With Large catastrophic wildfires becoming common, Technology coming to rescue for wildfire prevention, detection, and suppression

Since May 2, 2016 the Fort McMurray fire has decimated over 240,700 hectares of boreal forest and destroyed over 2,400 buildings. Insurance losses are estimated at over 9 billion Canadian dollars. Wildfires in Canada and the US burn an average of 54,500 square kilometers (13,000,000 acres) per year.

In the United States, there are typically between 60,000 and 80,000 wildfires that occur each year, burning an average of 7 million acres of land each year. For the last 10 years, the USFS and Department of Interior have spent a combined average of about $1.5 billion annually on wildfire suppression.

Communities across the Western U.S. and Canada may have to adapt to living with the ever-increasing threat of catastrophic wildfires as global warming heats up and dries out forests across the West, according to a University of Colorado study. “Neither suppression nor current approaches to fuels management adequately reduce vulnerability of communities to increasing wildfire,” said the study’s lead author, Tania Schoennagel, a research scientist at the University of Colorado-Boulder’s Institute of Arctic and Alpine Research. “We’ve been very effective with fire suppression for many years, but wildfires are increasing beyond our capacity to control, especially with more people in fire’s way.”

Between about June and October 2015 in Indonesia, more than 100,000 fires burned down millions of hectares of fragile forest lands. There were human and animal fatalities, and the economic damage was estimated to be more than $15bn (£10bn).

Over the past few decades, wildfire suppression costs have increased as fire seasons have grown longer and the frequency, size, and severity of wildfires has increased. Large catastrophic wildfires have become common, especially in association with extended drought and extreme weather. Worldwide damage from wildfires is in the billions of euros annually. Between 1997 and 2008 wild fires scorched 330-431 million hectares of global vegetation each year. That is an area nearly twice the size of Mexico. Disaster fires affect every region of the world and every vegetated biome.

Strategies for wildfire prevention, detection, and suppression

Strategies of wildfire prevention, detection, and suppression have varied over the years, and international wildfire management experts encourage further development of technology and research.

“According to the Paris Agreement, action on loss and damage could include developing early warning systems, emergency preparedness, and risk insurance. Currently less than half of the countries in the world have a national fire warning system in place. Fire warnings can be used to pre-position fire fighters and equipment, helicopters, and fixed wing air tankers,” write Z. Zommers, United Nations Environment Programme and others.

“Money for preparatory action can also be released based on pre-defined thresholds within forecasts. Such “forecast based action” is being tested for other climate extremes in Peru and Uganda by the Red Cross and the World Food Program is linking “climate and hazard forecasting with flexible multi-year financing”.

Prevention

Wildfire prevention refers to the preemptive methods of reducing the risk of fires as well as lessening its severity and spread. Effective prevention techniques allow supervising agencies to manage air quality, maintain ecological balances, protect resources, and to limit the effects of future uncontrolled fires.

Wildfires are caused by a combination of natural factors such as topography, fuels and weather. Other than reducing human infractions, only fuels may be altered to affect future fire risk and behavior.

Wildfire prevention programs around the world may employ techniques such as wildland fire use and prescribed or controlled burns. Wildland fire use refers to any fire of natural causes that is monitored but allowed to burn.

Controlled burns are fires ignited by government agencies under less dangerous weather conditions. Controlled burns are reportedly “the most effective treatment for reducing a fire’s rate of spread, fireline intensity, flame length, and heat per unit of area” according to Jan Van Wagtendonk, a biologist at the Yellowstone Field Station.

At the Canadian Forest Service’s Northern Forestry Centre headquarters in Edmonton, fire research scientist Kerry Anderson analyses weather information from 2,500 weather stations across North America and data from satellites passing overhead. “We enter that into the Canadian forest fire danger rating system to assess what the values are and what the fire danger is across the country," he said.

Mark Cochrane, a senior scientist at the Geospatial Sciences Center of Excellence at South Dakota State University, is using satellites data to determine the best techniques for preventing wildfires. "This information helps us understand how what we've done on the landscape affects fires now," Cochrane told LiveScience. Though it varies by region, forest thinning and prescribed burns – both of which aim to eliminate fire fuel before the fire occurs – seem to be the most effective methods, he said.

Building codes in fire-prone areas typically require that structures be built of flame-resistant materials and a defensible space be maintained by clearing flammable materials within a prescribed distance from the structure.

Detection

Fast and effective detection is a key factor in wildfire fighting. A small, high risk area that features thick vegetation, a strong human presence, or is close to a critical urban area can be monitored using a local sensor network. Detection systems may include wireless sensor networks that act as automated weather systems: detecting temperature, humidity, and smoke. These may be battery-powered, solar-powered, or tree-rechargeable: able to recharge their battery systems using the small electrical currents in plant material.

Larger, medium-risk areas can be monitored by scanning towers that incorporate fixed cameras and sensors to detect smoke or additional factors such as the infrared signature of carbon dioxide produced by fires. Additional capabilities such as night vision, brightness detection, and color change detection may also be incorporated into sensor arrays.

Satellite-mounted sensors such as Envisat's Advanced Along

Track Scanning Radiometer and European Remote-Sensing Satellite's Along-Track Scanning Radiometer can measure infrared radiation emitted by fires, identifying hot spots greater than 39 °C (102 °F). The National Oceanic and Atmospheric Administration's Hazard Mapping System combines remote-sensing data from satellite sources such as Geostationary Operational Environmental Satellite (GOES), Moderate-Resolution Imaging Spectroradiometer (MODIS), and Advanced Very High Resolution Radiometer (AVHRR) for detection of fire and smoke plume locations.

However, satellite detection is prone to offset errors, anywhere from 2 to 3 kilometers (1 to 2 mi) for MODIS and AVHRR data and up to 12 kilometers (7.5 mi) for GOES data. Satellites in geostationary orbits may become disabled, and satellites in polar orbits are often limited by their short window of observation time. Cloud cover and image resolution and may also limit the effectiveness of satellite imagery.

Satellite and aerial monitoring through the use of planes, helicopter, or UAVs can provide a wider view and may be sufficient to monitor very large, low risk areas. These more sophisticated systems employ GPS and aircraft-mounted infrared or high-resolution visible cameras to identify and target wildfires.

In recent fires in canada airborne infrared scanner was used to know where these ground fires are and information is relayed to ground on a map with co-ordinates. "The ground crew can then take those co-ordinates and pinpoint the exact location of underground fires using GPS. The firefighters systematically go through and knock them off," Wildfire ranger Dan Gorzeman said

Military technology tested to track, map

wildfires

This high-powered Synthetic aperture radar (SAR) sensor technology, used by the military in combat zones for years, is now being tested by the San Diego Fire-Rescue Department to help fight wildfires and provide early warning for evacuations. Flying

Linden Blue, chief executive officer of General Atomics Aeronautical Systems, said the manned aircraft flying at altitudes of 13,000 to 15,000 feet, can stay far above air tankers and firefighting helicopters, smoke plumes and low clouds , collecting video and data, for four to six hours at a time. SAR allows to see through the clouds, smoke, even treetops, to find flames as well as hot soil. After testing the equipment using the plane, Blue said they would like to expand to using an unmanned aircraft.

“This year we’re adding an element that’s going to make our city safer,” Mayor Kevin Faulconer said. He said the General Atomics senors will “revolutionize the way we attack wildfires,” offering advanced, real-time data.

Fire Chief Brian Fennessy said the technology includes the ability to relay communications between dispatchers and firefighters isolated in canyons and even to track the firefighters for their safety. Evacuation warnings could be made more timely with mapping that shows precisely which way flames are moving.

Drones

For the first time, firefighters have deployed a Predator drone to fly over the Rim Fire in Yosemite, Calif. In contrast to a manned airplane, the remotely piloted aircraft doesn’t risk the life of the pilot, and can fly over the fire for much longer. Firefighters are using information gathered by the drone to guide the allocation of firefighting resources on the ground to where they are most needed. The aerial view also reveals the location of critical infrastructure such as power lines, gas lines and water systems in the fire's path.

An integrated approach of multiple systems can be used to merge satellite data, aerial imagery, and personnel position via Global Positioning System (GPS) into a collective whole for near-realtime use by wireless Incident Command Centers

Robots : Thermite

Fire-fighting bots such as Thermite, developed by Howe and Howe Tech, are remote-controlled machines with multi-directional nozzles backed by pumps that deliver up to 600 gallons of water per minute. These robots help first respondents by reducing the flames, enabling firefighters to get reach otherwise hostile environments after industrial, nuclear and chemical fires.

Suppression

Once a wildfire gets going, containing the blaze is the immediate priority. The standard response includes fire trucks (and related equipment), ground crews, bulldozers and aircraft. On the ground, firefighters lay down fire hoses along the fire's edge, every 100 feet (30 meters) or so. Then firefighter crews or bulldozers create what's known as a firebreak or fire line around the perimeter of the blaze, a strip of land or trench where any potential fuel — such as dry brush or grass — has been removed.

"We don't want the fire to come out of that area, and the only way to do that is to remove any fuel," Julie Hutchinson, said battalion chief of the California Department of Forestry and

Fire Protection (CAL FIRE).
Aircraft play an important role, too. Helicopters fly over and dump water or sometimes suppressant foam on fire hotspots. The foam acts as insulation to prevent unburned fuels from catching fire.
Silver iodide can be used to encourage snow fall, while fire retardants and water can be dropped onto fires by unmanned aerial vehicles, planes, and helicopters.

Fire retardant

Fixed wing aircraft called air tankers fly over the blaze dumping flame retardant chemicals, such as ammonium phosphate
Fire retardants are used to help slow wildfires, coat fuels, and lessen oxygen availability as required by various firefighting situations. They are composed of nitrates, ammonia, phosphates and sulfates, as well as other chemicals and thickening agents. The choice of whether to apply retardant depends on the magnitude, location and intensity of the wildfire.

Fire retardants are used to reach inaccessible geographical regions where ground firefighting crews are unable to reach a wildfire or in any occasion where human safety and structures are endangered. In certain instances, fire retardant may also be applied ahead of wildfires for protection of structures and vegetation as a precautionary fire defense measure.
The application of aerial fire retardants creates an atypical appearance on land and water surfaces and has the potential to change soil chemistry. Aerial uses of fire retardant are required to avoid application near waterways and endangered species (plant and animal habitats).

Complete fire suppression is no longer an expectation, but the majority of wildfires are often extinguished before they grow out of control. While more than 99% of the 10,000 new wildfires each year are contained, escaped wildfires can cause extensive damage.

DARPA’s Persistent Close Air Support (PCAS) Technology for battling Wildfires

DARPA’s Persistent Close Air Support (PCAS) program seeks to fundamentally increase CAS effectiveness by enabling soldiers and combat aircrews to share real-time situational awareness, and weapons system data and reduce engagement time to as little as six minutes.

DARPA collaborated with firefighters to test the potential value of PCAS technology for these public servants who face challenges when battling wildfires similar to those that troops face in battle—the need for situational awareness, precise coordination of airborne water drops and ensuring fellow firefighters are kept safe from rapidly moving and shifting flames.

They developed Fire Line Advanced Situational Awareness for Handhelds (FLASH) prototype system that includes a ruggedized tablet computer and MANET-capable radio that firefighters and other responders can wear, freeing their hands for other tasks in the field. The system overlays multiple streams of information from airborne sensors, firefighters and fire command posts onto a shared digital map visible via tablet computers.

The demonstration took place near where 19 firefighters from the Prescott Fire Department’s Granite Mountain Hot Shots unit gave their lives on June 30, 2013, battling the Yarnell Hill wildfire. The demonstration used Mobile Ad Hoc Networking (MANET) capable tactical radio of Persistent Systems, LLC.

Whatever goes into the radio, goes out everywhere on the network of nodes that make up the MANET. Users can tether mobile computers, cameras and sensors to the nodes to exchange video feeds, positional data, and, with the push of a button, voice to everyone on the network. The MANET forms automatically, routes data fast, and can grow and shrink as users move in and out of radio range. All of this happens without a central point of control.

Future technologies: Unmanned Ground Vehicles

The military has developing autonomous unmanned ground vehicles which can navigate on all kinds of terrains and which can carry variety of payloads including day night all weather surveillance, are expected to assist firemen in battle to prevent and contain wildfires. Canada used the all-terrain carrier called a Hägglund easily stores all the gear firefighters need to tackle any situation and rumbles effortlessly on its huge tracks over toppled trees, through thick mud and streams.

Big data and Social Media

Big data is already being used to understand and predict wildfire spread. Further into the future, artificial intelligence playing a larger role to fight fires on the ground will become commonplace.

“Crowdsourced information pulled from social media has been seen as a helpful tool to identifying the spread of wildfires and helping to deploy forces. Monitoring social posts for mentions or pictures of fire or smoke from at-risk locations could be an important data stream, thus creating an early warning system when wildfires start or spread. This could become particularly useful, given the increasing number of people choosing to live in and around the periphery of at-risk land," writes Joe Cecin in techcrunch.

Factors leading to wildfires

Wildfires are 'quasi-natural' hazards, meaning that they are not entirely natural features (like volcanoes, earthquakes and tropical storms). This is because they are caused by humans as well.

There are many factors that lead to wildfires, the major ones being the presence of fuels, a source of ignition and conducive weather conditions. The four major natural causes of wildfire ignitions are lightning, volcanic eruption, sparks from rockfalls, and spontaneous combustion.

The most common cause of wildfires varies throughout the world. In Canada and northwest China, for example, lightning is the major source of ignition. In other parts of the world, human involvement is a major contributor. In Mexico, Central America, South America, Africa, Southeast Asia, Fiji, and New Zealand, wildfires can be attributed to human activities such as animal husbandry, agriculture, and land-conversion burning. Human carelessness is a major cause of wildfires in China and in the Mediterranean Basin. In the United States and Australia, the source of wildfires can be traced to both lightning strikes and human activities such as machinery sparks and cast-away cigarette butts

Characteristics of Wildfires

Wildfires occur when all of the necessary elements of a fire triangle come together in a susceptible area: an ignition source is brought into contact with a combustible material such as vegetation, that is subjected to sufficient heat and has an adequate supply of oxygen from the ambient air. A high moisture content usually prevents ignition and slows propagation, because higher temperatures are required to evaporate any water within the material and heat the material to its fire point

A wildfire front is the portion sustaining continuous flaming combustion, where unburned material meets active flames, or the smoldering transition between unburned and burned material. As the front approaches, the fire heats both the surrounding air and woody material through convection and thermal radiation.

First, wood is dried as water is vaporized at a temperature of 100 °C (212 °F). Next, the pyrolysis of wood at 230 °C (450 °F) releases flammable gases. Finally, wood can smoulder at 380 °C (720 °F) or, when heated sufficiently, ignite at 590 °C (1,000 °F). Even before the flames of a wildfire arrive at a particular location, heat transfer from the wildfire front warms the air to 800 °C (1,470 °F), which pre-heats and dries flammable materials, causing materials to ignite faster and allowing the fire to spread faster

Wildfires have a rapid forward rate of spread (FROS) when burning through dense, uninterrupted fuels. They can move as fast as 10.8 kilometres per hour (6.7 mph) in forests and 22 kilometres per hour (14 mph) in grasslands. Wildfires can advance tangential to the main front to form a flanking front, or burn in the opposite direction of the main front by backing.
They may also spread by jumping or spotting as winds and vertical convection columns carry firebrands (hot wood embers)

and other burning materials through the air over roads, rivers, and other barriers that may otherwise act as firebreaks.

Wildfire Propagation Model

Wildfire modeling is concerned with numerical simulation of wildfires in order to comprehend and predict fire behavior. Wildfire modeling can ultimately aid wildfire suppression, increase the safety of firefighters and the public, and minimize damage. Using computational science, wildfire modeling involves the statistical analysis of past fire events to predict spotting risks and front behavior.

Modern growth models utilize a combination of past ellipsoidal descriptions and Huygens' Principle to simulate fire growth as a continuously expanding polygon.

At the Canadian Forest Service's Northern Forestry Centre headquarters in Edmonton, fire research scientist Kerry Anderson, also monitor fires that are burning and try to predict where they'll go next using computer models to spread a forest fire into the future.

These models provide a snapshot of the fire's potential, Hutchinson said. "Where it becomes important is when you start having multiple fires in a state, and you're having to allocate resources," she added.

Need for Fire risk management maps

"With data on fire ignitions, weather, vegetation and topography, we can build models to demonstrate how we expect a region to burn should it catch fire. These can show two things that are important to guide policy: the probability of burning, and the likely fire intensity. The first shows the chances of a fire taking hold, and the second indicates how severe the consequences will be," writes Marc-André Parisien in Nature.

"These maps show which areas, if they ignite, will burn at such a high temperature that attempts to fight the fire will never succeed. The only option is to evacuate, or not to live there in the first place. The maps can also identify parts of the forest where, because of the nature of the landscape and flora, fire would be easier to prevent and tackle. This knowledge can be used to allocate money and effort to places where mitigation is more likely to work."

"Continued human expansion into the Canadian boreal forest for natural-resource extraction and housing is inevitable. Risk-assessment maps can guide this new development and direct it to low-risk areas. Some of these places are obvious: new settlements could take advantage of natural firebreaks such as large lakes to help shield them."

"We're losing homes in fires because homes are being put into hazardous conditions," said Jon Keeley, a fire ecologist with the U.S Geological Survey (USGS). "The important thing is not to blame it on the fire event, but instead to think about planning and reduce putting people at risk."

"Ultimately, if our climate is changing, human systems must also change. Urban areas are expanding at a relentless pace. For communities to be truly sustainable, all of our systems—building codes, insurance policies, market-based incentives, community planning and early warning systems—must change to reduce risks. We need to have better ecosystem services management, and it needs to be integrated into a coordinated suite of policies that sustain human settlements in dangerously shifting conditions. Only then can we "dampen" loss and damage," write Z. Zommers, United Nations Environment Programme and others.

Reference and Resources also include:

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