Effective Situational Awareness to Wildfire Emergency Command Based on Multi-model Forecasting System

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ABSTRACT
Maintaining and sustaining situational awareness is regarded as a primary task in a wildfire incident response. Clearly, due to the complexity of wildfire incidents, there are a wide range of significant hazards and risks which need to be considered. To better conduct situational awareness during wildfire emergency, we established a multi-model forecasting system to predict the fire behavior, estimate the resource requirements and share multi-source information based on weather prediction model, wildfire behavior prediction model, resource scheduling model and GIS. Multi-model forecasting system provides the emergency managers periodic situational awareness for quick and efficient responses to a wildfire emergency.

Keywords
Wildfire, Emergency management, Multi-model forecasting system, Situational awareness

1. INTRODUCTION
Wildfire, one of the most important natural disasters, should be seen as a serious threat to the safety of attending personnel, communities and the resilience of fire and rescue services. The international disaster database [1] reported that totally 397 events occurred during 1900 to 2016 all over the world, resulting in 3,787 total deaths, 6,471,033 total affected and nearly 58 billion US$ total damage. Wildfires have been raging across California, the Iberian peninsula, and Provence in the south of France, underlining the growing threat to life and property posed by this natural hazard as global temperatures rise and drought conditions spread in many regions which may now be leading to a loss of ecosystem services in the range of US$146-US$191 billion per year. The latest serious wildfire occurred in United States in 2016, which destroyed 18 homes in mountains north of Los Angeles and swelled 20,000 acres hundreds of residents being ordered to evacuate their homes.

The priorities of the wildfire emergency management are including saving lives, stabilizing the incident and protecting property and the environment [2]. To achieve these priorities, the fire and rescue service, along with other responding agencies and other stakeholders must work together to effectively share resources, integrate tactics, and take actions to meet the needs of communities during incidents. Alleviating the detrimental effects of wildfire extremely rely on timely collecting the disaster-related data, accurately estimating disaster damage, rapidly planning evacuation routes, and effectively scheduling emergency resource [3]. Establishing and maintaining situational awareness are two important prerequisites for rapidly and appropriately response to wildfire emergency by providing time-critical information.

Situational awareness is simply “knowing what is going on so you can figure out what to do”. In order to maintain situational awareness, incident managers should answer “what is happening and why is it happening?” by gathering, collating, synthesizing, and disseminating incident information to and from all appropriate parties; “what will be happen next?” by predicting wildfire behavior, and “what can I do about it?” by planning the tactical plan based on full consideration of incident information, resource information, hazard and safety information.

Another important prerequisites for rapidly and appropriately response to wildfire emergency is a common operating picture to view relevant information and get quick access to tools they need to do their job. GIS have evolved to service those needs by quickly answer complex spatial queries such as requests for the population distribution, land vegetation cover, or the number and the location of critical infrastructure assets in a disaster zone. The situational awareness need GIS for producing incident-related maps to support response and/or recovery operations. Besides, the general public has become increasingly map aware, particularly over the past few years with the widespread adoption of personal navigation system and web maps, making easier operation of real-time tracking emergency resources and tasks.

Under wildfire emergency, managers need basic data, real-time data and predicted data from multiple information resources, such as government departments, public, websites, social media, and emergency personnel on-scene as well as fire behavior prediction models. The objective of this paper is to establish and maintain situational awareness during the fire emergency management process using multi-model forecasting system based on fire weather, fire behavior, resource scheduling and GIS.

2. ESTABLISHMENT OF MULTI-MODEL FORECASTING SYSTEM
According to the Food and Agriculture Organization of the United Nations (FAO), a wildfire emergency can be considered as meeting one or more of the following criteria: (1) Involves a geographical area of >1 hectare; (2) Has a sustained flame length of >1.5 meters; (3) Requires a committed resource of ≥ 4 Fire and Rescue Service appliances; (4) Requires resources to be committed for ≥ 6 hours and (5) Presents a serious threat to life, environment, property and infrastructure, which is taking full consideration of geographical area, risk to personnel, service resilience, resource implications, associated financial costs,
impact on ‘business as usual’ and risk to their local communities, environment and infrastructure.

In order for successful emergency management and incident response to occur, emergency managers must have a clear understanding of their roles and responsibilities during the whole wildfire; identify community values at risk; identify the capacity to implement fire-adapted community activities; assess any gaps or limitations in funding, resources, partnerships and workforce/volunteers and prioritize the response procedures.

According to Gazzard et al. [4] the standard operating procedure (SOP) of wildfire has been derived into six clearly identified phases, including mobilizing and En-route, arriving and gathering information, planning the tactic plan, implementing the tactic plan, evaluating the tactic plan and close the tactic plan. During the whole SOP, the corresponding situational awareness is summarized in figure 1.

![Wildfire SOP Timeline](image1)

**Fig. 1 Wildfire incident standard operating procedure and the content of situational awareness**

The situational awareness includes four major parts as shown in Fig. 1. All those complex situational awareness are highly rely on the following factors: (1) persons in attendance at the scene; (2) fire behavior; (3) the possible involvement of infrastructure; (4) urban interface fires; (5) the potential influence areas; (6) the potential requirement of resources; (7) appropriate routes to be taken to the scene; and (8) the potential the fire has to spread across the landscape and the changes to fire behavior that this will bring.

To better perform the situational awareness mentioned above, we establish the multi-model forecasting system based on weather prediction model [5], wildfire behavior prediction model [6], resource scheduling model [7] and GIS.

Weather is a key wildfire factor due to its significant impact on the fuel complex, fire intensities, the rates of spread, levels of risk and the broader wildfire environment. The most relevant factors are temperatures, moistures (precipitation, dew) and air movements (katabatic and anabatic winds). The workflow of the weather prediction model is as follows (figure 2):

![Weather prediction model](image2)

**Fig. 2 The workflow of fire weather prediction model**

It is also important to realize that although fire behavior appears to change unexpectedly, the fire is simply reacting to its environment which is dominated by fuel, weather and topography as shown in figure 3. Wildfire behavior prediction model is a tool used to forecast future behavior of a fire based on the wildfire triangle. The intensity of any fire will be dictated by the fuel complex in which a fire has the opportunity to burn, and the support given to it by the topographical and meteorological alignment forces used in the prediction system.

![Wildfire behavior prediction model](image3)

**Fig. 3 The workflow of wildfire behavior prediction model**

Resource scheduling model is used to identify the prediction resources requirements, including personnel, equipment, services and supplies which are either available or potentially available for assignment to a wildfire incident, based on the prediction wildfire behavior. The resource scheduling are depended on both prediction resources requirements and the on-scene resources requirements gathered during their scene assessment as shown in figure 4. The key factors considered during the prediction process are the potential scale of the incident, the potential fire spread, the possible involvement of infrastructure and the potential burning area and the trigger point, a pre-designated point in time or place whereby a predicted change in fire behavior will influence tactical decision-making. The key resources during a wildfire are including specialist wildfire vehicles and equipment, trained and experienced Fire and Rescue Service personnel, specialist wildfire teams, air support from commercial providers, police or the military, Mountain Rescue Teams, and water resources.

![Resource scheduling model](image4)

**Fig. 4 The workflow of resource scheduling model**

GIS designed to capture, store, manipulate, analyze, and present geographically referenced data to support multi-system and multi-agency interoperability. GIS integration with weather prediction model, wildfire behavior prediction model, resource scheduling model and on-scene information is certainly a value-added functionality in spatial information query, analysis and display.
Emergency managers need real-time data from multiple systems, brought together in a common operating picture, with secure and controlled workflow capabilities to ensure the right level of information is shared across one or multiple agencies or departments.

![Fig. 5 The workflow of GIS](image)

3. APPLICATION OF MULTI-MODEL FORECASTING SYSTEM

Multi-model forecasting system provides direction, guidance, and assistance in implementing the wildfire situational awareness to assist an effective and efficient response to wildfire incident (Fig. 6). As shown in figure 6, wildfire emergency managers should conduct periodic wildfire situational awareness during the whole incident disposal cycle.

![Fig. 6 Workflow of multi-model forecasting system during a wildfire incident](image)

When wildfire incident occurred, the basic and on-scene information should be collected as soon as possible, including land use information, vegetation cover information, protective target information, resource information, wild land and urban interface information, fuel information, weather information, tactical management area information, shelter information, damage information, resource requirement information, population information, water resource information, traffic information and so on.

Based on on-scene fire behavior and predicted weather information, the wildfire behavior prediction model can predict the potential fire behavior, including estimation of potential head fire spread rate, fuel consumption, and fire intensity, as well as fire descriptions, and then the emergency managers can get the potential fire area, perimeter, perimeter growth rate, and flank and back fire behavior. Finally, incident managers can get the resource estimations through resource scheduling model based on prediction resource requirements, on-scene resource requirements and the availability of the resources. Situational awareness is periodically conducted until the end of the whole incident disposal.

The core target of emergency management is collecting, analyzing and sharing information and effective response. GIS provides a common operating platform to realize new developments to be quickly posted onto a map to ensure the right level of information is shared across one or multiple agencies or departments.

4. CONCLUSION

Multi-model forecasting system can tell the incident managers what happened, how it happened, what will happen next, and if it happen what should we do? Also, the multi-model forecasting system assist an effective information exchange spanning all levels of emergency managers. A quick and efficient response to a wildfire emergency is reached due to multi-model forecasting system when professional situational awareness is provided to assist incident managers to have immediate access to the essential information they need.

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REFERENCES


