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Chapter 3

Forest Fire Monitoring

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Additional information is available at the end of the chapter

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Abstract

Thousands of hectares around the globe destroyed by forest fires every year causing tragic loss of houses, properties, lives, fauna and flora. Forest fires are a great menace to ecologically healthy grown forests and protection of the environment. This problem has been the research interest for years, and there are a number of solutions available to resolve this problem. In this chapter, a summary is given for all the technologies that have been used for forest fire detection with explanation of what parameters these systems looking for to understand the fire behaviour.

Keywords: forest fire detection, forest fire monitoring, forest fire system, forest fire behaviour, fire early warning systems

1. Introduction

Forests play a vital role in maintaining the Earth's ecological balance. Unfortunately, the forest fire is usually only observed when it has already spread over a large area, making its control and stoppage arduous and even impossible at times. The result is irreparable damage to the atmosphere and environment, where 30% of CO_2 in the atmosphere produced by forest fires [1, 2]. Among other consequences of forest fires are long-term disastrous effects such as impacts on local weather patterns, global warming and extinction of rare species of the flora and fauna.

Forests are vast remote abandoned areas, full of highly combustible material with dry leaves and branches to the Earth surface composites, where these are perfect to act as a fuel source for fire ignition and later fire stages. The fire ignition may be caused through human actions or by natural reasons. The initial stage of ignition is normally referred to as "surface fire" stage. This may then lead to feeding the fire flame, thus becoming "crown fire." Mostly, at

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this stage, the fire becomes uncontrollable, and the damage to the landscape may become excessive and could last for a very long time depending on prevailing weather conditions and the terrain.

2. Problem size

Forest fire is a global environmental problem causing extensive damage every year. According to International Union for Conservation of Nature (IUCN) Report "Global Review of Forest Fire 2000," wild fire is a natural phenomenon. However, over 90% of all wildland fires are due to human action causing significant forest loss, that is 6–14 million hectares of forest per annum, and 30% of the CO_2 in the atmosphere produces from forest fire. This leads to enormous economic losses, damage to environmental, recreational and amenity assets, global warming and loss of life. There is a strong recognition that action is needed to catalyse a strategic international response to forest fires [3].

2.1. In the case of the USA

In the 2003–2004 wildfire sieges, CAL FIRE's fire suppression costs exceeded $252.3 million; property damage costs exceeded $974 million; 5394 structures were destroyed; and more than 23 people lost their lives as a result of California wildfires. "Increasingly destructive wildfires are ravaging homes and businesses in more than three-fourths of the states. One of the most devastating fires in recent history was the $1 billion Witch Creek Wildfire that decimated vast parts of San Diego County, California, in October 2007. By the time it was fully contained, the fire had burned an estimated 198,000 acres and damaged or destroyed more than 1200 homes and 500 outbuildings."

In terms of scale, the 2007 fire season was second only to last year in acres burned and costs expended. In 2007, there were 27 fires costing over $10 million whose total suppression cost approached $547 million, exclusive of burned area emergency rehabilitation costs. These fires alone accounted for just less than 3 million burned acres. All wildfire acres reported to the National Interagency Coordination Centre in calendar year 2007 totalled 9.32 million acres at a federal cost of approximately $1.8 billion. On 17 June 2002, an estimated $9,403,000 was spent battling 196 wildland fires that scorched over 51,000 acres of land in parts of 11 states in the USA [4].

Hundreds of thousands of acres is burnt within the wildland urban interface (WUI) each year. Each year, over $100 million is spent on suppression efforts and more in the disaster recovery phases of catastrophic, natural and/or human-caused hazards, but the losses continue to mount.

2.2. In the case of Canada

Canada has approximately 10% of the world's forests. However, about 7400 forest fires have occurred in Canada every year over the last decade, burning an average of 1.9 million hectares of forests. In British Columbia alone in 2006, which was not a peak fire year, there were 2590

forest fires destroying 131,086 hectares and costing $156 million. Fire suppression expenses during the last decade in Canada have exceeded the $500 million and almost hit the $1 billion a year. [Facts about Wildland Fire in Canada, 2012.] On 5 October 2009, for example, a huge fire in the San Bernardino National Forest, CA, burned 3500 acres. More than 500 firefighters found it hard to control due to the strong 72 km/h wind speed [5]. The story continued year after year in Canada (see **Table 1**).

2.3. In the case of Europe

On 14 August 2012, the following report was published in *ScienceDaily—'the 2012 fire season has been characterized by a high number of fires in the early season. Over 100,000 hectares had already been consumed by fire at the end of March. July brought critical fire episodes in Spain and Portugal, which led to a number of human casualties'*.

There was a high fire risk in southern Europe during the last period, specifically in France, Portugal, central and southern Italy, the Balkan region, Spain, Greece and Turkey.

The European Forest Fire Information System (EFFIS) provides monitoring and fire mapping, regular forecasts for fire danger up to 6 days in advance and provides near-real time estimations for fire damages across Europe.

Until present, almost 580,000 hectares, in the area monitored by EFFIS, have been burnt this year, which includes Europe, North Africa and Middle East countries [ScienceDaily 2012]. In August 2009, forest fires wreaked havoc in Greece (3700 acres, hundreds of houses). Also in 2007, there was a terrible fire in Greece.

Year	Number of fires	Number of hectares burned	Total cost (millions)
2006	2590	131,086	$156.0
2005	976	34,588	$47.2
2004	2394	220,516	$164.6
2003	2473	265,050	$371.9
2002	1783	8539	$37.5
2001	1266	9677	$53.8
2000	1539	17,673	$52.7
1999	1208	11,581	$21.1
1998	2665	76,574	$153.9
1997	1175	2960	$19.0
1996	1358	20,669	$37.1
1995	1474	48,080	$38.5

Table 1. Forest fire in Canada [5].

2.4. In the case of Australia

On 21 November 2009, in Tasmania, Australia, a horrible forest fire was reported [5]. Some of the fires could be natural disasters or directly or indirectly the product of human negligence and abuse of the environment (including the rise of temperature associated with the global warming).

"In February 2009, Victoria was devastated by one of the worst bushfires in Australia's history. The Black Saturday fires caused many deaths and injuries and directly affected many towns and communities, destroying homes, businesses, schools and kindergartens. Key statistics from the Victorian Bushfire Reconstruction and Recovery Authority are:

- deaths 173
- area burnt 430,000 hectares (including 51 towns, 78 communities)
- total property dollar losses $1.35 billion
- homes lost 2129, valued at $713 million (includes contents and buildings)."
- Too many horrible fires occurred in Australian history, probably that resulted from its nature.

2.5. In the case of the UK

South Wales Fire and Rescue Service cover an area of 2712 km squared, which is divided into 10 "Unitary Authorities": Bridgend, Vale of Glamorgan, Rhondda, Cynon Taff, Cardiff, Caerphilly, Merthyr, Blaenau Gwent, Torfaen, Newport and Monmouthshire, where a population of 1.4 million covered by their services [6].

The Welsh society statistics provided by the Fire and Rescue Services of Wales continues to be high. It shows that, in purely economic views, the expenditure to Wales's areas in years 2006 and 2007 was £56.3 million. In South Wales area alone, the cost was about £35.2 million.



Figure 1. The aim of forest fire monitoring systems.

Forest fire monitoring systems can help in fire suppression. The fire department will receive the information and evaluate the situation. The known rules apply here: 1 min—1 cup of water, 2 min—100 liter of water, 10 min—1000 liter of water. The main aim of the systems is shown in **Figure 1**.

3. Overview of forest fire behaviour

Let us define the fire first:

"Combustion is a complex process in which fuel is heated, ignites, and oxidizes rapidly, giving off heat in the process. Fire is a special case of combustion—self-perpetuating combustion characterized by the emission of heat and accompanied by flame and/or smoke. With fire, the supply of combustible fuel is controlled by heat given off during combustion" [7]

Fire requires three components: fuel, heat and oxygen to be present. If one of the factors is missing, the fire will go out. There must be (**Figure 2**):

1. a source of fuel for combustion,
2. a source of heat to promote the reaction (the fire itself),
3. oxygen in fair concentration to maintain the reaction.

A forest fire is a dynamic phenomenon that changes its behaviour in time. Fire spreads through forest fuel. It is performed by a complex heat transfer and thermo chemical processes that determine fire behaviour [8].

There is more than 27 mathematical models defined to describe the forest fire behaviour; each model was built according to different experiences in different countries with forest fire. Every model differs from the others according to the input and the environmental parameters (fuel indexing [9, 10]). Researchers in some countries manage to use some of these models in simulation programs or even create their own methods for mapping the landscape and the fire behaviour on monitoring screens for analysis and expectation of fire behaviour to help the firefighters to determine the best method to extinguish the fire such as BehavePlus, FlamMap,



Figure 2. Fire triangle factors [7].

FARSITE, Geodatabase and ArcSDE. On the other hand, researcher's target is to find a reliable technology that can detect and localise the fire, help in decision-making of crisis possibility or a high fire risk situation. As a result, the fire can be extinguished in early stages within a short time to minimise the damage save lives, environment, firefighter equipment, time and effort.

A wildfire burning in constant environment takes the shape of an ellipse. Environment can be a variable of time. A fire might have different parts burning in different environments, such as moisture contents, wind speed, wind direction, slope and so forth. The environment heterogeneity might result in a very complex fire shape [7, 9] (**Figure 3**).

The fire parts are shown in **Figure 4**:

- A finger is a long, narrow extension of the main body of fire.
- A pocket is an unburned indentation of the fire perimeter surrounded on three sides by the fire.



Figure 3. Fire elliptical shape under constant environment.

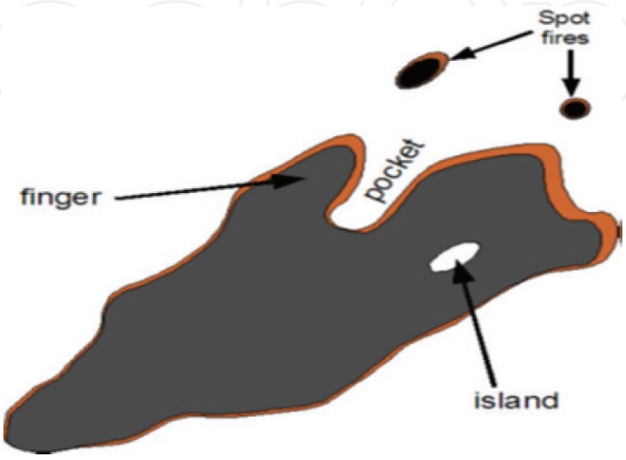


Figure 4. Parts of fire [7].

- An island is an unburned area surrounded by burned area within fire.
- A spot fire is a fire initiated outside the main fire.

These parts have no reference scales. For example, a finger might be one foot long or may exceed a one mile. Fingers might have fingers and spots might have spot fires.

The direction of the fire spread has two parameters: the maximum spread direction and long axis of the ellipse, as shown in **Figure 5**. The relative direction is the angle between the front flame orientation and the maximum spread direction.

Three types of fire propagation are as follows: ground fire, surface fire and crown fire. The perfect fire environment is a forest full of trees and shrubs, to start with surface fire then extend it through the tall trees to crown fire. At this stage, the fire will start to propagate, and it becomes hard to extinguish (**Figure 6**).

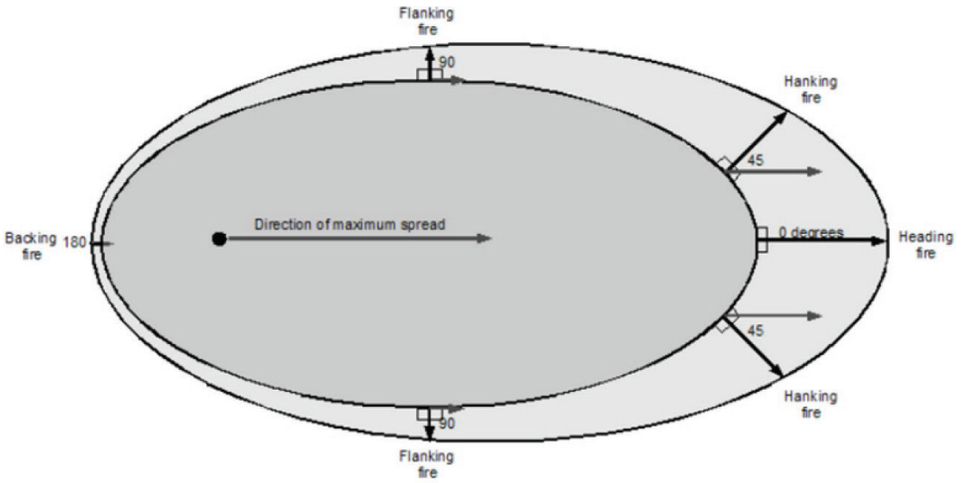


Figure 5. Fire spread directions [7].



Figure 6. Crown fire.

4. Monitoring systems

The information produced from monitoring can help the firefighters to understand the fire behaviour such as point of ignition, the spread speed and the direction of maximum spread. These parameters can be used as input for fire simulation programme to help extinguishing fire and provide safety to firefighter. Team work is very important for fire fighting to optimise the work with minimum efforts, minimum damage and the shortest time, for example, if the fire spread direction endangers human areas, the team priority target is to stop the propagation in that direction, so more firefighters should focus in that direction. On the contrary, to extinguish the fire with the shortest time, more firefighters can focus the team work on the mother/main fire not the finger to weaken the front flame, reduce the fire intensity, limit the spreading, reduce the dangerous and make it easier to extinguish (**Figure 7**).

4.1. Fire suppression authorities and detection techniques

The common techniques used by authorities for fire detection and suppression [1]:

i. controlled/supervised burning,

ii. fire and weather casting and estimation for the fuel moisture level,

iii. human watchtower,

iv. optical smoke detection,

v. light detectors to detect and coordinate strikes,

vi. infrared,

vii. spotter planes,

viii. water tankers,

ix. mobile/smartphone calls.

Detection and monitoring systems are divided into two main groups:

a. volunteer reporting-public reporting of fires, public aircraft and ground-based field staff,

b. operational detection systems: fire towers, aerial patrols, electronic lightning detectors and automatic detection systems.



Figure 7. Fire management.

Many techniques used in fire suppression in different countries, like using flying water tankers like in Canada and burning dry region under the supervision of fire fighters rather than having a crisis later. Other countries sweep away the surrounding area to stop spreading and isolate it as in the Middle East. Australian authorities sometimes leave the fire to burn, until it dies alone, if it causes no harm for humans or properties.

4.2. Satellite system

Earth-orbiting satellites and even air-floating devices have been employed for the observation and detection of forest fires. Satellite images generated mainly by two satellites launched specifically for forest fire detection purposes—the advanced very high resolution radiometer (AVHRR) [11] launched in 1998 and the moderate resolution imaging spectroradiometer (MODIS) [12] launched in 1999—have been used. These satellites can provide images of the Earth once every 2 days and that is a long delay for fire scanning; in addition, the quality of satellite images depends on weather condition [13].

Any satellite-based observation for forest fires suffers from severe limitations resulting in a failure in the speed of detection or the quality or the running cost to produce effective control for forest areas. Some limitations in observation of forest fires from geostationary (GEO) or Low Earth Orbit (LEO) satellite are as follows: it is impossible to provide a full coverage by using satellite monitoring. GEO and LEO satellites are located on orbits over 22,800 miles above the Earth's surface. Infrared radiations emitted by fire flames may be too feeble in intensity to be detected by satellites at early stage. The intensity of radiation decreases with the square distance, and the radiation beam angle of arrival in regards to the surface of the detector or camera. However, satellites are not the best choice to detect the forest fires at early stages.

Some satellites might not be equipped with detection of forest fires, such as transponders, frequency translation, amplification reception, regeneration, antennas and downlink transmission. In fact, formal allocation for appropriate frequency and bandwidth for forest fire detection purposes is not available yet.

4.3. Optical sensor and digital camera

Camera surveillance and wireless sensor network are the other available techniques for forest fire detection. The technology advancement of cameras, image processing, industrial computers and sensors resulted in advance automated for early warning systems. Many types of detection are used in terrestrial systems [14]:

- **i.** video camera system is able to recognise a spectrum of smoke and fire during day and night.
- **ii.** thermal cameras detect the heat glow of fire.
- **iii.** IR spectrometers are used for the identification of spectral characteristics of smoke
- **iv.** LIDAR (detection of light and range) systems measure reflected laser rays from smoke particles.

All variety of optical camera systems used different algorithms designed by experts, where all rely on the same general concept (smoke and fire glow detection). In general, cameras capture images every certain time, where images are number of pixels. The image-processing unit (1) tracks motion between sequenced images and (2) checks and compares pixels that contain smoke or fire glow. Then the results used in another algorithm to make a final decision whether the current situation requires action. Optical systems are integrated with geographical maps for localisation purposes (see **Figure 8**).

Use of a given type of camera or sensor depends not only on the specific conditions of the operation but also on the financial resources available. The following are some available systems in the market:

AlarmEYE is a video and infrared camera system used for to detect early forest fire. It is based on black and white colour frequency where the infrared filter can distinguish between heat vapour and flames. This system was produced and deployed in Thailand [16].

EYEfi SPARC. Optical sensors are produced by EYEfi, Australia, for forest fire detection. Optical sensors consist of:

i. camera (ultralow light grey scale at night and colour during the day)

ii. lightening detection sensor

iii. communication unit

iv. weather station

v. power system

vi. tilt zoom cameras can be added to the system

EYEfi cannot provide a smoke detection, but it is on the future plans. Simply, EYEfi can play a helping role in providing images for fire agencies after the operator spots smoke by using the

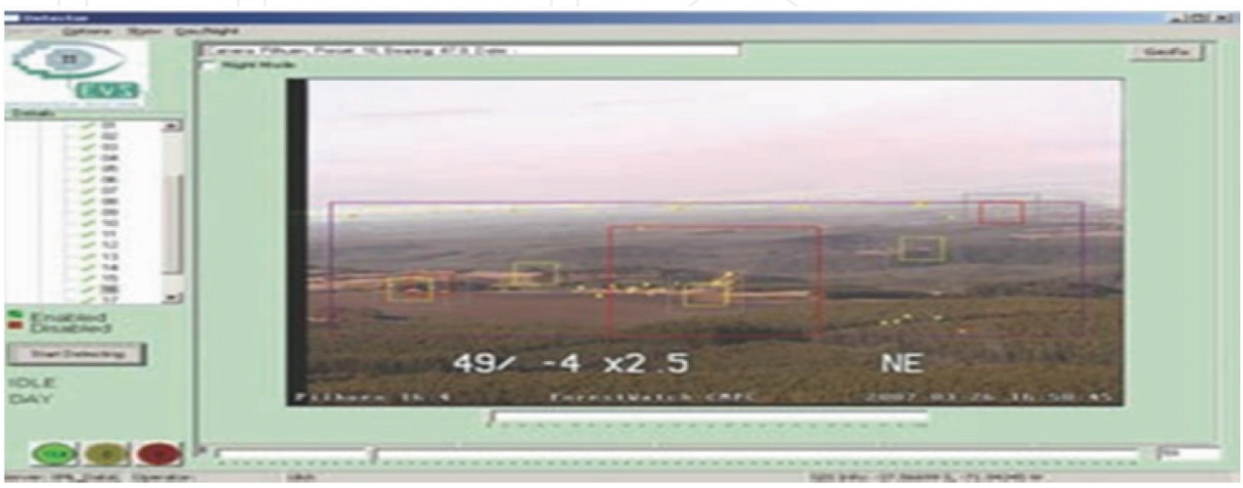


Figure 8. ForestWatch system [15].

EYEfi software and GIS map to localise the smoke position on the ground. A weather station and lightening detector are included in the system for more accuracy [14, 16].

UraFire system focused on reducing the number of false alarms by identifying smoke based on two inputs: (1) clustering motions and (2) a time input. The UraFire system is used and produced in France [14, 17, 18].

Forest Fire Finder is a unique, smart and complicated system based on atmosphere analysis instead of detecting fire glow or column of smoke. Forest Fire Finder tracks the way the atmosphere absorbs the sunlight. Naturally, the absorption depends on the chemical molecules or composition in the atmosphere. Different composition has different absorption behaviours; therefore, Forest Fire Finder can define different kinds of smoke based on the source in a range of 15 km, such as the organic smoke from burnt trees and the industrial smoke. The equipment installed in tree crowns for faster detection, and this system is used in Portuguese forests [16, 19] (see **Figure 9**).

ForestWatch is an optical system based on sensor cameras, which provide a semiautomatic fire detection produced by Enviro-Vision Solutions, South Africa. The camera tower scans the forest in a range of 16–20 km for a column of smoke during day and fire glow during night. [20, 21]. ForestWatch consists of [15]:

i. a 360° Pan tilt cameras to allow +33 to −83 tilt from horizon, with 24× optical zoom,

ii. telecommunications system such as microwave, 3G or satellite,

iii. image sampling engine,

iv. processing software to evaluate the current situation.

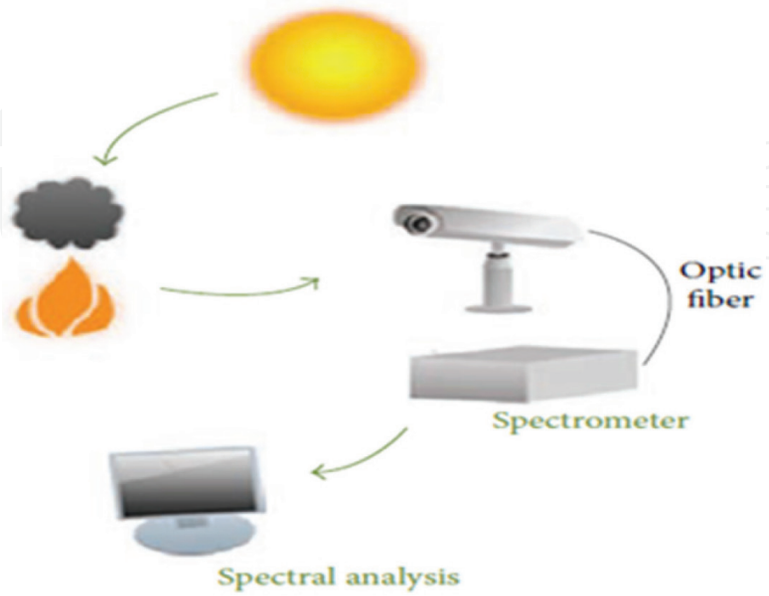


Figure 9. Forest fire finder.

The most popular system in forest fire detection is ForestWatch. On the contrary, only Canada has documented its own experience with the system. Canada pointed that fires were detected in a range of 20 km reliably, but a large number of faulty alarms were also generated. Operational ForestWatch systems are in use in the USA (22 towers), Canada (4 towers), South Africa (83 towers), Chile (20 towers), Swaziland (5 towers) and Slovakia (4 towers). A pilot scale operation (2 towers) is installed in Greece [20, 21].

FireWatch has been studied for years (since 1992) in Germany, and now it is produced by German Aerospace Institute (DLR). It is an automatic smoke detection within a range of 10–40 km. FireWatch systems are used in Estonia (5 towers, 1 control room), Germany (178 towers, 22 control rooms), Mexico (1 tower, 1 control room) and Cyprus (2 towers, 1 control room). Pilot systems (1 or 2 towers) are in use in Italy, Czech Republic, the USA, Spain, Greece and Portugal [20]. FireWatch components consist of [22]:

i. Optical sensor system (OSS): the optical system performs a 360° rotation once every 4–6 min during day and 8–12 min during night in 10-degree steps.

ii. Data transfer: wireless connection between OSS and officer computer.

iii. Central office: the work space/area (computers, monitors and printer) (see **Figure 10**).

FireHawk. A risk management system that can localise fire consists of the following layers [14]:

i. imaging layer: represents cameras installation on suitable positions,

ii. communication layers: wireless links,

iii. machine vision layer: FireHawk uses the GIS and the ForestWatch software to localise and find the shortest path to the fire. FireHawk is deployed in two areas in South Africa.

The Bushfire Cooperative Research Centre in collaboration with the Australian government published a very interesting report about the experience of using three optical systems. The target is to testify the performance of each one of the systems compared to normal human

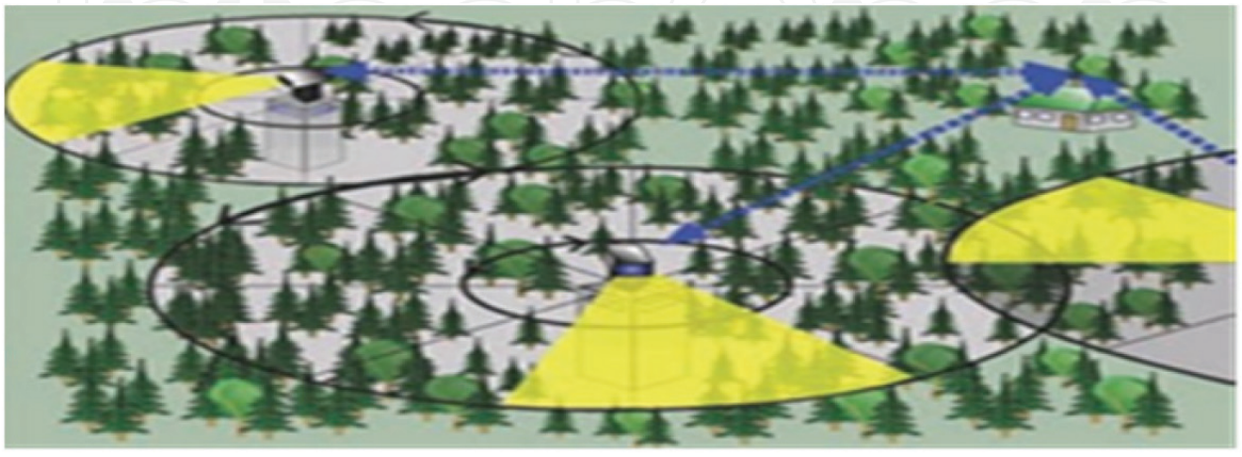


Figure 10. FireWatch [22].

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observation towers [20]. The report provides full details about the project, environment, experiment, analysis and results. The three systems used in this project are FireWatch, EYEfi and ForestWatch in 2010, all of which had been tested on three kinds of fires: agency burning, private burning and research burning in Otway Ranges in Victoria and Tumut in NSW (see **Figure 11**).

Some of the results explored on the NSW trials are shown in **Table 1**:

i. More than 250 private fires were reported in the study area. A high proportion of them were reported by observation towers not by cameras.

ii. Thirty-seven prescribed fires and burn-off fires were conducted as part of land management tasks during the post fire season in NSW forests, National Parks and Wildlife Service and Victorian Department of Sustainability and Environment. One unplanned bushfire was reported in Victoria and none in NSW.

As a result of this project, the trained human tower observer is more reliable and faster than the three systems together, and it is not possible to rely on optical cameras only. However, it might be useful to improve the performance of human observer or cover unstaffed tower or remote areas. They indicate that FireWatch detected more fires than the other systems and the only system to report the forest burns, although the detection was 35 min later than the human tower detection and the fire was five times bigger. The system performance was partially a function of distance from camera and the size of the fire; moderate burns (10–20 km) were missed while large burns were detected at long distances (70 km). The systems are not able to take landscape topography in calculation, which leads to misallocation of the fire. The causes for that are shown in **Figure 12**.

They concluded the report with the following points.

i. Cameras are not suitable replacements for trained human observation tower.

ii. Human towers and optical systems were used for forest fire scanning for column of smoke. There is a delay between ignition time and a noticeable column of smoke that can be detected by optical cameras or human.

iii. Landscape appearance, atmosphere conditions, and the properties of the smoke are different from one country to another.



Figure 11. Tower in Tumut, Australia, with the three systems [20].

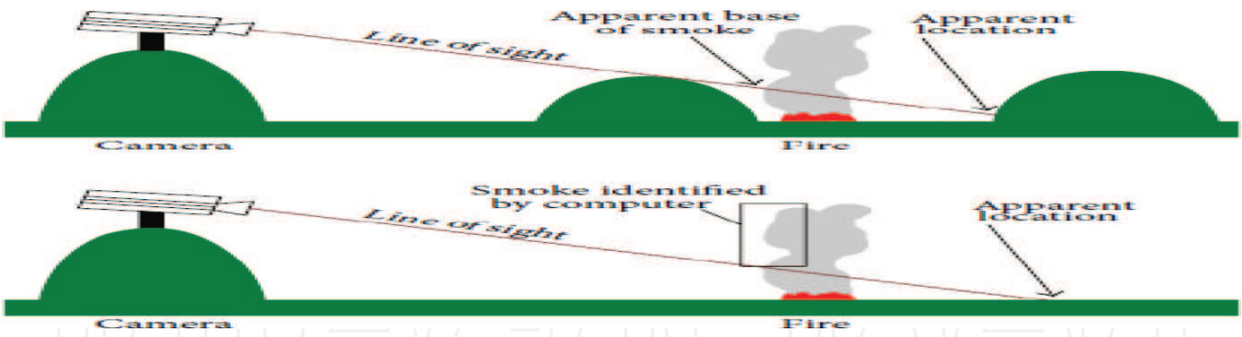


Figure 12. Localisation error reason [20].

Optical systems require more improved and intelligent algorithms and techniques in regard to the number of faulty alarms caused by various dynamic phenomena such as reflections, wind-tossed trees, human activity and cloud shadows. Processing landscape images is very difficult due to nature variety and to the dynamic events that may cause various illuminating, which depends on distance, weather, masking objects, time of day and so forth. These events produce dynamic envelopes, which are not always caused by motion and consist of time-varying grey levels of connected pixels in several image regions.

Optical cameras are designed to cover large areas (in a range of 15–80 km) with a minimum number of camera towers, and they can only provide a line of sight vision, which is a problem in the forest areas, as hills, high trees and mountains might block the vision. Weather condition and night vision reflect on the camera performance.

Camera surveillance technology with short distance links was also tried, despite the need for manual installation for every camera in a suitable position. Still the line of sight images, bad weather image, night images and high probability of false alarms for the following reasons: (1) daily motion of the Sun, (2) vegetation, (3) variation of atmospheric extinction and (4) moving clouds.

Finally, optical systems are extremely expensive; optical tower might worth more than $30,000 per tower, and there is a need to build these towers and install a communication infrastructure in the remote areas inside the forests.

4.4. Wireless sensor network

The line of sight problem of optical cameras in forests can be solved with the second type of sensors. A new technology called wireless sensor network (WSN) can be deployed in large number of systems, one potential application is forest fire detection. The same printed circuit board integrates the wireless transceiver, sensors and data processing. Sensors are able to influence the physical parameters such as pressure, temperature, gases, radiations, humidity and many other parameters. Sensor network normally deployed in a large-scale random distribution on remote or inaccessible places and under harsh environment for a certain period of lifetime. This technology relied on low data rate and short ranges of communication with multi-hope fashion to reach the sink.

The recent advancement in sensor network technology has made it possible to use this technology in early forest fire detection. A number of studies have considered using WSN in wood fire systems.

Spain used a sensor network and IP cameras to detect the fire ignition by sensors and use the closest camera to provide images for fire. Spain tried four IP cameras where they installed manually in the forest and images are heavy load on such a limited resources network such as sensor network [23].

Forest Fire Surveillance System (FFSS) is a South Korean system. The surveillance is done by sensor network to observe illumination, temperature and humidity. These readings go into a database to make a daily calculation and comparison in order to evaluate the hazards [24].

FireWxNet is a system target to study the forest fire behaviour not detection. The system uses wireless sensor network to provide data for weather status and web cameras to provide images for the fire. The system uses a tiered structure, which starts with directional antennas on the top of mountains and ends with multi-hope sensor network to observe the required environmental parameters. They used web cameras to provide vision data as well, and they equipped the sensors with a small GPS device to provide the location information (see **Figure 13**) [25].

It is a very smart system proposed in Canada. The system based on fire weather index (FWI) to calculate the probability of fire and the spread speed of the fire. The model provides the fire probability, spread speed, weather observation, moisture content and the fuel codes, which is divided into the following three types to describe the soil content of forest ground [26].

i. Fine Fuel Code (FFMC) represents the litter and fine fuels for 2 cm deep.

ii. Duff Moisture Code (DMC) represents moisture content of decomposing organic material for 5–10 cm deep.

iii. Drought Code (DC) represents the moisture organic content for 10–20 cm deep (see **Figure 14**).

It is a Forest Fire Detection project in Pennsylvania [27]. The system uses fire sensors and GPS devices. The project has two aims: (1) rely on the existing technology and (2) replace all the existing fire detection techniques with more efficient ones.

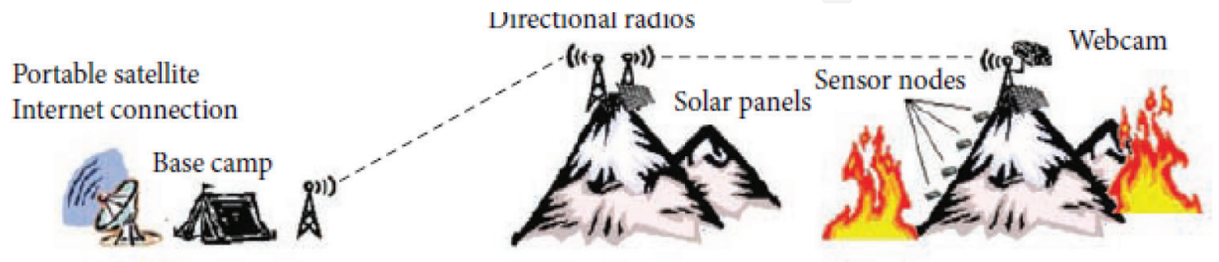


Figure 13. FireWxNet [25].

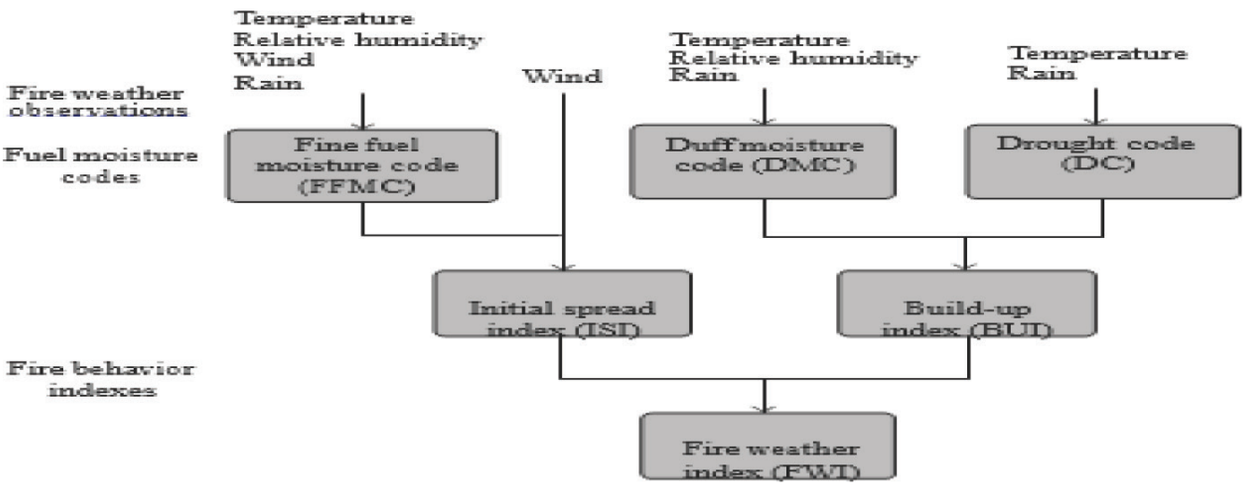


Figure 14. FWI system [26].

The project plan is to install 12,000 units within 48 months, 4000 devices every 12–15 months. When the sensor detects fire or smoke, a signal is sent through GPS device to Satellite, and then Satellite will forward the signal to monitoring screen and other handheld devices (see **Figure 15**).

Inner magnolia forest fire research has been done by a system of three parts: (1) monitoring, (2) information management and database system and (3) decision-making system. The system provides a fire simulation from the field images in 3D maps by using Geodatabase and ArcSDE programs for fire simulation [28].

FIRESENSE (Fire Detection and Management through a Multisensor Network for the Protection of Cultural Heritage Areas from the Risk of Fire and Extreme Weather Conditions, FP7-ENV-2009-1-244,088-FIRESENSE) [29] is a Specific Targeted Research Project of the European Union's 7th Framework Program Environment (including climate change). The FIRESENSE FP7 is a target to monitor remote areas and provide warning system. FIRESENSE is a very advanced system; it relies on IR, optical, temperature sensors, PTZ cameras and weather stations. All these sensors collect and process data to provide a clear understanding for the event to the local authority. The project deployments will be in Turkey, Italy Tunisia and Greece (see **Figure 16**).

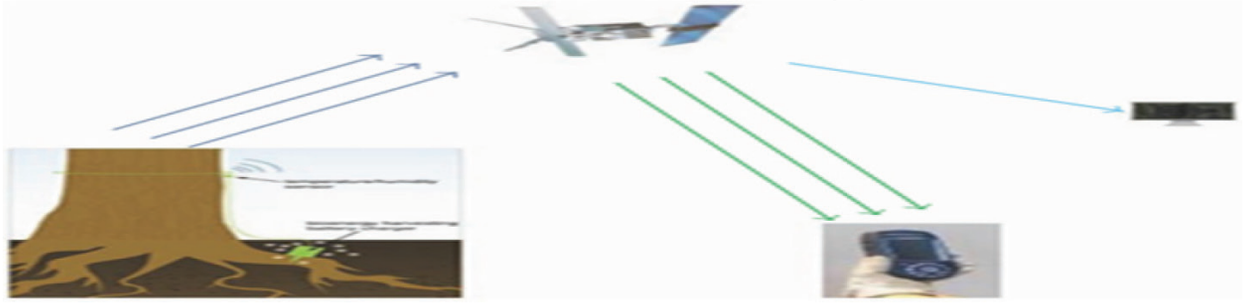


Figure 15. Pennsylvania project [27].

http://dx.doi.org/10.5772/intechopen.72059

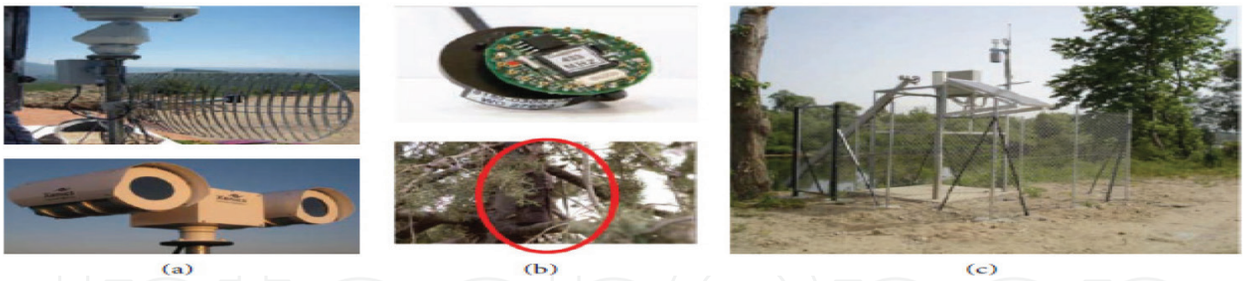


Figure 16. FIRESENSE FP7.

FP7 relies on complicated models, algorithms, concepts and comparisons. They are given as follows:

i. Scene model (Planck's radiation formula): the heat flux, thermal emitting, smoke, the fire, the reflectance, flickering, absorption emission lines, analysis of the atoms (e.g. potassium) and the molecules (water and carbon dioxide) are characteristics to be investigated.

ii. Thermal heat emitted from the background, sunlight reflection, clouds shadow, the buildings and the sky polarisation.

iii. Atmosphere gases (N2, O_2, CO, CO_2, H_2O, etc.); each gas behaves and absorbs differently; water vapour concentration; carbon dioxide is more uniformly distributed—its value is larger over industrial cities and vegetation fields than over oceans and deserts. **Figure 17** shows the physical aspects related to forest fire detection.

Libelium [30] is a Spanish wireless sensor network company. They named their product Waspmote and proposed it for many WSN applications such as forest fire detection, smart cities, water pollution and many other applications. With regard to forest fire detection, they used Waspmote nodes equipped with GPS device for localisation, and gas boards to measure temperature, carbon dioxide (CO_2), carbon monoxide (CO) and humidity for detection. Libelium deployed 90 nodes with solar panels for power scavenging to measure parameters every 5 min (see **Figure 18**).



Figure 17. How FIRESENSE analyse images [29].



Figure 18. Waspmote and gas board [30].

Wireless sensor network technology usually deployed in large number that can observe and the surrounding environment, transforming it into electrical signals, to send to the sink in a multi-hop fashion for processing. By this way, there is no need to build towers or set up complicated communication links such as microwave and satellite. WSN works on short communication links fashion and can provide real-time monitoring, where using this technology for forest fire application requires a large number of randomly deployed nodes to provide a reliable network if the key issues were addressed for this network: (1) localisation, (2) coverage, (3) network life span and (4) fire detection method.

5. Summary of existing techniques

- The first technique is human observation towers, but this technique is inaccurate and inefficient.
- Optical systems were used in many countries, and they also proved inefficiency due to camera manual installation and line of sight and night images problems.
- Satellite scanning is mainly done by two satellites: the Advance Very High Resolution Radiometer (AVHRR), launched in 1998, and the moderate resolution imaging Spectroradiometer (MODIS), launched in 1999. A full scanning for the Earth requires 2 days, which is considered long delay to detect the fire. Satellite images quality is related to weather conditions.
- Finally, WSN started to be considered as a partial solution, where this kind of technology is used together with other technologies such as IP cameras, weather databases and fuel databases.

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