Implementing a Global Early Warning System for Wildland Fire

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Abstract

Every year, wildland fires burn several hundred million hectares of vegetation around the world, of which a proportion becomes wildfire causing disastrous social, economic and/or environmental impacts. Disaster fires occur in every global region and vegetated biome. To mitigate wildfire problems, fire managers require early warning of extreme fire danger conditions. This allows time to implement fire prevention, detection, and pre-suppression action plans before disaster fires occur. Fire danger rating is the cornerstone of fire management decision-making and is commonly used to provide early warning of potential wildfires. Currently, less than half of the world has a national fire danger rating system in place. Fire danger rating systems usually provide a 4- to 6-hour early warning of peak daily fire danger. However, early warning of 1-2 weeks can be provided using longer-term forecast data from advanced numerical weather models, and products are further enhanced with satellite data. This extra time allows for greater coordination of resource-sharing and mobilization within and between countries in advance of disaster conditions. The purpose of the Global Early Warning System for Wildland Fire (EWS-Fire) is to provide open access to a globally consistent suite of fire danger and early warning products in support of increased international fire management collaboration. The Global EWS-Fire is structured to build on existing national fire danger rating systems and to connect systems from global to local levels. It provides longer term fire danger predictions for all countries, and it provides an operational fire danger rating system for the many countries that do not have a national system in place. The Global EWS-Fire aims to contribute to the Global Multi-Hazard Early Warning System evolving under the auspices of the United Nations International Strategy for Disaster Reduction and contribute to implementation of the Hyogo Framework for Action. This paper provides an overview and update of the Global EWS-Fire.

Keywords: fire danger rating, fire weather forecasting, international fire management, remote sensing

1. Introduction

Every year, wildland fires burn several hundred million hectares of vegetation around the world. Many global regions have reported increasing fire activity in recent decades, which is attributed to numerous factors such as climate change-altered fire regimes, rural-urban population shifts, and land use change affecting vegetation and fuel conditions. Approximately 80% of global fire occurs in grasslands and savannas, primarily in Africa and Australia, but also in South Asia and South America; the remaining 20% occurs in the worlds forests. The large majority of wildland fire is human-caused. With the vast amount of fire that occurs globally, a proportion inevitably becomes uncontrolled wildfire of which some have disastrous social, economic and/or environmental impacts. Most global fire is unmonitored and undocumented so the record of wildland fire disasters is incomplete. However, the existing record indicates that disaster fires occur in every global region and in every vegetated biome on a regular basis. Disaster conditions are defined as any wildfire(s) situation that overwhelms fire suppression capacity to the point that human life, property, and livelihood cannot be protected. Besides the threat to human safety, these fires can also have serious negative impacts on human health, regional economies, global climate change, and ecosystems in non-fire-prone biomes. To mitigate fire-related problems and escalating fire suppression costs, forest and land management agencies, as well as land owners and communities, require early warning of extreme fire danger conditions that lead to uncontrolled wildfires. Early warning of these conditions allows fire managers to implement fire prevention, detection, and pre-suppression action plans before fire problems begin.

The global wildland fire community recognizes that no individual country is capable of solving the problem of increasing fire activity and disaster fire occurrence on its own, and that greater international cooperation is required. The Global Early Warning System for Wildland Fire (EWS-Fire) is one component of *A Strategy to Enhance International Cooperation in Fire Management* (FAO, 2006). The objective of the Global EWS-Fire is to provide a scientifically supported, systematic procedure for assessing current and future fire danger that can be applied from local to global scales. The system is not intended to replace the many different fire danger rating systems currently in use, but rather to support and build on existing national and regional fire management programs by providing:

- new longer term predictions of fire danger based on advanced numerical weather models
- common global fire danger metrics to support international fire management cooperation, including resource-sharing during times of fire disaster
- a fire danger rating system for the many countries that do not have the financial or institutional capacity to develop their own system.

The primary purpose of the Global EWS-Fire Project is to develop a globally consistent suite of fire danger and early warning products to support international collaboration and reduce wildfire disaster. As part of the process, fire danger and early warning information will be made widely available to all countries through open access. As well, the Global EWS-Fire Project actively supports projects to assist countries with limited fire management capacity in the local use and application of fire danger and early warning information. The Global EWS-Fire will become operational in stages as regional and national centres and other fire management offices link with the system. Therefore, the system will be an expanding work in progress for a number of years. This paper summarizes recent progress on system development (since de Groot et al., 2006) and the current status and future vision of the system.

2. Fire Danger Rating

Fire danger rating is commonly used to provide early warning of the potential for serious wildfires based on daily weather data. Fire danger information is often enhanced with satellite data, such as hot spots for early fire detection, and with spectral data on land cover and fuel conditions. Normally, fire danger rating systems provide a 4- to 6-hour early warning of the highest fire danger for any particular day that the weather data is supplied. However, by using forecasted conditions from advanced numerical weather models, extended early warning (i.e., 1-2 weeks) can be provided. This extra time allows for greater coordination of resource-sharing and mobilization within and between countries.

Fire danger rating[1] is the systematic assessment of fire risk and potential impact, and it is the cornerstone of contemporary fire management programs. Is is used to determine suppression resource levels (fire fighters, equipment, helicopters, air tankers), mobilization, and strategic prepositioning; to define safe and acceptable prescribed burn prescription criteria; and to establish fire management budgets based on long-term fire danger statistics, and to justify increased funding during times of wildfire disaster. Fire danger rating research has been ongoing since the 1920's, resulting in operational fire danger rating systems being available for about 40 years in Canada (Stocks et al., 1989), the United States (Deeming et al., 1977), and Australia (Luke and McArthur, 1978). Numerous other weather-based systems and indices have been developed worldwide (others listed in de Groot et al., 2006) and were primarily designed to support landscape-level decision-making in fire management. Continuing research in this field has also led to more detailed, smaller-scale models of fire behaviour, fire spread, and fire effects. Despite the considerable progress that has been made in fire danger rating and related sciences in the last 8-9 decades, less than half of the world has a national fire danger rating system in place to support fire management. Most countries that do not have an operational fire danger rating system are in that situation because of a lack of institutional and/or financial capacity to build a national system. Ironically, fire danger rating systems need not be expensive, as very simple and reliable systems can be developed from existing science and technology with minimal capital costs. The only real expense necessary is the cost of technology transfer, specifically training to provide local capacity-building.

3. Global EWS history

Following the recommendations of the UN World Conference on Disaster Reduction (WCDR) in Kobe, Japan, January 2005, and the proposal of the UN Secretary General to develop a Global Multi-Hazard Early Warning System (GEWS), a call for project proposals for building a GEWS was issued in preparation for the 3rd International Conference on Early Warning (EWC-III) (27–29 March 2006, Bonn, Germany), sponsored by the United

[1] Technically, fire danger is a measure of the ability for a fire to start, spread and do damage; fire danger rating is an assessment of fire danger.

Nations International Strategy for Disaster Reduction (UNISDR) and the German Foreign Office (www.ewc3.org/). An international consortium of institutions cooperating in wildland fire early warning research and development submitted a proposal for the Global EWS-Fire, and it was selected for presentation at EWC-III. The outcomes of the discussions, which are documented on the GFMC Early Warning Portal (www.fire.uni-freiburg.de/fwf/EWS.htm), reveal the high interest in and endorsement by government and international institutions.

The Global EWS-Fire is a project of the Global Observation of Forest Cover and Global Observation of Landcover Dynamics (GOFC-GOLD) Fire Implementation Team, which is comprised of numerous international wildland fire, remote sensing, and weather agency representatives. The Global EWS-Fire is also included as task in the work plan of the Global Earth Observation System of Systems (GEOSS), an international initiative involving more than 150 countries and 35 international organizations. Regionally, it has been presented at the *Conference on Promoting Partnerships for the Implementation of the ASEAN Agreement on Transboundary Haze Pollution* in Hanoi, Vietnam (11–13 May 2006), at the GOFC-GOLD and University of Ghana (Legon) sponsored workshop on *Requirements for Fire Early Warning Systems in Africa* held in Accra, Ghana (12–16 November 2007), and the Southern African Development Community (SADC) Regional Consultative Workshop on *Development of a SADC Cross-border Fire Management Programme: a Contribution to Regional Disaster Risk Reduction in Response to Global Climate Change* in Maputo, Mozambique (25–27 January 2010).

4. System structure

The Global EWS has four operating levels (global, regional, national, local) that are integrated to exchange daily information (Table 1). In general, the global level provides longer-term and coarse-scale forecasts to other levels, and global fire danger forecasts are updated daily with current actual fire danger to ensure proper forecast calibration. Every source of fire danger data (e.g., regional, national, or district office, or community) is also capable of operating independently in the short term in case of technical problems in data exchange The system is also structured as a network (Figure 1) rather than a hierarchy from local to global, to provide redundancy in communication linkages. This design provides communication flexibility to reduce disruptions in information flow to decision-makers, as well as continued calculation of fire danger at all levels (separately from other levels) in case of a complete communication failure.

4.1 Global level

The Global EWS-Fire uses ground-based and remotely sensed data to present current and forecasted fire danger products. Current daily fire danger is presented in two forms at the global level: an aggregation of different fire danger indicators as provided by national and regional centres, and as a globally-uniform calculation of fire danger based on data from the global World Meteorological Organization (WMO) Network. The advantage of the aggregation method is that fire danger is based on a national or regional fire weather data network of greater density than the global network, so it presents fire danger in greater detail and with better local accuracy. The problem with aggregation is that there are many different fire danger systems being used around the world, so the final product is a

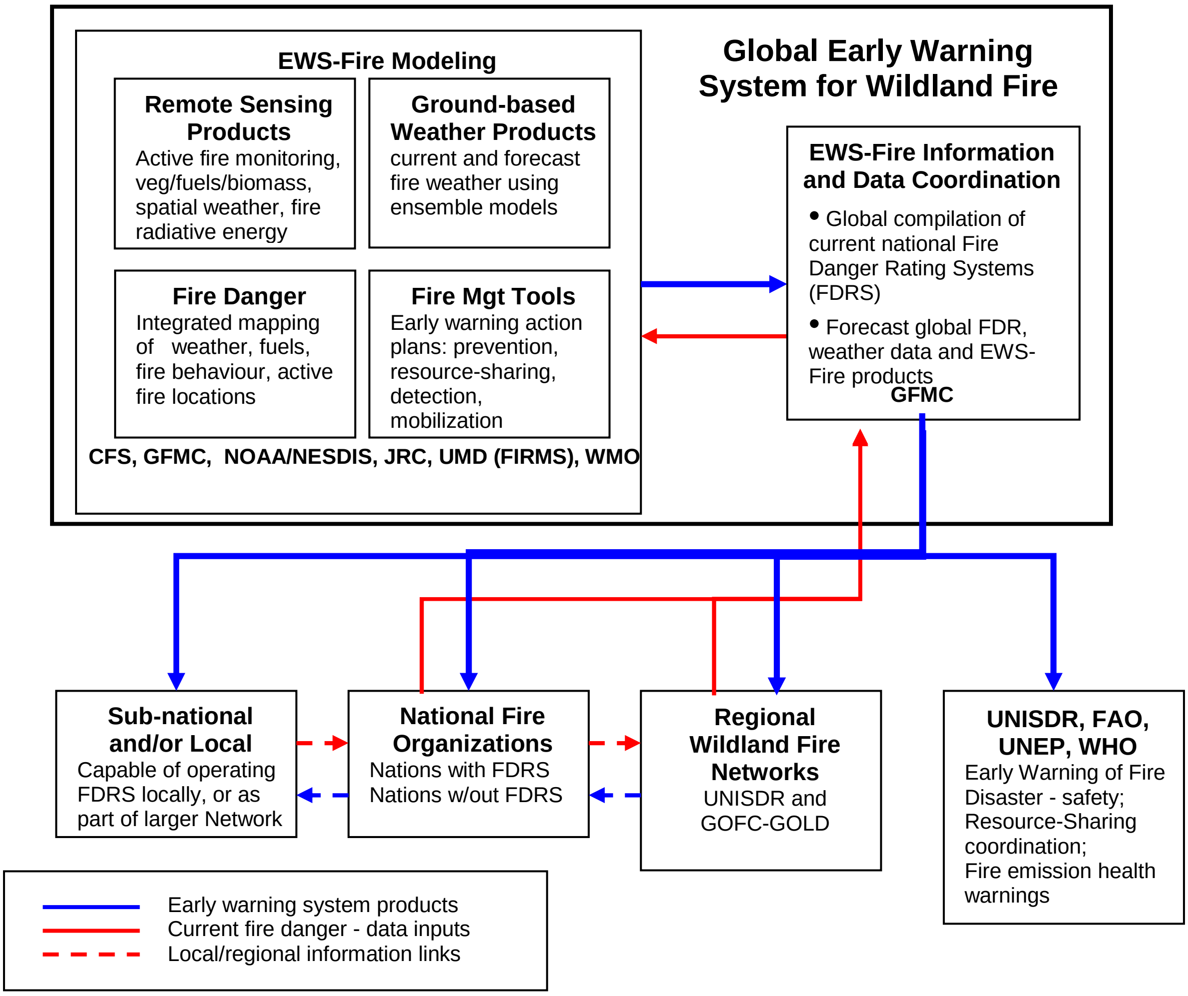
Table 1. Summary of general fire danger and fire management activities at different early warning levels in the Global Early Warning System for Wildland Fire (EWS-Fire).

EWS-Fire Level	Current Fire Danger	Future Fire Danger	Fire Management
Global	- collect and present current fire danger from available national sources - collect daily global fire weather data from WMO network - calculate and present daily fire danger for countries that do not produce national summaries	- provide 1-14 day forecast fire danger using global numerical weather models	- provide early warning of fire danger to national and international wildland fire and disaster management agencies (all countries via GFMC website, and UNISDR, FAO, WHO, etc.)
Regional [a]	- assist countries in calculating national-level fire danger, and sub-national and local fire danger as necessary - facilitate exchange of national fire danger to global level	- facilitate exchange of global fire danger forecasts to national, sub-national and local levels	- assist countries in fire management planning activities
National (or sub-national) [b]	- collect data from national synoptic and fire weather station networks - calculate national fire danger 1-2 times daily - assist in daily fire danger calculations at sub-national and local levels - transfer daily national (and sub-national and local) fire danger to global level	- calculate 1-3 day national fire danger forecast - receive 2-week global forecast from global level	- determine resource-sharing within country, and bilaterally with other countries - based on nationally-derived guidelines on prescribed fire and fire control
Local	- collect fire weather data from local weather station - calculate local fire danger 1-2 times daily, or hourly during periods of extreme conditions - transfer daily fire danger to national (or sub-national) level	- receive 1-3 day local fire danger forecast from National or sub-national level - receive 2-week global fire danger forecast from global level	- determine daily fire prevention, detection, and suppression activities at the local level - based on locally-derived guidelines on prescribed fire and fire control

[a] Regional level only operates in certain global areas with limited capacity to operationally run fire danger models, and only to provide national support

[b] Depending on State, Province, or Territory responsibility within countries

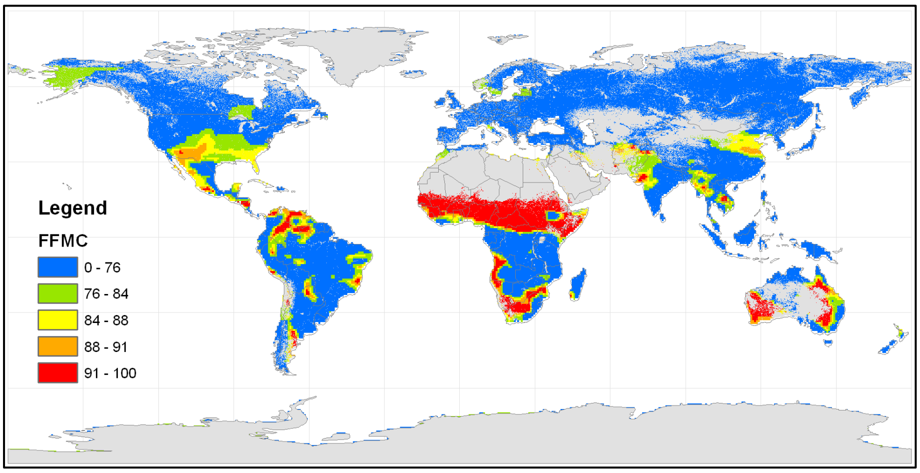
Figure 1. Structure of the Global Early Warning System for Wildland Fire (EWS-Fire). Partner agencies currently involved are Canadian Forest Service (CFS), University of Maryland (UMD) and the Fire Information for Resource Management Systems (FIRMS), Global Fire Monitoring Centre (GFMC), National Oceanic and Atmospheric Administration-National Environmental Satellite, Data, and Information Service (NOAA-NESDIS), European Union- Joint Research Centre (JRC), and World Meteorological Organization (WMO).



patchwork of images with different scales that are stitched together and are very difficult to interpret across jurisdictional boundaries. Another problem is that there are many countries that do not calculate any fire danger data. The global calculation method (Figure 2) presents a more coarse-scaled product due to lower network density, but it has a globally-uniform scale for easy interpretation across all boundaries, and it can be presented using a number of different fire danger models.

Forecasted fire danger of up to 14 days is currently being produced using data provided by the Canadian Meteorological Centre. In future, forecasted fire danger will also include products from the European Commission - Joint Research Centre (currently providing the European Forest Fire Information System products). All fire danger maps are supplemented with MODIS hot spot data for visual comparison with current fire activity. Global level

Figure 2. Example of global level product, indicating the Fine Fuel Moisture Code (FFMC) of the Canadian Forest Fire Weather Index System for 12 January 2010.



products are made available via the Global Fire Monitoring Centre website and can be tailored to meet specific international information needs for agencies such as the UNISDR, Food and Agriculture Organization, World Health Organization, and the United Nations Environment Program.

4.2 Regional level

Organized regional fire groups, such as the Regional Networks of the UNISDR Wildland Fire Advisory Group and the GOFC-GOLD Regional Networks, have the mandate to promote regional fire management collaboration and provide national support in the practical application of wildland fire science and technology. As such, regional groups will serve as the formal linkage between global and national levels. For example, in some global regions, national level fire danger and early warning information will be calculated and distributed by a regional partner. The European Forest Fire Information System[2] and the Southeast Asia Fire Danger Rating System represent regional fire danger rating systems already in operation. Regional systems are often an efficient way to operate a system for many countries in an area with common values and fire issues. Other candidate regions include Africa (or Southern Africa and West Africa), Central and South America, and central Asia.

4.3 National level

For centrally organized fire management agencies, the national or sub-national (provinces, states, and/or territories) level is the point of primary decision-making. Fire danger information is used to determine resource-sharing and mobilization within the country, and bi-laterally with other countries. Daily operational decisions are based on nationally-derived guidelines for prescribed fire and fire control. Current national fire danger is usually produced by collecting data from national synoptic and/or fire weather station networks, and is calculated once or twice daily. Fire danger may be updated hourly during

[2] EFIS website: http://effis.jrc.ec.europa.eu

extreme conditions. National fire danger forecasts of 1-3 days are typical, although a few countries provide longer term forecasts. As a partner in the Global EWS-Fire, national level current fire danger will be provided to the global level for presentation in the aggregated global fire danger product, and to be used for re-calibrating 'day 0' values for all of the forecasted global products. In return, the longer-term global level forecasts are provided to all countries.

4.4 Local level

Communities, districts, and parks are examples of the local level in fire management. In most cases, these locations make field-level decisions about fire prevention, detection and suppression activities at local level based on locally-derived guidelines for prescribed fire and fire control. Fire weather data is usually collected locally (often manually) and fire danger can be calculated daily or hourly as necessary. Forecasted data of 1-3 days may be provided from the national, sub-national, or regional level, but seldom is there access to long-term forecasted data. As a partner in the Global EWS-Fire, the local level provides current actual fire weather and fire danger data to the national and other levels, and receives 2-week extended forecast data from the global level; data communication in both directions may occur via the national level.

5. Regional early warning systems

The global level design of the Global EWS-Fire has been in place as a demonstration model since November 2009, with planned implementation as a fully operational model by the end of 2010. Two Regional level prototype models were also developed for the Global EWS-Fire targeting areas with minimal fire danger or early warning information. The purpose of the Regional prototype models was to demonstrate 1) the system's capacity to provide early warning of critical fire danger conditions using recent historical conditions, and 2) the use of fire danger-based decision-aids (e.g., for prevention, detection, and pre-suppression planning) to mitigate or prevent wildfire disaster impacts.

5.1 Sub-Saharan Africa

An overview of sub-Saharan Africa Regional EWS prototype was first presented at the GOFC-GOLD Fire Side Event meeting[3] held during the 4th International Wildland Fire Conference (Seville, Spain 13–18 May 2007). This Regional protoype was presented[4] at the Southern African Development Community (SADC) Workshop in Maputo, Mozambique (25–27 January 2010). The prototype was demonstrated using the extreme burning conditions that occurred in Southern Africa during August 2008 as the basis for a simulation example. A review of historical MODIS hot spots for Southern Africa indicated a peak burning period near 1 September 2008, so this was chosen as the target date for early warning. The simulation was run with a 2-week forecast, so forecasted fire danger products for 1 September 2008 were created using data available on 18 August 2008.

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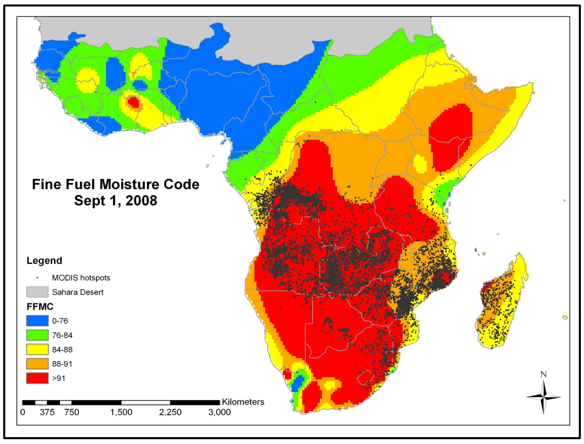
[3] Presentationa title: *Developing an Early Warning System for Wildland Fire in Africa*

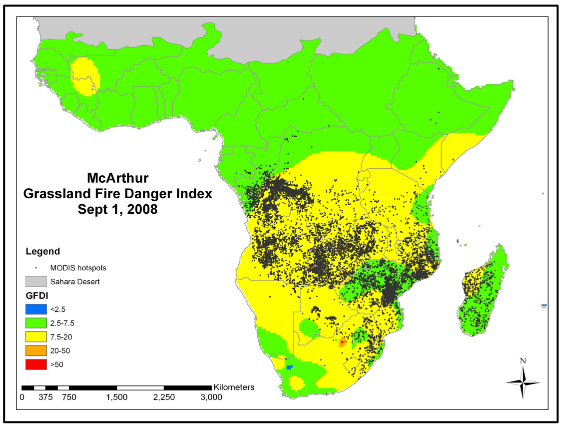
[4] *The Global Early Warning System for Wildland Fire: African Developments*, presented at the SADC Regional Consultative Workshop on *Development of a SADC Cross-border Fire Management Programme: a Contribution to Regional Disaster Risk Reduction in Response to Global Climate Change*

Figure 3. Examples of Regional Early Warning System products for Africa using MODIS hot spots and 14-day forecasted fire danger conditions available on 18 August 2008 for a) the Canadian Fine Fuel Moisture Code, b) McArthur's Grassland Fire Danger Index, and c) the South African Lowveld Fire Danger Index

a)



b)



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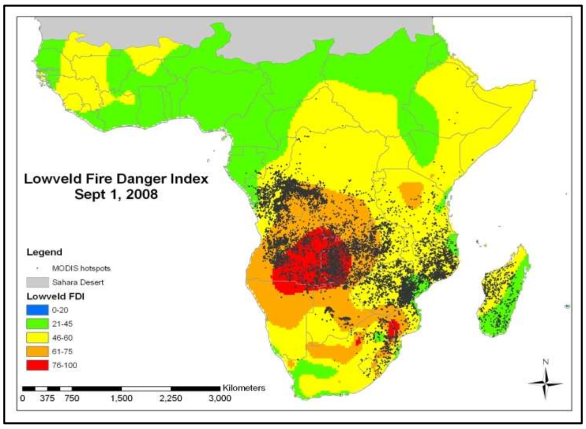


There is a wide range of early warning products that can potentially be presented for any specific area, but the products need to reflect the fire regime and fire management issues of the area. In Southern Africa, the primary fuel type is grassland and savannah, which is best represented by grass fuel models. Dead grass and other fine fuels are the first fuels to become flammable under drying conditions and can easily support high intensity fires with increased wind speed. For this reason, three fine fuel and grass-related fire danger indices were presented for this Regional example. Although the three fire danger indices in Figure 3 have independent scales and are not directly comparable, they all indicate the same general areas of highest fire danger. Virtually all wildland fire in Africa is human-caused, and there is extensive use of prescribed fire for various land and resource management objectives. Areas with a high density of hot spots are generally an indication of a high level of prescribed fire activity. Priority areas for early fire management planning are where high density hot spots overlay with areas of extreme future burning conditions.

In this example, grass and fine fuel indices can be used to implement prevention and detection action plans in advance of extreme burning conditions. Table 2 provides examples of fire management guidelines that can be used with fire danger information to support the planning and appropriate use of prescribed fire (Table 2a), to plan prevention and detection

Table 2. Examples of a) prescribed fire, b) fire prevention and detection, and c) fire suppression decision-aids.

a)

Fire danger level	Prescribed fire activity	Fire severity	Period
Low	Nil – too wet	Nil	All day
Moderate	Centre fire ignition	Low	1000-1400 hrs
	Strip ignition	Moderate	1400-1800 hrs
High	Strip ignition	Moderate	0800-1200 hrs
	Strip ignition during low winds only	High	1200-2000 hrs
Extreme	Strip ignition during low winds only	High	Before 1000 hrs
	Prescribed fire ban	Extreme	1000–2000 hrs

b)

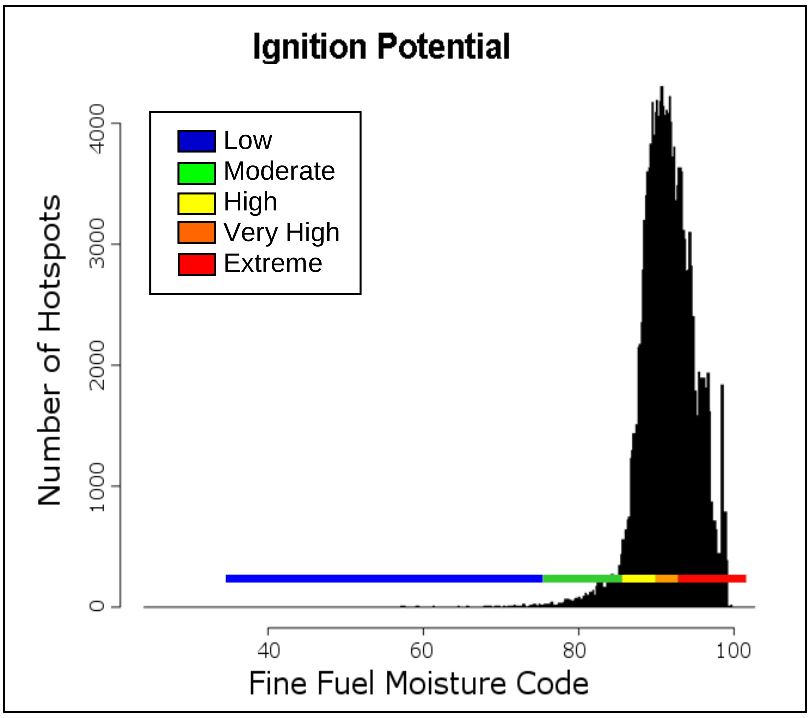
Fire danger level	Prevention activity	Detection	
		Activity	Period
Low	None	None	None
Moderate	Post local warning signs	Towers	Mid-day
High	Local media warnings	Towers	All day
	Open burning restrictions	Vehicle patrol	Mid-day
Extreme	TV and radio warnings	Towers	All day
	Open burning ban	Vehicle patrol	All day
	Local community meetings	Aircraft patrol	Mid-day

c)

Fire danger level	Suppression resource	Alert period	Dispatch time
Low	Crews, hand tools	Mid-day	60 min
Moderate	Crews, hand tools	All day	30 min
	Pumps, water tanks	Mid-day	60 min
High	Crews, hand tools	All day	15 min
	Pumps, water tanks	All day	30 min
	Control line-building equipment	Mid-day	60 min
Extreme	Crews, hand tools	All day	15 min
	Pumps, water tanks	All day	15 min
	Control line-building equipment	All day	30 min
	Aircraft, burnout equipment	Mid-day	60 min

activities (Table 2b), and to plan future fire suppression resource needs and mobilization to critical areas, and alert schedules (Table 2c). Another very useful product for fire management planning is a spatial display of the potential for new fire starts. Figure 4 presents a calibration of the FFMC scale using hot spot frequency in sub-Saharan Africa to establish 'Ignition Potential' categories that can be used to build predictive maps indicating potential for new fire starts.

Figure 4. Calibrating the Fine Fuel Moisture Code (FFMC) with satellite-detected hot spots to construct a fire start predictor, or 'Ignition Potential' indicator. This example uses one year of MODIS hot spot data for sub-Saharan Africa and corresponding FFMC data for the hot spot location. Similar calibrations have been done for SE Asia (de Groot et al. 2005) and for Central and South America resulting in very similar FFMC scale calibrations.



5.2 Central and South America

A similar Regional EWS prototype was prepared for Central and South America using recent time periods to demonstrate the system's application in other global regions. A summary of this prototype demonstration can be found on the Global EWS-Fire website[5]. In brief, a similar presentation of potential products were presented for Central America using the late March 2010 time period, and for South America using the late August 2009 time period. Figure 5 presents an example of a fire behaviour product for Mexico and South America that combines fuel type classification with a fire danger-based rate of spread model, illustrating expected head fire intensity in grasslands.

6. Future system development and implementation plans

There are a number of satellite data and modeling enhancements to the Global EWS-Fire that are being explored. Advances in measuring spatial precipitation from space would offer the single largest improvement to the accuracy of fire danger maps and would reduce or eliminate the need for spatial interpolation of precipitation from ground-based point sources. Remotely sensed fuel mapping is also being pursued to develop a global fuel type map, which would be a first step towards developing global fire behavior prediction

[5] http://www.fire.uni-freiburg.de/gwfews/demos.html

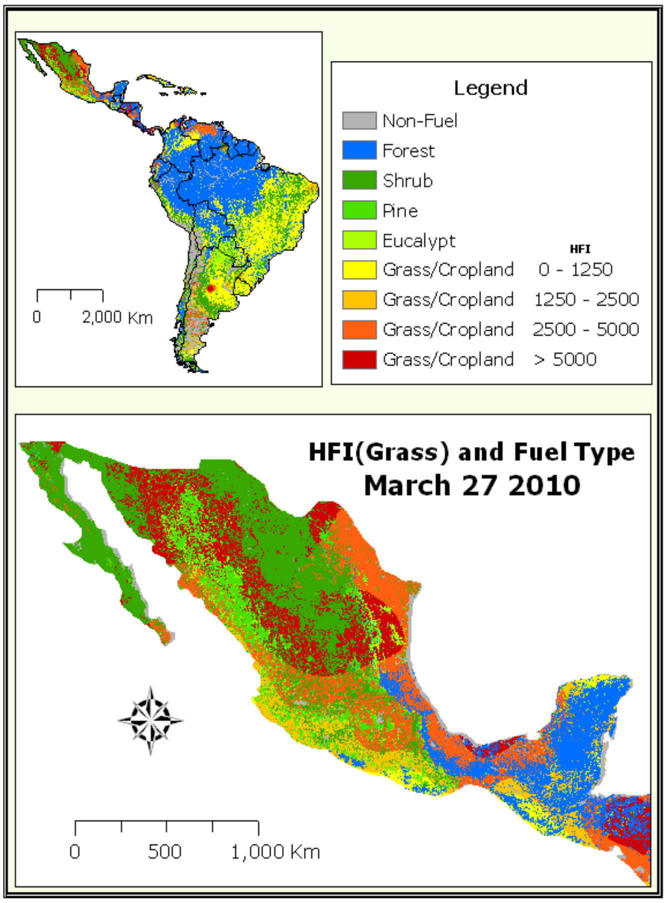


Figure 5. Example of Regional Early Warning System products for Central and South America. In this example, fuel types have been interpreted from landcover data (ESA Globcover Project) and head fire intensity (HFI, kW/m) in grasslands is identified using a fire danger-based fire rate of spread model (Forestry Canada Fire Danger Group 1992) and an estimated grassland fuel load of 3 t/ha.

models. Monitoring of live fuel moisture (Ceccato et al. 2003) can contribute to establishing fuel flammability and seasonal criteria that are important to fire behaviour models and monitoring/modeling of fuel consumption, fire spread rate, and carbon emissions. The use of remotely sensed fire radiative energy to estimate fuel consumption and carbon emissions is currently being studied (Wooster 2002, Wooster *et al.* 2003). Fuel consumption could also potentially be combined with satellite-monitored daily fire spread data to calculate fire intensity. Lastly, seasonal fire weather forecasts may also be added to the system in the future.

Implementation of the Global EWS-Fire is anticipated to occur in stages as the system develops. Once it is producing daily, global-level early warning products, regional-level systems will be incorporated as they are implemented. The Global EWS-Fire will also be integrated with established national systems once it is fully operational at the global level. A key aspect to the successful implementation of a fully integrated (local to global) system is technology transfer to the many countries that do not currently use fire danger information. Training in the practical use of early warning and fire danger information will be critical to local capacity building and long-term institutionalization of the system.

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