Chapter 29
Forest Fire Detection Using Satellite Images

Kakarapalli Lalitha and Geesala Veerapandu

Abstract Forest represents a complex ecosystem on earth that is a refuge to several living beings such as plants, animals, birds and also a huge resource of minerals, lakes and rivers. It almost covers 30% land of the earth and is highly necessary to balance the ecosystem along with the climate. Therefore, the loss of forests is a severe disaster. Along with deforestation, forest fire has a major impact. Although, the wildfires are not in control fully and most of the time in the various region of the earth, which not only harm the climate but also make a very bad impact on the ecosystem. As forest fires are a very common phenomenon, some of the preventive actions and units are already defined such as McArthur Forest Fire Danger Index (FFDI), the establishment of a separate section in the disaster team for monitoring and assessment of wildfire but intense research for preventing wildfire is highly necessary. Nowadays, satellites are used to scan the earth's surface. This technique can also be used to detect forest fires. With the help of the spatial high-resolution imagery system, the hot spot areas can be accurately located for determining the forest fire's locations.

29.1 Introduction

Wildfires are one of the most challenging global environmental issues that cause significant harm to natural and environmental resources. Most cases of fire in forests occurred during the summer seasons. Once the spark takes place anyhow in the forest, the large unmanaged area is filled with dry woods and leaves which act as fuel to this spark and due to this favorable and highly flammable environment, the spark will turn into the uncontrollable fire within a few moments. Estimating the risk of forest fires would be a great help to disaster management authorities in taking the appropriate actions in order to minimize the losses in terms of the evacuation of the area and saving lives of animals as well as local residents [1–3]. A huge number of commercial

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fire detection sensor systems are available in the market, but all of them have their own limitations. For use in wide-open areas such as forests, certain parameters of these alarming systems such as response time, maintenance requirements, cost, etc. must be critically taken into account. As forests are a very important factor to maintain our ecosystem, hence it is highly necessary to prevent these forests from any losses to maintain the ecosystem balance of nature. For taking one example forests are highly needed to maintain our global climate stability. However, due to natural (e.g., forest fire disasters) and human-caused disturbances, the worldwide forest area has changed considerably, resulting in a deterioration of forest covering and carbon stores in terrestrial ecosystems, where a variety of living organisms and resources coexist. The most serious uncontrollable threat in the woods is a forest fire [4, 5]. To identify the event of forest fires in a stimulated time, a variety of methods have been used. One of the conventional ways to measure the intensity of the wildlife fire is named as McArthur Forest Fire Danger Index (McArthur FFDI). It is developed by the scientist A. G. McArthur in 1960. This method necessitates a significant amount of data from numerous sources, as well as a lengthier computation time. McArthur FFDI is calculated using meteorological stations and ground data. However, collecting these diverse data sets for the assessment of fire hazards is quite challenging and also unavailable sometimes. These limitations motivate to pursue this research in pursuit of a universal approach to quickly assess fire threats and accounting for it as a huge disaster. Researchers worldwide are continuously working in the direction to minimize the losses due to the wildlife fire to save the climate. In this context, the goal of the study is to adapt the McArthur fire danger indicator by replacing its drought with a satellite-based indicator. Using satellite images to identify the wildfires are one of the potential techniques among all. In this technique, the images of the forest are captured by the satellite and with the help of image processing, these images are analyzed. As in the orbit of the earth, there are numerous satellites equipped with high-resolution cameras, this method is one of the most efficient techniques to detect the fire in forest in timely and help the disaster management team to make suitable plans, take appropriate preventive actions and analyse the risk factors in order to minimize the losses [6–8]. A block diagram of Fig. 29.1 stepwise approach of identification of the forest fire with the help of satellite imagery is given below.

In Fig. 29.1 all of these techniques consider weather factors while calculating a numerical index that measures fire danger. For fire and land managers, fire danger indices are critical indicators. The severity of a fire is usually defined as a number or an adjective. For analyzing the fire conditions in order to take preventive action, it is necessary to understand how fire affects the soil mantle, stems, and trees, as well as how to detect underground fires. All the influencing climatic variables such as air temperature, wind speed, relative humidity, the topography of the surface, etc. are also necessary to be taken care of. Using satellite images, help to make us understand the boundaries of fire regions and estimate their extent, these images also direct us toward the effects of fire in a specific circumstance, as well as the degree of difficulty to control it, which in turn enable us to take quick and cost-effective approaches to minimize the losses [9–13].

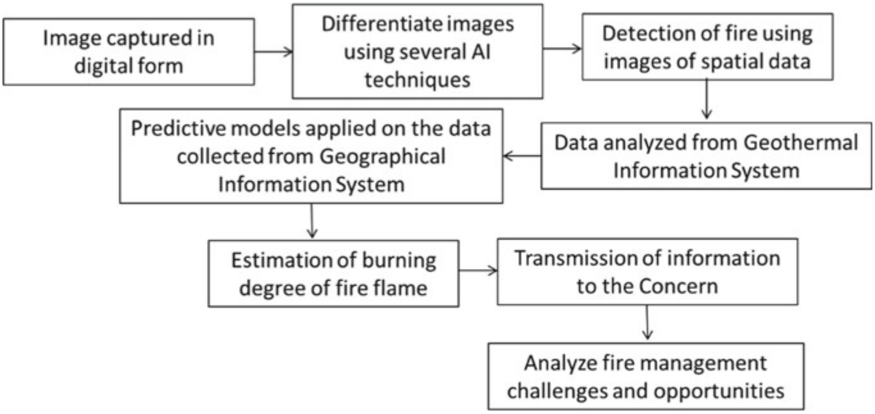

Fig. 29.1 Stepwise identification of detecting forest fire and its processing using satellite

29.2 Related Work

In the year 2003, Yong et al. concluded their study based on forest fire that occurred during May 4 to June 6, 1987, in northeast China and stated that the forests, as a complex ecosystem, provide a safe haven for all living creatures, including plants, animals, and birds, as well as numerous resources such as rivers, lakes, and minerals. Jungles encompass around 30% of the earth's surface. Satellites have been used to search for flames on the earth's surface. These satellites with identical orbits and having high-resolution spatial imaginary systems are used to capture the hot spot locations (using their zoom property) and correctly detect individual fires so that the type of cover impacted by the fire can be determined. Furthermore, satellite imaginary can be constructed at various scales, which is also helpful to estimate the factors accurately [1]. In the year 2007, Badrinath et al. performed their observation on the region of northeast India and presented their observations as tropical biomass ablaze and accompanying aerosol emissions into the environment contribute significantly to atmospheric disturbance and climate change. Using satellite data, this letter intends to investigate the influence of forest fires on aerosol concentration over this area. Also due to slash-and-burn agricultural techniques, the forests of this region are susceptible to catastrophic fire occurrences every year between January and May, the day-to-day active forest fire sites throughout the north-eastern region can be calculated by means of night-time satellite records from the Meteorological Satellite Program-Operational Line Scan system [2].

In reality, forest fire monitoring and assessment are critical components of good fire management. Estimating the risk of forest fires assists disaster management officials in taking the appropriate mitigation measures to reduce losses and evacuate local residents. Based on meteorological station parameters and ground datasets, fire hazard rating systems forecast the fire danger [3]. By using the image processing techniques for the identification of forest fires, at first, a model is required for fire pixel classification. In this rule-based color model, the RGB color spaces are used to develop an algorithm. In the year 2012, Vipin proposed a new color system model using Y Cb Cr color spaces and compare this with the conventional RGB model. In these two models, the YCbCr color system has the advantage of being able to differentiate brightness and chrominance better than RGB color space while comparing. These proposed algorithms' performances are evaluated using two sets of photos, one of which contains fire and another containing fire-like regions. The algorithm's performance is calculated using standard methods. The proposed method offers a higher detection rate as well as a reduced rate of false alarms. As the proposed system is computationally light, it can be used to identify forest fires in real-time [6].

Earlier, in the year 2005, Yu et al. presented a model using a genetic algorithm in which the cost function is minimized for unsupervised change detection in a forest fire with the help of multi-temporal satellite images. In this technique, at first, the multi-temporal satellite images are differentiated into two separate sections named "changed" and "unchanged", then the difference image is computed through the binary change detection mask realization with the help of a genetic algorithm. Now, determine the mean square error between the difference image values and its average for each of the regions and use the weighted sum of the MSE as a cost value for the corresponding change detection mask realization for both changed and unchanged regions. The final change detection is computed by applying the GA with the minimum cost. This minimum cost is evaluated using the initial realization of the binary change detection mask [7]. Apart from the summer season, the forest fire also occurs in the winter season. In the year 2017 Marchese et al. presented a new study in which the investigation has done on the winter fire regions. This study is basically a comparative study in which the RST-FIRES are compared with the well-established fire detection systems in terms of their appropriateness in identifying fires in the winter region. This investigation has done with the help of an Advanced Very High-Resolution Radiometer (AVHRR).

29.3 Forest Fire Detection Using Satellite

It is observed that despite the benefits of self-adaptive algorithms such as RST-FIRES at a local/regional level, the incidences of jungle ablaze in the winter season can easily be identified with the help of satellite images, which is a less complex process [8]. However, finding the smoke color, as a wildfire is identified in a smoke color, is a tedious job due to the variation in smoke color, environmental illumination and bad quality of images. It needed the appropriate combination of color space and pixel level. A variety of color space transformations are examined even from the non-smoke classes of pixels, between smoke and a mixture of color space and pixel-level for identifying an efficient smoke segmentation algorithm [9]. For detection and mapping of active forest fire using satellite data, two major algorithms are designed, which is based on brightness temperature band. From this study, it is observed that the short-wave infrared band is switched to the thermal brightness temperature band

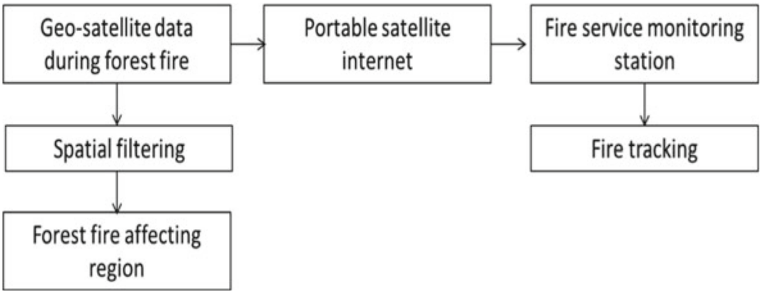

Fig. 29.2 Methods for detecting forest fire using satellite

if the data is collected during the night [10]. In Fig. 29.2 represents step by step approach of identification of the forest fire with the help of satellite imagery is given in Fig. 29.2.

As the forests are very wide-open areas and it is highly challenging to observe and control the fires in inaccessible and gigantic areas like a jungle. To address this issue Ganesan et al. proposed a new modified fuzzy c-means clustering approach in order to identify the probable region of wildfire using RGB and CIEL lab color space [11]. This early approximate detection of forest fire helps the forest management to make preventive action plans from spreading fire which causes severe ecological and financial damage. By using the negative relationship between the surface and land temperature, the threshold temperature can be calculated on which the probability of getting the forest fire is high. This computation is based on the differences in brightness temperature in remote-sensing data and an expected one derived from a regression model of brightness temperature and vegetation amount as indicated by the normalized difference vegetation index [12]. The experimental and technical research in the domain of fire monitoring is analyzed by Ruckchin et al. in the year 2015 and they proposed the algorithm for fire identification and its spreading rate measurement using satellite images. This technique is implemented in the smart telecommunication structures uses NM640X processor system which is equipped with the ability to learn the conditions of uncertainty [13]. Regardless, these advanced levels of findings and studies in this field are still needed improvement. This satellite-based wildfire detection is still immature and fails to a quick and efficient control forest fire. Due to the radiation beam and receiving signal direction and also because the intensity reduces with the inverse square of the distance, this technique suffers a great limitation as it could not identify forest fire at the initial stage.

29.4 Detection Result and Discussion

There were 140 firefighting agency reports in Japan airlines, 156 by USA and 52 flight reports in the Russian area that matched the satellite images. Its ground truth data and satellite pictures matched 4502 times, while Japan Airlines had only 450 such comparisons. As reported by the Russian agency, ground monitoring sites are not used to detect forest fires in incidents, according to the agency. Satellite photography can identify forest fires at a higher rate than traditional methods, despite its limitations. The oldest hotspot connected with each forest fire incident is determined by aggregating the comparative data, as illustrated. This is seen in Fig. 29.3. In other scenes, the forest fire region was not included in the time-series data. As long as there are hotspots, satellite imaging can help pinpoint a forest fire. As a result, we are able to detect forest fires earlier than local authorities. Fire detection success was characterized as a hotspot on a satellite image that corresponded to the fire. A comparable hotspot was identified within 10 km of the reported site for a period of 11 days surrounding the forest fire observation date. At least one hotspot on satellite imagery taken before the fire was seen qualifies as early discovery. The photographs we used were not geolocated due to technical concerns. Imagery from the Advanced Very High-Resolution Radiometer (AVHRR) provides an accuracy of up to 10 km without geolocation data. In addition, we defined the forest fire detection rate as the percentage of forest fires that were detected among the total number of forest fire reports made. Detection of forest fires was deemed a success by the number of fires that were noticed earlier than ground surveillance. According to our definition, successful early detection involves being able to detect reported fires before they are detected on the ground. We define early detection rate as the early detection rate of all reported fires. Forest fire detection rates are shown in Table 29.1.

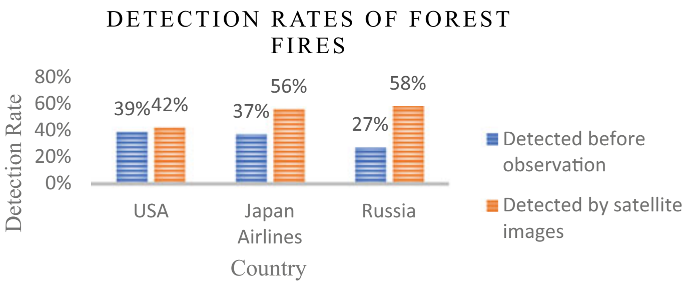

Fig. 29.3 Graphical representation of forest fire detection

Table 29.1 Detection rates of forest fires for each observation source

Fire observed by	No. of reports	Detected before observation	Early detection rate (%)	Detected by satellite images	Total detection rate (%)
USA	156	49	39	67	42
Japan Airlines	52	19	37	29	56
Russia	140	38	27	81	58
Total	348	106	31	177	52

Forest fire early detection rates were poor despite a relatively high fire detection rate, as seen in Fig. 29.3. Many of the pixels that match the reported flames are skewed and the detection analysis is limited. There was a considerable discrepancy between the observations of the firefighter and those of JAL's aircraft. Smaller flames can be seen by fire fighters' shorter observation distance of a few hundred meters in altitude. Location of nodes in a sensor network is optimized by minimizing the number of connections and computing costs. Estimation of the distance between regular nodes begins with head anchors and proceeds from there. A regular node's location is decided based on the anchor node's position. With a greater anchor ratio, location estimation becomes more accurate. There are a number of different ways to find grids, including anchor nodes with one and two hops and multiple hops. The average of the valid grids is used to identify the location of a normal sensor node. For the purpose of removing faulty grids and improving the accuracy of location estimates, head anchor information is used. A sensor network's accuracy in estimating position is increased by employing the ratio of anchor nodes to head anchors. The algorithm's accuracy grows as the number of anchors and anchors heads increases.

29.5 Conclusion

Wildfire is one of the major disasters for the ecosystem and the climate. If the ratio between the areas covered by forest and the human colony has misbalanced, the life on the earth will be in danger. This necessitates removing the forest fire at any cost. Among all of the conventional and modern techniques to identify and control forest fire, using satellite images is one of the efficient and effective methods. However, this technique has its own limitations but with the help of advanced image processing techniques and highly efficient complex algorithms, this technique has a major impact. Although, segmentation, illumination variation need to improve more in order to act this technique as a full proof and this study has still some deficiency but a mile to go with study and need to do a lot of research and improvements this method will act as a removal technique of wildfire.

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