance in UNECE countries in recent years is *prescribed fire* used to reduce vegetative fuels ahead of the high danger periods of the fire season. Many countries have started working with prescribed fire with the aims of increasing the effectiveness of legally-binding land clearing laws around buildings and preventing severe fires in forests by instigating low-intensity burns in cool or humid weather. An exceptional example exists in Ireland, where the acceptance of traditional use of prescribed fire in heathlands has instigated authorities to formalise and regulate this activity through legal means and the publication of the *Prescribed Burning Code of Practice* (Nugent 2012). Such activity must always be based on deep understanding of the nature of fire in the landscape – a goal pursued by agencies such as the US

Forest Service, the Eurasian Fire in Nature Conservation Network and the EU *Fire Paradox* project. The results of the *Fire Paradox* Project and the practical outreach work and pilot projects of the Fire Ecology Research Group continue to influence fire mitigation strategies across Europe – particularly the Mediterranean (Lazaro & Montiel 2010, Goldammer 2009). Outside of the EU and North America prescribed burning is regaining recognition in Russia and some neighbouring countries as a research topic. It has been practiced in the past, but since the 1980s has fallen out of favour. If found to be effective and controllable, it can be expected that fuel management through planned burning will filter through into forest and landscape management (Valendik et al 2013).

Rural empowerment

Adding another layer to the idea that wildland fire must be dealt with using a whole-of-landscape approach, it is essential to consider local communities and their residents – particularly in rural areas (Montiel & Herrero 2010). It is well known that no single agency can ‘deal’ with the complex issues concerning wildland fire, so it follows logically that those with the most to lose – potentially their lives, property and livelihoods – should be fundamentally involved in managing fire in the landscape (Moore et al 2002). This idea is considered across the UNECE region but usually extends only to fire suppression, when more or less organised local residents willingly leap into action to protect themselves and their neighbours (VDPO 2013). However, as has been discussed, wildland fire management is about a lot more than fire prevention, and the cross-boundary nature of fire would logically lead to the conclusion that all regional land owners and managers (the community) be involved in all stages of the fire management process through true community engagement (Moore et al 2002).

The concept of community engagement has been formalised by the term Community-Based Fire Management (CBFiM), which itself developed from the term Integrated Forest Fire Management (IFFM) - a concept that became popular as part of development strategies in the 1990s starting in Indonesia and Namibia. In more recent years CBFiM principles have been applied beyond the traditional ‘development’ context as so-called ‘developed’ countries have reflected on how these principles are implemented in their own wildland fire management systems (FAO 2003, Goldammer et al 2002).

This is evident in publications related to the European *Fire Paradox* project, which ran through the first decade of the 2000s and which is partly based on the principle of ‘Integrated Fire Management’ – the shortened name also signifying a move away from the view that wildland fires are purely a forest phenomenon (Silva et al 2002).

The most common form of CBFiM operating across the UNECE region is the existence of volunteer fire brigades made up of local community members, particularly in rural areas (VDPO 2013, European Commission 2012). Intimate local knowledge of terrain and accessibility and the fact that small teams are dispersed across the rural landscape means that these volunteer brigades are very often first to respond to vegetation fires, and often act without requiring any support from professional crews (VDPO 2013, FAO 2003, 2006). This is relevant over the length and breadth of the UNECE region, although the details of how volunteer fire brigades are organised and funded and their exact responsibilities do differ.

The primary role of volunteer fire brigades is to support the professional fire authorities in fire suppression activities, although often this ‘support’ takes the form of a leading role. Good examples of this include the USA and Poland (Everett 2002, IBLES 2002). However, a number of problems arise when citizens are doing potentially dangerous work for the benefit of the community.

The first of these is appropriate training and equipment. While volunteers may provide willing and cost-free labour, ensuring safe and efficient operation demands that volunteers are trained and equipped sufficiently to deal with the situations they are expected to face (ITS 2012, IBLES 2002). In some countries, for example Germany, the organised and highly resourced Volunteer Fire Brigades (*Freiwillige Feuerwehr*) are in fact poorly prepared to deal with vegetation fires – acting without specific training or tools (Lazaro & Montiel 2010). On a related point, issues such as liability have the potential to become relevant, especially considering on whose behalf these volunteers are working

(Morgera & Cirelli 2009). Volunteer Fire Brigades in Russia and Kazakhstan exist traditionally as a true community initiative. Although they are coordinated to some degree at the national level by, for example, the *All-Russian Volunteer Fire Organisation*, government regulation in terms of training and liability is generally rejected as it is seen to clash with the fundamental concept of a community initiative (Vorobyov 2012, MCHS 2010). This potentially puts the actions and possible damages of such volunteer forces into a legal grey area.

The second and more fundamental problem associated with the prevailing arrangement of volunteer fire brigades is that it approaches Community-Based Fire Management at only one point of the wildland fire cycle. While it is certainly a boon to fire suppression to be able to tap into low-cost, locally-knowledgeable human resources, these same resources are rarely utilised as part of wildfire prevention activities (Everett 2002). The prevention phase of wildland fire management is well recognised as being economically and socially much better value – not least because it may reduce the need for community members to throw themselves into hazardous fire suppression activities (Montiel & Herrero 2010).

A number of UNECE member states, particularly where fire is a common threat, require or recommend that residents take some kind prophylactic action against vegetation fire damages. However, these only extend to the property of the individual. France is an example of this, where clearing distances around buildings are regulated and monitored in fire-prone areas. Taking this a step further, programmes such as FireWise in the United States and FireSmart in Canada aim to build community awareness, including working with neighbours and existing community groups to build resilience to wildland fire as a community. In both cases, communities can gain recognition for actions they take part in, including consulting with local land management agencies to inform themselves of the threat to their particular community (NFPA 2013, PiP 2013).

However, even these programmes do not truly qualify as 'CBFiM' because they do not extend fire prevention rights beyond the borders of an individual's property, i.e. residents do not have explicit influence over neighbouring lands, even those that are publicly owned, such as forests (Moore et al 2002, Everett 2002). This signifies the lack of a central facet to wildfire prevention because vegetation fires generally cross ownership boundaries before causing great damage. It can be reasonably assumed that each land manager will act to reduce fire risk and consider their neighbours. However, a structural lack of communication and coordination between centrally-managed public lands and privately-owned property runs counter to the ideas of Community-Based Fire Management and Integrated Fire Management and is widespread across the UNECE region.

Village Defence Guidelines

A current and ongoing development in the UNECE that is closely linked to the *EuroFire* wildland fire suppression modules mentioned above is the drafting of the *Village Defence Guidelines for Rural Communities*. As a joint initiative of the Global Fire Monitoring Center (GFMC), the European and Mediterranean Major Hazards Agreement (EUR-OPA) and the Maria Tsakos Foundation (Greece), guidelines have been compiled that includes separable sections relevant to local residents and local governments, respectively (GFMC 2013c). When combined with the *EuroFire Competency Standards*, a coherent set of three documents can be distributed to the relevant parties in rural areas – organisational guidelines for local government, *EuroFire* training and assessment materials emergency services and home defence guidelines for local residents. Based on social research in Greece and backed up by the word of managers across Europe it was found that local residents are often not aware of what they can do to prevent fire damage to their property or of the respective responsibilities of various government agencies (Mitsopoulos 2013). This trio of documents is primarily aimed at the eastern Mediterranean region and synthesises home-defence and community preparedness examples from across the world into a set of guidelines relevant to the local environmental and socio-economic circumstances. The format, like *EuroFire*, is one that can be modified and translated for use in other countries and regions.

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5. Existing International Agreements Relevant to the UNECE

Wildland fire, by nature, is not bound by arbitrary human boundaries such as ownership or other property rights. As has been previously discussed in terms of national wildland fire preparedness, this poses certain challenges in the management of fire as a landscape-scale disturbance. The natural end-point of this theme is to consider the management of wildland fire at the international level – where agreements must be made with neighbours and other countries further afield. This chapter will outline important agreements that are currently valid for the UNECE region, as well as some international examples that may be useful in considering what else could be done in the region.¹

Cross-border Agreements

From the most practical perspective, bilateral agreements between countries sharing common borders have been in place in a number of instances in the UNECE for many years. Examples from the US-Canada (1947, 1986, 1998), the France-Spain (1960) and the Finland-Russia (1994) border regions are among a large number – many drafted in the 1990s – of agreements that stipulate the terms upon which border-region cooperation in wildland fire prevention and suppression is based. A list of 15 elements, which are recommended to be considered in agreements is provided in Appendix 1. This list mirrors *Paper II* of the *Outcomes of the 2003 International Wildland Fire Summit* (Sydney, Australia, 2003) (Frey & Velez-Muñoz 2003) and a review featured by Goldammer (2013).

Following such guidelines allows the local authorities in border regions to cooperate with their counterparts across the border and even move across the frontier without needing to go through the unwieldy process of seeking permission from a central authority. Potentially problematic factors such as the communication, compensation, legal questions and the exact area of allowable activity are organised ahead of time and refreshed at the beginning of each fire season, making joint response smooth and effective (Rodriguez y Silva 2003).

To reinforce the advantages of pre-determined wildfire suppression arrangements, Rodriguez y Silva (2003) cites a number of cases across the Mediterranean where coordinated wildfire response has failed due to incomplete agreements being hastily drafted in the throes of an unfolding emergency. It seems that such failures have led, in some way, to wider involvement of fire-prone countries in bilateral agreements.

While most international, cross-border agreements involve just two countries (or even just the provinces either side of the border) working bilaterally, there are some cases where a single agreement is designed to be effective across a number of countries. Since early 2013 the former Soviet States making up the Commonwealth of Independent States (CIS) appear to be working on coming to such an agreement including joint training, preventative actions and suppression activity up to 10km each side of national borders (Novitskaya 2013). While this may create a positive regional community appearance, bilateral agreements are often preferred due to their relative simplicity in initial drafting and especially in their revision, when necessary.

¹ For further reading see reviews by the GFMC (Goldammer 2006, GFMC 2012).

Long-distance Agreements

Since the early 2000s there have been some cases where bilateral agreements have not followed the typical cross-border model, but rather been forged between distant partners. The most notable agreements exist between North American countries (United States and Canada) and Pacific countries (Australia and New Zealand). These agreements are based on a fundamentally different principle than those across a land border – instead of relying on the neighbours, it is understood that the neighbours are likely to experience a similar fire danger situation at the same time, so may be busy. Forging agreements between the Northern and Southern Hemispheres largely avoids this problem, with the respective fire seasons being almost mutually exclusive (Anonymous 2003, 2003a, 2003b).

While factors such as cost-sharing and liability arrangements needed to be drafted specifically for these cases, there are aspects to these agreements that have certainly made the process a lot easier than may otherwise have been the case. To start, the almost exclusive use of English between all countries involved allows visiting crews to work with their hosts effectively without the need for a specific structure designed to deal purely with language. Starting from a common language also greatly helps the process in achieving a common understanding of wildland fire-specific terminology. The requirement of a common terminology is mentioned in all reports and templates for building an effective working relationship – especially in emergency situations. Finally, willingness to use a common incident management system – in this case the Incident Command System (ICS) – in all joint operations allows visiting crews to fit into and understand, the structure of command used by the local forces – again highly advantageous in emergency situations (Goldammer 2013).

Regional Agreements

Other long-distance, bilateral, wildland fire agreements mostly exist in the context of development, such as the Finland-Burkina Faso (1998) agreement mentioned by FAO (2004). On the other hand, there are cases where a common understanding of direct, but long-distance effects of wildland fire may logically lead to a legal agreement between several distant countries at the regional scale. The transport of wildland fire smoke and soot has come to the attention of international bodies such as the Arctic Council and the UNECE Convention on Long-Range Transport of Air Pollution in the UNECE region, as well as the Association of South East Asian Nations (ASEAN) outside of the UNECE.

Some other regional agreements exist or are under construction for a combination of the reasons mentioned. The European Commission and Southern African Development Community are working toward functional regional agreements that will serve to limit damaging wildland fires through cooperative planning and prevention and assisted response.

European Union

A regional initiative on dealing with wildland fires that is particularly relevant to the UNECE is the Civil Protection Mechanism (CPM), administered by the European Community Humanitarian Office (OCHA). The CPM is a mechanism designed primarily to provide reliable and standardised response to natural and technological disasters to assist the affected country in the recovery phase. While it was originally designed to provide mutual assistance between the member states, it has quickly become the case that most responses occur outside of these countries to third parties (ECHO 2013).

Wildland fire is one of the categories of disaster and assistance packages listed as eligible for response, but is not central to the CPM's operations. The general role of the various agencies that constitute the CPM are described below, with wildland fire-specific information also provided.

The CPM responds to natural and technological disasters by way of activating disaster recovery 'modules' according to what is requested by the hosting country. In all cases these modules must be able to work almost wholly independently in order to avoid duplication of efforts and other problems that may arise due to language and coordination limitations in the 'clean-up' and recovery phases of disaster management.

In the case of wildland fire, almost all 'activations' of the CPM comprise of aerial assistance in the form of helicopters and Canadair CL-215 water-bombing aircraft. In most cases this has simply provided a different organisational structure to pre-existing bilateral agreements on the sharing of aerial resources between west Mediterranean countries, although activations have spread toward the Balkan states in recent years (ECHO 2013a).

As yet the CPM has not been able to develop international wildland fire response capability far beyond what was already in existence prior to its inception in 2001. There remain no centrally-recommended Standard Operating Procedures (SOPs) for the commonly-utilised aerial response and mobilisation of expert fire suppression commanders or ground forces has been almost non-existent (ECHO 2013b, ECHO 2013c). Part of the problem is that wildland fire presents a different type of challenge than other emergencies, such as floods and earthquakes. Wildfire can potentially be managed during the event by aircraft but usually does not last long enough for ground crews and vehicles to be of much use if they have to travel long distances. This unique combination requires very rapid response by aerial resources and assisting experts followed by assistance with recovery, if that is also beyond the national capabilities. The CPM has not developed systems of deployment that improve this kind of response beyond what was already available. However, it has seen increasing use as member states make use of the centralised information and coordination facility.

Since May 2013 the Emergency Response and Coordination Centre (ERCC) has taken over the central organisation role of the Civil Protection Mechanism that was previously played by the Monitoring and Information Centre (MIC). This body's primary function is to organise requests and offers of responding modules in the case of emergency. All participating parties work through the ERCC rather than contacting each other directly. The ERCC is also responsible for communicating the regional risk of vegetation fire based on input from the European Forest Fire Information Service (EFFIS) (ECHO 2013).

As well as the activities mentioned, a key aspect of the EU Civil Protection Mechanism is to improve joint preparedness of the European Community for emergency events in the region. This is done through joint training and the *Exchange of Experts* programme (ECHO 2013b). While these activities have been regularly practiced for other types of emergencies, the capacity to deal with vegetation fire has not seen a great deal of attention (ECHO 2012). Related to wildfire, the *Exchange of Experts* programme has been used six times since its inception in 2008, with some interesting exchanges occurring between northern and southern European countries. Although a system of seasonal wildfire manager secondments is part of the CPM system, it appears that this hasn't yet been utilised through the CPM (ECHO 2013d). A joint training exercise with a partial focus on wildfires is planned in the Balkan region for early 2014 (ECHO 2013).

UNECE Convention on Long Range Transport of Air Pollution

Smoke pollution episodes emanating from Russia in the early 2000s that affected East Asia and Britain led, for a short time, to discussions of how vegetation fire smoke may be tackled as part of the existing UNECE Convention on Long-Range Transport of Air Pollution (CLRTAP) (Goldammer 2010). More recently, this debate has transformed to focus on Black Carbon pollution and particularly its affect on albedo of ice- and snow-covered regions in the Arctic after deposition. The Gothenburg Protocol of 1999 extended the original 1979 CLRTAP to include a number of industrial pollutants such as sulphur compounds and Volatile Organic Compounds (VOCs) negatively affecting forests, water bodies and soils. In 2012 this was amended to include Black Carbon (soot) as a short-lived atmospheric pollutant with significant climate forcing potential. As well as industrial and transport sources of Black Carbon, agricultural practices are explicitly mentioned in this amendment, making management for mitigation of smoke episodes a responsibility of the UNECE member states (UNECE 2013).

Arctic Council

In a move that strongly supports the CLRTAP decision to extend its focus to Black Carbon, the Arctic Council, which consists of eight member states with overlapping membership of the UNECE, has also begun to focus on Black Carbon as a pollutant affecting the arctic environment. The 2011 and 2013

Task Force on Short-lived Atmospheric Pollutants reports both identify vegetation fires as important targets for the management of Black Carbon emissions. As a short-lived pollutant, the temporal and spatial patterns of Black Carbon emissions are highly influential in determining their effect on Arctic Warming. Consequently, successful mitigation should have a very meaningful impact on localised climate change and ice-melt in the Arctic (Arctic Council 2013).

Asia Pacific Economic Cooperation

In October 2010 member states of the Asia Pacific Economic Cooperation (APEC) met in Khabarovsk, in Russia's Far East to discuss vegetation fire management at the regional level. The resulting paper – 'Recommendations on Management and International Cooperation in Preventing Forest Fires in the APEC Region' – encouraged member states to seek and enter into bilateral agreements within the region to cooperate on preventing forest fires and promoting sustainable forestry as well as to support the APEC secretariat in cooperation with neighbouring regional entities such as ASEAN and UNECE. However, since this time APEC appears to have been relatively dormant in action on forest and other vegetation fires, with disaster and emergency focus moving toward other issues such as flooding and tsunamis (Goldammer 2013, APEC 2013).

Council of Europe

In light of devastating wildfire events in Russia, the Balkans and Greece between 2007 and 2010 and the moves towards a unified European Forest Code, the members of the European Major Hazards Agreement (EUR-OPA) have recommended that the organisation increase its work on encouraging cooperation on forest fires in the region both to protect forests and the communities living in contact with them. A particular focus of the EUR-OPA work on wildland fire has been in relation to lands contaminated by radioactivity, unexploded ordnance and other industrial pollutants (Council of Europe 2011).

There are significant cases of contaminated lands in the member states of the Council of Europe and the UNECE, and only recently has this come to the conscience attention of national and regional land and fire managers. The complications of fire burning in radioactively contaminated land in Ukraine, Belarus and Russia and land containing unexploded ordnance in military training areas and formally mined areas has important consequences for firefighter safety, public health and security and nature conservation (Goldammer 2013a).

Organization for Security and Cooperation in Europe (OSCE)

The OSCE has been working with UN Environment and Security (ENVSEC) and the Global Fire Monitoring Center in Georgia, Armenia and Azerbaijan to build understanding and cooperation in the region from the perspective of common interest in positive environmental outcomes in border areas. Development of national fire management capacity and cross-border cooperative strategies of vegetation fires are seen as important bridges upon which to build regional confidence and, to some degree, security (Goldammer 2013, ENVSEC 2013).

Association of South East Asian Nations (ASEAN)

Throughout the 1980s and 1990s a number of smoke and haze episodes in South East Asia related to, often illegal, land use and forest fires prompted ASEAN member states to draft the Agreement on Transboundary Haze Pollution in 2003. Globally, this was the first multilateral agreement to focus on vegetation fire and its effects in a legally-binding way. The agreement bound ratifying nations to cooperate to regulate and reduce forest and land-use fires, prevent their occurrence, warn of their likelihood, respond to active fires and impose sanctions upon those breaking the laws. These actions are coordinated through a regional centre, which is unfortunately hindered in its potency by the fact that Indonesia – a country heavily affected by vegetation fires – has not yet ratified the haze agreement (Nguitragool 2011).

Southern African Development Community (SADC)

In a region that acutely recognises the natural and cultural importance of fire in the environment as well as its potential to inflict damage, the Southern African Development Community (SADC) has made important steps in recent years toward tackling damaging wildland fire through the *Regional Fire Management Programme*, officially launched in 2010. Building on the SADC *Forestry Strategy* of 2002, the 14 member states focus on fire in the specific context of the region and its characteristics – a largely fire prone landscape with a large, highly diverse and mostly rural population. As such, the principles of Community-Based Fire Management (CBFiM) have been taken on as central to the ethos and operations of fire management in the region. Other activities include joint goal-setting, shared GIS and fire detection systems and joint, standardised training through the ‘Working on Fire’ initiative and the *Wildland Fire Training Centre* in South Africa (Goldammer 2013, SADC 2010).

South and Central America

Since the first Mesoamerican Meeting of Forest Fire Protection in Guatemala City in 2002 cooperative agreements have developed across this region and in South America. The Caribbean, Central America and South America Regions of the Global Wildland Fire Network (GWFN) work closely together and with other regions of the GWFN to better deal with wildland fire in the highly varied landscapes of the region. Cooperation includes working with the forestry sector, emergency services and universities (Goldammer 2013).

Operational International Fire Management Guidelines

Fire Management Guidelines

A number of examples exist where international organisations have published fire management guidelines to be used as a basis upon which to develop guidelines at the national level. The *Fire Management Voluntary Guidelines* (FAO 2006), *Forest Fires and the Law* (Morgera and Cirelli 2009) and the *Handbook for Trainers*, published by Heikkilä et al (2007) offer good general overviews of the important components of functional and achievable internal wildland fire management.

Regionally specific guidelines exist for much of the world, including *Tropical Forests, Peatlands and Peatland Forests, Temperate and Boreal Forests* and *Sub-sahara Africa* created by ITTO (1997), Adinugroho et al (2011), FAO (2002) and Goldammer & de Ronde (2004), respectively.

All these guidelines offer more or less detailed advice on how successful fire management programmes can be developed with the specific goal of tailoring the message to the locally prevalent ecological, economic, social and political circumstances of each region.

EuroFire Competency Standards

One aspect of successful wildland fire management touched upon by all wildland fire management guidelines is that appropriate standards of operation should exist in order to effectively and safely work with fire in the environment. One response to this has been the development of the *EuroFire Competency Standards* developed under the banner of the EU Leonardo da Vinci Programme. Based on a detailed review of international best practice in actual fire suppression, these standards were developed within the *European Qualifications Framework* in order to adhere to a widely-accepted model for training and assessing skills for work in potentially dangerous environments (GFMC 2013).

Originally produced in French, German and English, the format of the training and assessment materials was designed to facilitate translation and has, as such, already been translated into Russian, Georgian, Armenian and Azerbaijani, with new versions currently in progress for use in Greece, FYR of Macedonia and Ukraine.

International Fire Aviation Working Group

The fact that the great majority of operational international wildfire cooperation takes place through the sharing of aerial assets has led the international wildland firefighting community to pursue greater harmony in this potentially hazardous work. The International Fire Aviation Working Group (IFAWG) was formed in 2008 and has since been working on developing a set of common rules specific to fire aviation operations to build on the already highly regulated world of civil aviation. Their work will be presented to the UNECE at the Fire Management Forum in November 2013 (Goldammer 2013).

United Nations Cooperation and Initiatives

None of the global, legally-binding United Nations conventions specifically refer to vegetation fires as a phenomenon in need of addressing. However, within the UN system a wide range of agencies have an interest in vegetation fire management as part of an overall strategy of achieving their particular goals. These range from the Rio Conventions and their interests in biodiversity and climate change to the UN Office for Disaster Risk Reduction (UNISDR) in planning for a more resilient future and the Office for the Coordination of Humanitarian Affairs (OCHA) in empowering and protecting communities from natural disasters and environmental emergencies. It is beyond the scope of paper to recall in detail the development of all interested parties or even to completely cover all actions supported by UN agencies. Rather, an overview is provided of the most relevant global UN agencies currently dealing with wildland fire.

United Nations Office for Disaster Risk Reduction (UNISDR)

At a strategic level, the UNISDR provides leadership to the UN agencies on matters relating to natural and technological disaster risk reduction. In recent years the emphasis from this central perspective has trended toward building 'resilience', having moved on from the concept of 'preparedness'. The central strategy dictating the current direction of the United Nations is the *Hyogo Framework for Action* (HFA), which was the major outcome of the first World Conference for Disaster Risk Reduction in 2005. Wildland fire is represented directly at the UNISDR level by the Global Fire Monitoring Center (GFMC), which in its function of coordinator of the Global Wildland Fire Network serves as one of 13 Thematic Platforms and advises the UN on such matters (UNISDR 2013).

In order to receive input from all parts of the globe both within and outside of the UN system, the UNISDR is advised by the Wildland Fire Advisory Group (WFAG). This group, whose secretariat is also housed by the GFMC, represents the regions of the Global Wildland Fire Network and international organizations, including UN agencies and programmes, and works toward the harmonisation of wildland fire management principles across the world through the sharing of information, human & technical capacity and resources. Members are organised into 14 networks around the globe and hail from all sectors related in some way to vegetation fire management in order to have the most effective transfer of information to the realm of policy and management (Goldammer 2013, GFMC 2012).

United Nations Food and Agriculture Organisation (FAO)

Again acting more at the strategic level, the FAO has conducted a high number of projects and case studies relating to forests and fire around the globe. The combined results of these activities have given the FAO a good overview of vegetation fire practices and vulnerabilities at the global scale. This has been put in use in the publication of thematic reviews such as *Legal Frameworks for Forest Fire Management* (FAO 2004) and practical guidelines such as the *Fire Management Voluntary Guidelines* and its oversight body – the *Fire Management Actions Alliance* (FAO 2006). FAO also partnered with the GFMC in developing *Global Forest Fire Assessments* and, jointly until 2005 with the Global Observation of Forest Cover / Global Observation of Landcover Dynamics (GOFCC/GOLD) Fire Mapping and Monitoring Team, in devising the idea of a "Framework for the Development of the International Wildland Fire Accord" (GFMC 2013).

United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA)

Within the United Nations' system, UN OCHA coordinates the practical UN response to emergency situations affecting the health and security of vulnerable populations, including natural disasters and environmental emergencies. Acting through the UN Disaster Assessment and Coordination Team (UNDAC) and the OCHA / UN Environment Programme Joint Environment Unit (JEU), OCHA serves member states by coordinating response efforts to environmental emergencies and natural disasters, as well as conflict-related and humanitarian emergencies. This response takes the form of expert individuals and teams with proven competencies that can be quickly deployed to the site of an unfolding catastrophe with the coordination of a central office. Development of the capacity of crews responding to internal or external emergencies can be arranged through OCHA to take advantage of the competency standards that have been developed (OCHA 2013). Currently vegetation fire is addressed by the OCHA system through interface procedures with the GFMC.²

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Appendix 1

International Wildland Fire Management Cooperation Agreements Standard Entries Used to Identify Common Elements in International Agreements

Source: International Wildland Fire Summit Paper #2³

Outline for International Cooperative Agreements

1. Parties to the Agreement
 - Includes governmental and non-governmental agencies and organizations at a variety of levels.
2. Purpose
 - Defines areas and forms of cooperation.
 - Define the scope of the cooperation.
3. Definition of Terms
 - Defines terms used in the agreement to insure there is no confusion or misinterpretation as to the meaning of the content of the agreement.
5. Expenses and Costs
 - Personnel- Defines how personnel costs will be set such as per person, per crew, per day or per assignment.
 - Equipment - Defines how equipment cost use will be set such as per day or per assignment.
 - Reimbursement of costs – Sets the procedures, amount, and criteria for reimbursement. Some agreements call for reimbursement only after a certain threshold of time or level of support has been reached.
 - Non-reimbursable – Under certain agreements all parties may agree to assist each other on a mutual aid, non-reimbursable basis.
6. Information and Coordination
 - Communication channels – Defines the protocols and methods to coordinate and exchange information.
 - Information exchange – Defines the types, amount and timing of information exchange.
 - Notifications – Sets the notification procedures for emergencies or for other significant events.
 - Coordination of work – Defines how and under what organizational structure the coordination of work will take place.
7. Liabilities, Claims and Compensations
 - Cross-wavier of claims/exemption from liability – Lists and defines how and when the cross-waivers and exemptions are in force for personnel that are being exchanged.
 - Exemptions to cross-wavier of claims – Lists and defines those areas or circumstances where the exemptions do not pertain to personnel that are being exchanged.
 - Damage to a third party – Outlines remediation methods and limitations for third party damage.
 - Medical assistance for injured personnel – Defines the protocols and procedures for assisting and possibly evacuating injured personnel.
 - Compensation in case of injury or death – Defines the timing, levels and limitations of compensation for injury or death. This may also be addressed above in the cross waivers and exemptions.

³ http://www.fire.uni-freiburg.de/iffn/iffn_29/IWFS-2-Paper-2.pdf For more details on the International Wildland Fire Summit see: <http://www.fire.uni-freiburg.de/summit-2003/introduction.htm> and Goldammer (2013)

- Privileges and immunities for the assisting personnel – Describes and defines the levels and limitations of privileges and immunities that the receiving country will provide to assisting country personnel.
8. Operating Plans / Operational Guidelines
- Provision for operating plans/operational guidelines – Operating plans/operational guidelines are a critical component of all cooperative agreements. They should be carefully crafted and reviewed by all parties to the agreement. The plans and guidelines outline and define specific operational areas to insure that the agreement can be implemented in a timely and efficient manner. They include items such as points of contact, procedures for requesting resources, entry procedures, annual updates of costs, reimbursements, and cross waivers, and updated standards, qualifications or training requirements. Also identifies how often and by whom the plans and guidelines will be reviewed, updated and the method for revalidating the contents of the plans and guidelines.
9. Border Crossings
- Sets protocols and procedures for simplifying of border crossing including the following:
 - Opening of alternative border-crossing points to facilitate the assistance
 - Customs provisions:
 - Concerning personnel
 - Concerning equipment and materials
 - Concerning officer responsible for equipment
 - Concerning aircraft
- Portions of this information will also be included in the operational plans and guidelines.
10. General Provisions
- Entry of force of the agreement - Defines when agreement is activated.
 - Duration – Specifies how long the agreement will remain in force
 - Withdrawal – Defines how countries or organizations can withdraw from the agreement.
 - Termination – Defines under what circumstances the agreement will terminate.
 - Interpretation – Provides understandings and interpretations for countries and organizations concerning under what circumstances and limitations each party is entering into the agreement.
 - Settlement of disputes – Defines the method of dispute resolution.
 - Amendments – Defines when and how amendments to the agreement may be submitted, reviewed, and acted upon.
11. Other Provisions
- Provides the opportunity for any country, agency or organization signing this agreement to define other areas of cooperation that they want to include in the agreement such as:
 - Shared training activities, including materials
 - Study tours, technical exchanges, and joint exercises
 - Relationship of this agreement to other agreements
 - Standards for personnel
 - Safety equipment
 - Limitations on the type and use of telecommunications equipment
 - Method of recall of firefighting resources
12. Participating Countries/Agencies/Organizations Signature Page
- It is important that all potential participants review and confirm their authorities to sign such an agreement.