forests

Review

Decision Support System Development of Wildland Fire: A Systematic Mapping

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Abstract: Wildland fires have been a rising problem on the worldwide level, generating ecological and economic losses. Specifically, between wildland fire types, uncontrolled fires are critical due to the potential damage to the ecosystem and their effects on the soil, and, in the last decade, different technologies have been applied to fight them. Selecting a specific technology and Decision Support Systems (DSS) is fundamental, since the results and validity of this could drastically oscillate according to the different environmental and geographic factors of the terrain to be studied. Given the above, a systematic mapping was realized, with the purpose of recognizing the most-used DSS and context where they have been applied. One hundred and eighty-three studies were found that used different types of DSS to solve problems of detection, prediction, prevention, monitoring, simulation, administration, and access to routes. The concepts key to the type of solution are related to the use or development of systems or Information and Communication Technologies (ICT) in the computer science area. Although the use of BA and Big Data has increased in recent years, there are still many challenges to face, such as staff training, the friendly environment of DSS, and real-time decision-making.

Keywords: wildland fire; forest fire; decision support systems; systematic mapping

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1. Introduction

Wildland areas tend to be complex environments that cover one-third of the Earth's surface [1]. These locations are affected by various environmental and anthropic factors and by fires, which are the most dangerous and destructive due to the speed of their propagation [2]. Approximately 67 million hectares were affected worldwide by wildland fires between 2003 and 2012 [3]. At present, despite a century of rapid technological advances, losses due to wildland fires continue to increase due to several factors [4]. The most significant is climate change, since it is the basis of a world trend in the increase of wildland fire activity. Another is the increase in communities on wildlands prone to fires due to vulnerable constructions that are poorly prepared for fires. Attempts at fire exclusion instead of land management have brought about ecological changes that are another factor to consider. In light of these issues, Finney described the prevention of disasters caused by wildland fires and the success in their management more completely as risk reduction [4].

In addition, the impact caused by a wildland fire can be seen based on the damage caused to the ecosystem (flora and fauna) and to all types of organisms existing in the affected perimeter, as well as a reduction in the regenerative capacity of the forest itself and conservation of the water resource [2]. Destructive and recurring (high-intensity) wildland fires are one of the greatest dangers to the viability and sustainable development of wildlands, and they affect the natural and cultural surroundings, the economy, and the quality of life of local and regional populations [5].

Wildland fires are classified into three categories according to their location and size. The first is known as an underground fire, where only the smoke is visible and no type of flame can be seen. The second classification is a surface fire, which means that smoke and flames are visible. If the second case cannot be controlled, then the third category is reached: the crown wildland fire, which is most noteworthy and known for its high flames and for engulfing large amounts of forest [6]. On the other hand, in the literature, we can also classify the different types of wildland fires as: prescribed or controlled and uncontrolled, which tend to grow indefinitely [7]. To act appropriately on a wildland fire and reduce the risk, one must be aware of the situation and know as many details as possible in order to make decisions. Situational awareness becomes a critical factor in any activity where the complexity negatively affects decision-making [8].

To support the decision-making, global predictions have been generated in specific areas through monitoring. This can be done using different technologies, such as satellite images, IoT, sensor networks, and many others [9]. Generating accurate predictions and monitoring fires and/or the biophysical variables involved becomes a key factor for scientists and authorities to estimate the economic and environmental consequences of the disaster, in addition to using these events as key data to avoid future fires [10]. However, the great heterogeneity of the information and the wide variety of technologies can be counter-productive, since depending on the land, environmental factors, sensors or satellites, the estimations, and results can vary drastically [10]. Hence, it becomes relevant to accurately select the tools and technologies to be applied in the development of the Decision Support Systems (DSS) used in management. Not considering the foregoing can generate an enormous cost in resources, not only in economic terms but also in the response time in combatting wildland fires [11]. The origin of DSS is the integration of two main research streams, the theoretical study of organizational decision-making (integrates intelligence, design, and choice) and interactive computer systems [12]. Since some years, DSS has incorporated other disciplines, such as artificial intelligence, operations research, organizational studies, and management information systems. On the other hand, these systems incorporate activities such as the acquisition of information relevant to the problem that needs a decision and action; the analysis of all the data to develop intelligent recommendations; the determination of the appropriate actions to achieve the objectives and solve problems; and the creation of a permanent record of acquisition, analysis, and application of information [13].

From here, the need arises to know the DSS for the existing wildland fire management so as to understand the different tools and technologies used in the different geographic areas and topographies around the world. To this end, the methodology of systematic mapping proposed by Petersen [14] was applied, based on the systematic review work proposed by Kitchenham [15]. The author adapted the methodology from the medical research sector for use in Information and Communication Technologies (ICT). The aim of the study is to present, through a general view of the DSS used to combat wildland fires, the different technologies used, the spheres where these systems are deployed, and the kinds of problems they solve. The key concepts related to the problem are relevant to the study if they are related to wildland fires. On the other hand, the concepts key to the type of solution must be related to the use or development of systems or ICT in the computer science area. Those documents that met both conditions were selected. We are aware that several papers that contain an important contribution to support decision-making were not selected, because they did not include a description of the system used.

The document will be structured as follows: Section 2 will present the background of the studies. Section 3 will present the research methodology and will detail the steps to be applied. Section 4 will detail the activities performed during the systematic mapping and its results. In Section 5, a discussion is presented regarding the most noteworthy contributions to the literature. Section 6 presents the limitations of this study. Finally, Section 7 contains the conclusions.

2. Background

2.1. Decision Support Systems and Wildland Fires

DSS are the area of the discipline of information systems (IS) that concentrates on supporting and improving managerial decision-making [16]. Given the research available on DSS, various definitions have been provided by scholars to present the differing perspectives on DSS [17]. According to Trianni et al. [18], DSS involves computer systems that address issues that could be a combination of structured and unstructured components. Romiszowski presented DSS as involving decision problems that were continuous and had programmed and unprogrammed components [19]. Samuel et al. [20] provided another perspective and presented DSS as how computers are involved in the decision-making processes as part of an overall system for organizations. The purpose of the development of a DSS is an attempt to improve the effectiveness of the decision-maker. In a real sense, DSS is a philosophy of information systems development and use and not a technology [21].

The origin of DSS dates back to previous works in two main research streams: the theoretical study of organizational decision-making that integrates three phases: intelligence, design, and choice and interactive computer systems [12]. However, the study of decision-making and DSS has evolved, incorporating other disciplines such as artificial intelligence, operations research, organizational studies, and management information systems that have added richness and complexity to DSS research.

In terms of contemporary professional practice, DSS includes support systems for personal decision-making (PDSS), negotiation support systems (NSS) [16], group support systems (GSS) [22], executive information systems (EIS), online analytical processing systems (OLAP) [23], intelligent decision support systems (IDSS) [24], business intelligence (BI) [25], and business analytics (BA) [21]. According to Arnott, each of these "DSS types" represents a different philosophy of support, system scale, level of investment, and potential organizational impact [21]. On the other hand, they can use quite different technologies and can support different management groups. Figure 1 broadens Arnott's analysis, including Big Data as a new type of DSS, since it combines BA with IDSS. The figure shows the evolution of DSS through partially connected subfields.

PDSS are small-scale systems normally developed for a manager, or a small number of independent managers, usually to manage a decision task that is made individually. A GSS consists of a set of software, hardware, language components, and software that supports a group of people who participate in a decision-making meeting [22]. In this case, the responsibility for the decision is shared by several managers.

NSS also operate in a group context, but as the name indicates, they involve the application of IT to facilitate the negotiations [16]. Two approaches arose, the first being problem-oriented and the second process-oriented [21].

AI techniques have been applied to support decisions, and these systems are normally called intelligent DSS or IDSS, although the term knowledge-based DSS has been used [24]. IDSS can be classified into two generations: the first involves the use of rule-based expert systems, and the second generation uses neuronal networks, genetic algorithms, and fuzzy logic.

On the other hand, a data warehouse is a multidimensional set of databases created to provide information on management indicators for decision-makers [23]. These systems provide processed data to support user-centered decision-making through PDSS, EIS, and OLAP.

The management of organizational knowledge (OK) has garnered a great deal of attention by executives and academics since the beginning of the 1990s. The action of organizations to manage what they consider knowledge is vital in their ability to increase innovation and the competitive edge and to support decision-making [21]. OK affects the entire organization and involves the management of several areas that include IT, organizational behavior, organizational structure, economics, and organizational strategy.

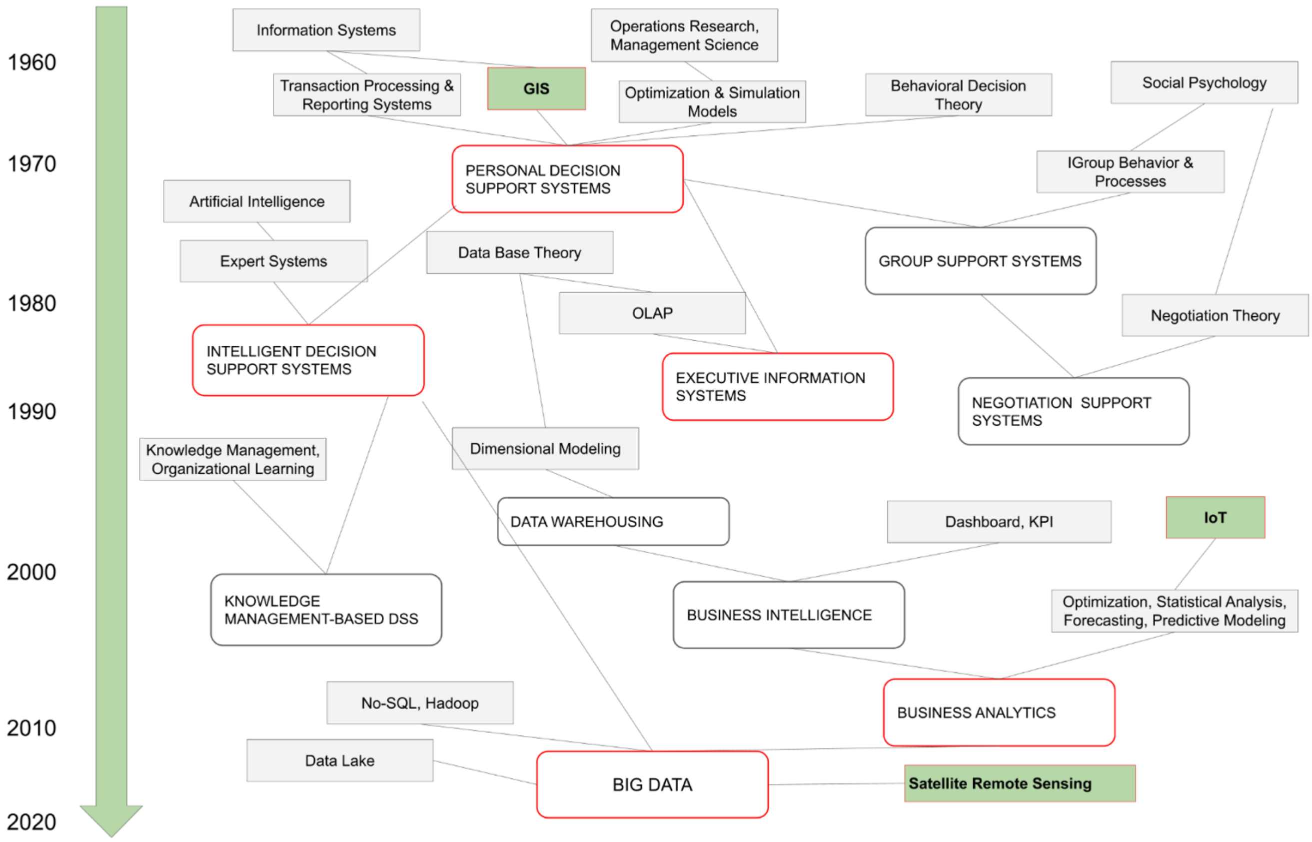


Figure 1. Evolution of DSS through partially connected subfields [21].

Analytics, BA, and BI are often used interchangeably in the business literature, and they convert data into useful information [25]. However, they differ in the purpose and methodologies used. BA sequentially applies a combination of descriptive (what is happening); predictive (why something is happening, what new trends may exist, and what will happen next); diagnostic (why it happened); and prescriptive (what is the best course for the future) analytics to generate new, unique, and valuable information that creates an improvement in the measurable commercial performance. The analyzed data can be obtained from commercial reports, databases, and commercial data stored in the cloud. On the other hand, BI concentrates on consultations and the generation of reports and can include information sent from a BA approach. BI uses OLAP to display management indicators through charts and pivot tables [23].

Big Data emerged as an ecosystem capable of successfully addressing contemporary digital challenges [26,27]. Nowadays, Big Data integrates the GIS [28] based on cloud technology, including wildland fire modeling technologies [29]. This makes it possible to create last-generation fire management services. On the other hand, Big Data integrates several types of DSS, since its architecture can administer the data of the business together with data from users, social networks, and the data from the fires themselves. This is due to the ability to integrate a variety of data [30].

The growing concern for subjects such as environmental quality or the sustainability of natural resources has led environmental decision-makers to use DSS, because they have evolved considerably and are equipped with a variety of tools such as graphs, interactive visual modeling, artificial intelligence techniques, fuzzy sets, and genetic algorithms [31]. This is due to the need to maintain the environment and global environmental well-being, the analysis required due to climate change, and the need to conserve species and biodiversity. Yet the management of natural resources due to the economic and recreational aspects is also necessary and must be considered by decision-makers.

The Wildland Fire DSS possesses many attributes that make it uniquely different from other decision systems that have been used in wildland fire management. These differences, along with implementation swiftness, represent a significant change in fire management practices [13]. Wildland Fire DSS fully utilizes all aspects of information management, facilitates the application of the latest science and technology, incorporates the most applicable attributes of accepted decision-making models, and modernizes fire management by advancing the decision-making capability [13]. According to the author, DSS should incorporate the following activities:

Acquisition: the rapid assimilation of all the relevant information for the topic or problem that needs a decision and action.

Analysis: the evaluation of all relevant data and information to develop recommendations to support decision-making.

Application: the process of making a decision, determining the appropriate actions to achieve objectives and solve problems.

Archive: the creation of a permanent record of the acquisition, analysis, and application of information.

The use of DSS by wildland fire administrators has increased rapidly due to the possibility of selecting strategies to manage wildland fires, considering both functional and economic efficiency. This has reinforced the ability to prevent and suppress wildland fires while protecting human life and property. Sakellariou conducted a study to analyze the state of the art of the DSS in use [5]. The systems have been classified as: (1) database management systems and mathematical/economic algorithms for the spatial optimization of fire fighting forces; (2) wildland fire simulators and satellite technology for the immediate detection and prediction of the evolution of wildland fires; and (3) GIS platforms that incorporate several tools to manipulate, process, and analyze geographic data and develop strategic and operating plans.

Themistocleous conducted a study that illustrates the contribution of Big Data to wildland fire prevention [29]. In this sense, Big Data can integrate all the types of systems previously mentioned. From Figure 1, we can see the types of DSS in red, which are those that have been used to solve wildland fire problems. Our study considers Big Data an important type of DSS in wildland fire administration, promising to be a technology that solves the current challenges.

Another point of view from the studies analyzed is that of Finney, who conducted a study on the use of modern wildland fire administration systems in terms of their historical context, mainly in the US, and analyzed some of the features of the systems and human culture that affect the potential impact of the innovations and engineering technologies [4].

On the other hand, Chuvieco analyzed various technologies used as support in wildland fires. That analysis followed the different categories of fire management: prevention, detection, and post-fire assessment [32].

Noble's study analyzed the adoption of DSS in the US Forest Service. The results indicated that fire administrators appreciate many components of DSS but see them mainly as a means to document fire management decisions [33]. This is due to several problems that must be faced when a wildland fire breaks out, such as the following: (1) it is difficult to communicate with all the members of a work team exactly when required, and therefore, the DSS cannot be used with all the information that it provides; (2) depending on the threat level, decisions are made only through conversations and expert judgment, not using data from the DSS; and (3) the lack of qualified personnel to use the DSS correctly. Noble notes that these factors influence the adequate use of the DSS, causing a low level of adoption.

A recent study on the use of technology tools to improve decision-making in wildfires at the U.S. Forest Service increased the ability of line officers to communicate their decisions more clearly and transparently to their colleagues and partners [34]. The system analyzed was Risk Management Assistance (RMA). The study by Schultz et al. revealed the complexity of adopting risk management in wildfires and, also, in other similar contexts, such as emergency management. The authors concluded that the integration of data-driven analytics into the risk management process supports decision-making during incidents by providing more operationally relevant information. Some examples of fire analysis include weather forecasts, safety zones and escape routes, suppression difficulty maps, and fire control location probabilities. Incorporating analytics is not a substitute for making real-time adjustments based on human judgment, but it can inform more strategic response decisions. Infusing risk management into the fire management system has the potential to improve decision-making, improve the safety and effectiveness of wildfire responses, and usher in a necessary change in wildfire management.

2.2. Challenges for the Use of DSS in Wildland Fires

This section describes the challenges of using DSS in wildfires, considering different points of view. Some of the authors included challenges for a specific DSS, others in its regional context, and others according to the findings found in a review or state-of = the-art technology.

Noble carried out a study on the adoption of DSS for wildland fire management in the USA [33]. Through interviews with the personnel who worked in different wildland fire roles, he found the following challenges that must be considered in the construction of DSS. See Table 1.

Table 1. Challenges for DSS in wildland fires in the USA according to Noble [33].

Challenge	Description
Lack of time	The interviewees explained that the operating pace of the fire frequently exceeds the managers' capacity to make a decision through a DSS. The time required to prepare a quality decision through a DSS and that is supported by careful analysis is often underestimated compared to the time invested in developing a strategy through dialogue.
The complexity of the DSS	Generally, the interviewees indicated that the DSS are not friendly, so they require full training in their correct use.
Lack of availability of users skilled in the use of DSS	Fire managers perceived that the DSS are more useful at reporting the decision-making when there are qualified personnel available to develop a fire management strategy using the decision-making process.
The high level of experience needed to execute DSS	One of the main challenges in the use of DSS, as the interviewees described it, was bringing together the right people at the right time to make a prompt decision.

These factors contribute to managers using DSS mainly for documentation instead of facilitating informed decision-making on the risks and effects in the field.

On the other hand, Finney explained that three challenges were evident and others according to their own cultures and beliefs. Table 2 describes these challenges.

Table 2. Challenges for DSS in wildland fires according to Finney [4].

Challenge	Description
Evident	(1) Acquiring knowledge of the physical science of the fire, (2) developing practical methods and tools to use this knowledge and educate the personnel, and (3) benefitting from having specialized knowledge accepted within the fire management culture must be appreciated and valued for the purposes of strategic planning and implementation
Culture and beliefs	(1) All fires are harmful and potential natural disasters, and (2) suppression is necessary, sufficient, and effective at protecting communities and natural resources.

Finney explained that belief culture has even greater validity, more than a fact-driven analytical system. The author explained that the most challenging feature of wildfire culture is that it shuns responsibility, except when you can blame yourself for starting a fire. There is no responsibility for the individual and collective actions (or inactions) that perpetuate the disaster cycle (land management, suppression, construction, zoning, etc.), and therefore, there is little incentive for any group to avoid continuing to perform their cultural roles [4].

Zaimes et al. analyzed the problems faced by six Black Sea countries regarding protected areas and wildland fires [35]. The authors demonstrated the need to include ICT for the suppression of wildland fires and the management of protected areas through expert surveys. They concluded that there is a growing awareness of the adverse impacts of climate change on protected areas and the frequency of wildland fires in the future. Table 3 summarizes these challenges.

Table 3. Challenges for DSS in wildland fires in the Black Sea according Zaimes [35].

Challenge	Description
implementation of ICT	ICT allows (1) changes in forest management, (2) better monitoring, (3) increased awareness information on the suppression of wildland fires, and (4) greater training of personnel to improve the conservation of protected areas.

According Martell [36], forest and wildland fires are natural ecosystem processes, but fire can and often does pose significant threats to public safety, property, and forest resources. They explained the challenges for fire managers that are charged with the responsibility for achieving an appropriate balance between the beneficial and detrimental impacts of fires. Table 4 summarizes these challenges.

Table 4. Challenges for DSS in wildland fires according to Martell [36].

Challenge	Description
achieving an appropriate balance between the beneficial and detrimental impacts of fire	Sound fire management calls for (1) fuel management, (2) fire prevention and detection, (3) the suppression of potentially destructive wildfires, and (4) the modified suppression of some wildfires, allowing some beneficial wildfires to burn, and the use of prescribed fires to achieve ecosystem management objectives.
how to contain a fire	Containing a fire is complicated by uncertainty concerning the weather and its impact on fire behavior and suppression resource effectiveness. (1) The resources used for the initial attack vary by agency, and the determination of which resources to dispatch and the order in which they are dispatched to each fire varies by agency and by fire. (2) Assess the fuel, weather, and topography and its impact on fire behavior and suppression crew effectiveness, all the while keeping in mind that wind and other weather variables can, and often do, change dramatically.
safety of the fire crews is paramount	Initial attack operations pose many complex decision-making challenges to the incident commander, who must resolve his or her decisions under uncertainty.

Martell explain modern fire management agencies face far more complex decision-making problems. The development of modern transportation and telecommunications systems have supported the creation of national and international collaborative agreements that make it possible for fire mangers to quickly mobilize much larger and more costly suppression forces than was ever the case in the past [36].

On the other hand, Pacheco et al. explained that wildfire management has been struggling with escalating devastation, expenditures, and complexity [37]. Given the copious factors involved and the complexity of their interactions, uncertainty in the outcomes is a prominent feature of wildfire management strategies at both the policy and operational levels. Therefore, improvements in risk handling and in risk-based decision support tools have a key role in addressing these challenges [37].

The author explained that a major challenge is the governance of the risk, which includes risk management, looking at the coordination or reconciliation requirements when a variety of actors is present, considering the historical and legal background, guiding principles, value systems, and perceptions, as well as organizational imperatives. In this context, the role of risk-based decision support is also challenged to be widened and encompass these additional aspects [37]. After conducting a literature review, they concluded that the implementation of DSS raises other important challenges, as described in Table 5.

Table 5. Challenges for DSS in wildland fires according to Pacheco et al. [37].

Challenge	Description
General Challenges	(1) The involvement of multiple stakeholders who must be considered in the decision-making processes, (2) the need for adaptation to local contexts, (3) and the strong influence of external pressures and opinion leaders on adoption decisions, (4) and how users perceive the system.
Risk-based analysis	(1) A risk-based analysis is required for the integration of risk handling and fire management, in order to improve the prioritization of future efforts to mitigate the risks associated with these natural and human caused disturbances. This asks for more research in biophysical and social sciences with a dynamic spatiotemporal perspective about fire spreading and effects models to fuel treatment effectiveness, climate change impacts, and social preferences. (2) Is required for the integration of risk handling and fire management, in order to improve the prioritization of future efforts to mitigate the risks associated with these natural and human-caused disturbances.

Another challenge to consider is the incorporation of studies of the physicochemical properties of the soil to analyze the effects of forest management after a wildland fire [38].

Opportunities to change wildfire outcomes, measured as reduced risks for both developed and ecological values, are primarily achieved through proactive fire management rather than emergency response [4]. In this regard, engineering should be encouraged to focus on research that increases the knowledge of wildfire behavior, develops modeling tools for the application of strategic planning, and then enhances the education and training of fire professionals: foresters who can design and execute proactive projects and fire management strategies. DSS become a crucial tool for these tasks, since they integrate a set of valuable data, which allows engineers to observe the data from different perspectives, not only those of the forest fire when it occurs.

3. Research Methodology

The research methodology used is known as systematic mapping, which is designed to define processes that can recognize and categorize the results that have been published in a certain area [14].

The main objective of mapping in itself is to classify; thus, it seeks to identify the main focal points of publication. It responds to questions like: What has been done to date in area X? An existing limitation is that such studies do not consider the quality of the works included.

Systematic mapping is based on the following stages: (i) define the research objectives, (ii) define the research questions, (iii) establish the search string, (iv) select studies and filter studies, (v) classify, (vi) extract data, and a systematic map. Figure 2 presents a summary of these stages.

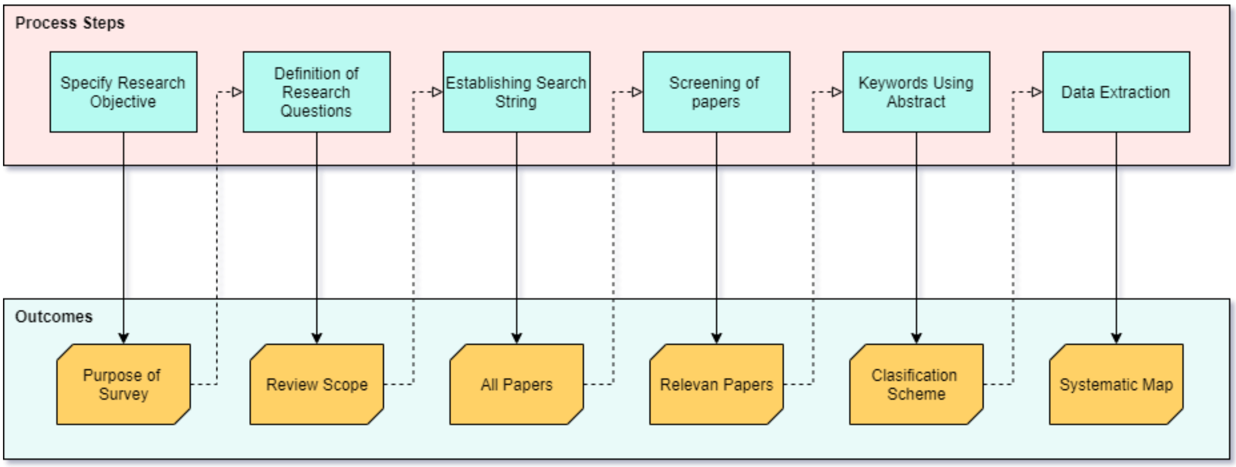


Figure 2. Stages of systematic mapping.

4. Activities Developed in Systematic Mapping

4.1. Research Objectives

The objectives of this research were as follows:

O1. Identify the studies that explain the use of DSS in wildland fire management.
O2. Characterize the DSS used in wildland fire management.
O3. Classify the types of DSS used according to the problems encountered in wildland fires.
O4. Identify the technologies used in the DSS for wildland fire support.
O5. Identify the type of research used and the study context.

4.2. Definition of the Research Questions

The research questions (RQ) were created using the methodology proposed by Kitchenham [15] through the PICO technique [39], where the population, intervention, comparison, and results are defined. This SLR addresses six research questions with their motivations, as shown in Table 6.

Table 6. Research questions.

N	Research Question	Main Motivation	Research Objectives
RQ1	What kind of wildland fire problems are solved through a DSS?	DSS have been used to solve various problems in wildfires. From different points of view, examples of problems are: early detection, prevention, mitigation, risk management, analysis of historical data, rescue, and simulations of scenarios, among others.	O1, O3
RQ2	What types of DSS were used?	DSS are classified according to Figure 1. Not all types of DSS have been used in wildfire management. The most used are PDSS, IDSS, EIS, BA, GSS, and Big Data.	O2
RQ3	What type of research was used, if it was a case study, experiment, or prototype?	Understanding the type of contribution is essential to determine the progress in the implementation of the DSS, especially those recently used, such as BA and Big Data.	O5
RQ4	In what context were these systems used, if it is in academia or in industry (real case)?	It allows to know the status of adoption of the DSS in the management of wildfire.	O5
RQ5	What technologies were used in the DSS found?	It allows to know the technologies used according to the type of DSS used and with respect to time.	O4
RQ6	How has the development of the DSS, for the management of forest fires, evolved over time?	It allows to analyze the evolution of the use of DSS in wildfire over time. With this, it is possible to discuss trends.	O1

4.3. Search String

The strategy used for the search was to use Boolean expressions, formed by the following keywords: "System", "Forest fire", and "Wildland Fire". The term "system" is used due to the definition of DSS according to Liu [12], since it integrates the theoretical study of organizational decision-making and interactive computer systems. In addition, year of publication was added as a condition to avoid out-of-date computer science systems or publications of systems not related to the computer science area. All this was disaggregated through the OR and AND Boolean expressions. The data sources used to test various search strings were Scopus and Google Scholar. Once the relevant string was selected (see Table 3), a search process was carried out in the sources Scopus, WoS, IEEExplore, ACM, MDPI, Springer, and Elservier, finding 22,200 documents, respectively.

The search string in Table 7 was applied to Titles, Abstracts, and Keywords in all the sources mentioned.

Table 7. Search string.

Sources	Search String	Item
IEEExplore, ACM, MDPI, Elsevier Springer Link, WoS, and Scopus	"system" AND ("Forest fire" OR "Wildland fire")	Titles, Abstract, Keywords

4.4. Screening of Relevant Papers

None of the papers were precisely relevant to the research questions. Therefore, these papers needed to be assessed according to the actual relevance. For this purpose, we used the search process defined by Dybå and Dingsøyr [40] for a screening of relevant papers. In the first screening phase, papers were selected based on their titles, and we excluded those studies that were irrelevant to the research area. In the second screening, we read the abstract of each paper selected in the first screening phase. Furthermore, inclusion and exclusion criteria were also used to screen the papers.

We excluded the following types of papers:

- Articles not published in the English language.
- Articles published other than conferences, journals, and technical reports.
- Articles published before 2010.
- Articles that did not include the use of DSS for support in wildland fires.
- Incomplete articles or that did not resolve a problem.
- Papers that were not relevant to the search string.

Papers were selected based on the given exclusion criteria, and after examining the abstracts of the selected studies, we decided to include them in the next screening phase.

4.5. Keywording Using the Abstract

To find the relevant papers through keywording using the abstracts, we used a process defined by Petersen et al. [14]. Keywording was done in two phases. First, we examined the abstract and identified the concepts and keywords that reflected the contributions of the studies. Concepts related to the problems to be solved and the types of solutions developed were found. The concepts related to the problems were relevant to the study if they were related to wildland fires. On the other hand, the concepts related to the types of solutions must be related to the use or development of systems or ICT. Those documents that met both conditions were selected.

In the second phase, the results and conclusions sections were reviewed. These sections provide information on the results obtained with the support of the system or ICT used to solve a problem in wildland fires. Special care was taken to select the documents that presented a clear solution to improve decision-making.

Various work meetings were held in order to achieve a correct selection of relevant documents. In the meetings, each researcher and assistant showed the results of the review of the abstracts and the results and conclusions. This allowed the resolving of doubts.

4.6. Study Selection Process

Figure 3 shows the results of the selection and search processes. Initially, 22,200 articles were selected when the search protocol was applied in the selected repositories. The selection process was applied based on the inclusion and exclusion criteria, keywords, titles, abstracts, and full articles of the retrieved articles. Three researchers selected papers based on searching through the designed search string. Then, the same research applied the selection criteria based on the title of the paper, obtaining a set of 3851 papers. Relevant titles were those that included the following key concepts: forest, fire, forest fire, wildland fire, wildfire, system, and DSS.

Eliminating duplicate papers, a new set of 2745 papers was obtained.

We analyzed the abstracts of each paper, selecting those that showed the use of DSS in wildland fires. We considered the characteristics described by Zimmerman [13] to determine if the papers described a DSS. Some of these features were based on the following components: acquisition, analysis, application, and archival. On the other hand, the author explained that the DSS have a constant flow of data; since they are acquired from various data sources, they are quickly processed to be analyzed and, finally, visualized at the right moment for decision-making.

A Cohen's kappa coefficient of 0.92 was used to determine an acceptable level of agreement between the authors [41]. For this, 20 papers were selected at random, which were reviewed by the researchers. Each paper was marked with the categories YES, NO, or DOUBT. This process was repeated several times until an index greater than 0.9 was obtained. When there was DOUBT, the abstract was analyzed as a team. Furthermore, after reading the full abstracts of the 2745 articles selected in the duplication phase, we selected 1470 papers based on their abstracts.

After reading the results and conclusions sections, we selected 183 pertinent papers that contained the necessary data to answer the research questions. The full paper was read only when necessary, as some documents did not include a results section.

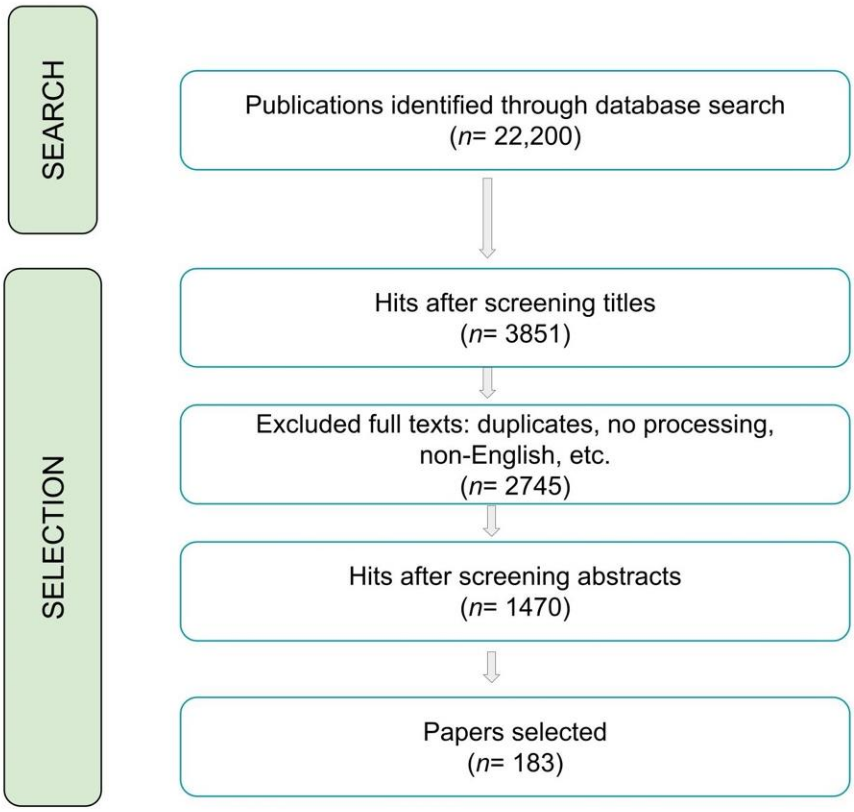


Figure 3. Papers selection process.

4.7. Data Extraction Method

The data extraction strategy was applied to provide a set of possible answers to the research questions defined.

The following classifications were considered on the basis of the RQ designed:

(i) Types of problems: These are classified according to the problem of wildland fire management that they solve. The most noteworthy problems include the divergence between the beginning of the fire and the detection, which, in this work, will be mentioned as a detection issue. Other types will be the monitoring of sectors with a potential fire hazard, the management of a fire that already is active, the prediction of future fires, the simulation of fire behavior, the prevention of how fires are generated, and the generation of access routes.

(ii) Types of DSS: These are classified according to the DSS presented in Figure 1. In the area of wildland fires, we found PDSS, IDSS, EIS, GSS, BA, and Big Data.

(iii) Types of research: The possible classifications are case study, experiment, or prototype. Case study corresponds to the process of focusing on a single case from a group or defined place; therefore, its results are inherent and exclusive to that group or place. An experiment corresponds to a procedure in which the goal is to make a discovery, prove a hypothesis, or verify a known fact. A prototype is a first product or proof of concept.

(iv) Context in which it is used: This is the developed context of the study, either in academia or industry (real case). The academia context is considered when the work is carried out within a research center, institute, university, or other. The industry context is used when the work was carried out in an organization, company, or business.

(v) Technologies used: These are all the technologies mentioned in the studies analyzed. Several technologies were used for the data intake, processing, analysis, and visualization of the results.

Figure 4 presents the classification scheme.

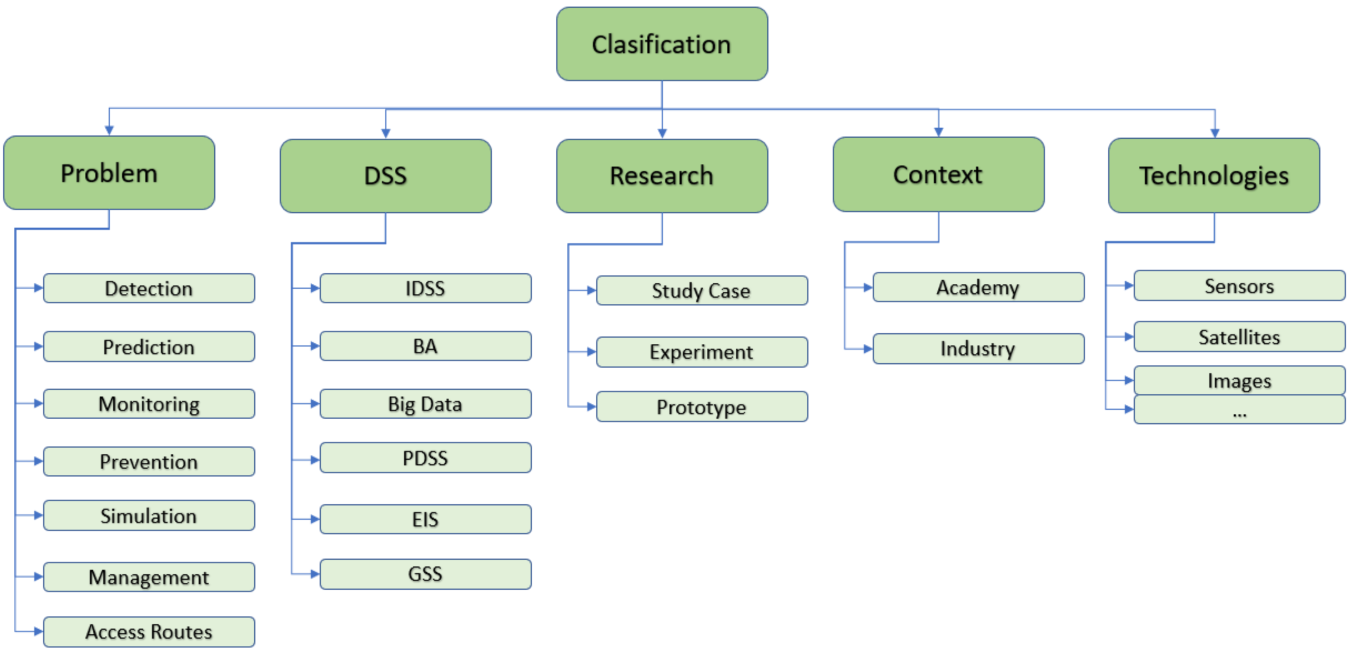


Figure 4. Classification scheme.

4.8. Selection of Results

To answer our research questions, we brought together 183 primary studies in this section. After analyzing the studies selected, we tried to answer each question with the information extracted. Table A1 presents the list of articles, the dissemination channel, the year of publication, and the number of citations. This makes it possible to obtain data from the main dissemination channels in this area of study.

4.9. Results of Systematic Mapping

In this section the designed RQ are answered. A discussion of the most relevant aspects also occurs.

Figure 5 presents the Systematic Map obtained. The bubble graph represents the number of studies found according to the classification. Thus, for example, it was found that 36 studies solved problems of monitoring through PDSS. On the other hand, 13 studies explained the use of EIS to solve management problems. The figure shows that, in 2014 and 2015, the number of studies in this area decreased. However, in recent years, it has increased considerably.

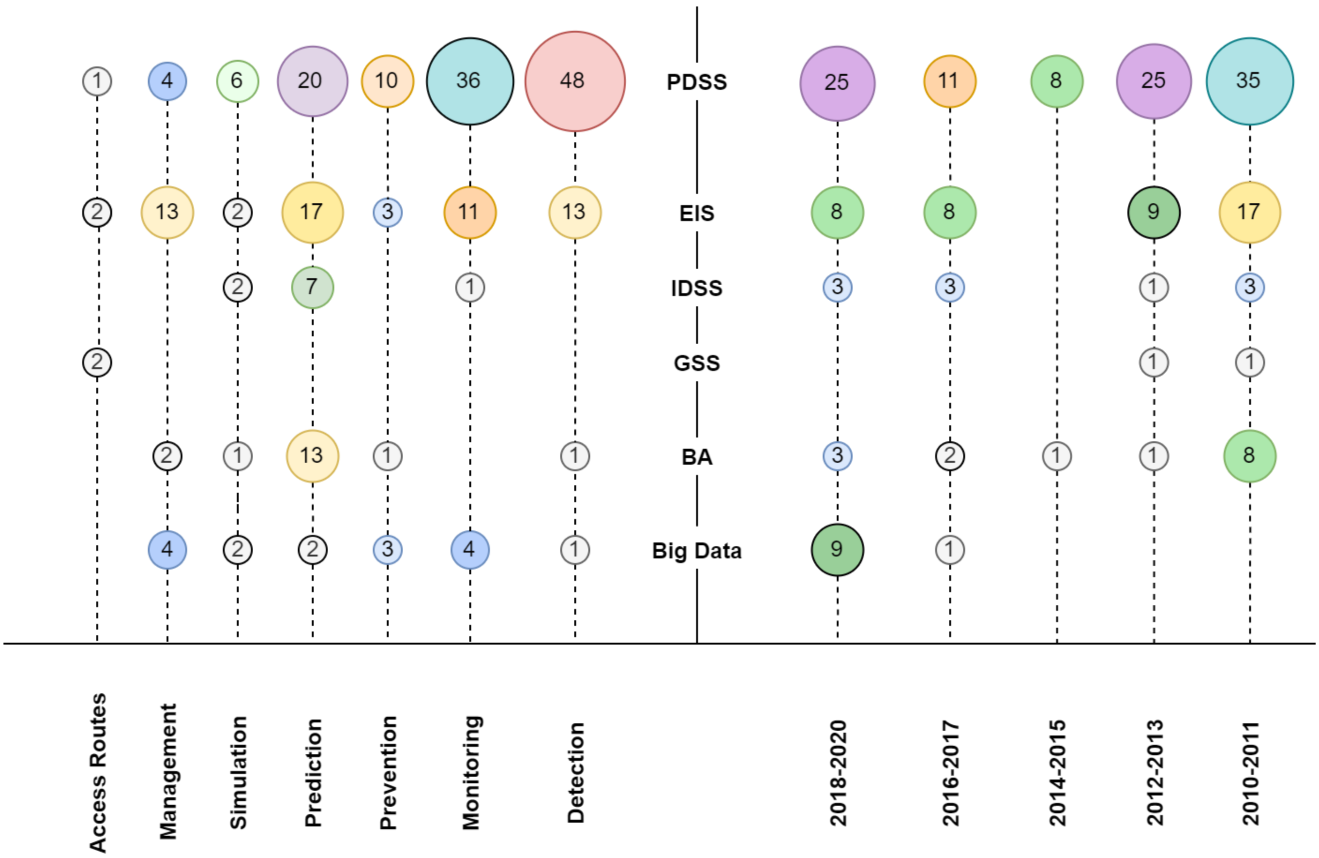


Figure 5. Systematic map.

4.10. Response to Research Questions (RQ)

In this section, the RQ designed in the first stage are answered.

RQ1. *What kind of wildland fire problems are solved through a DSS*?

Management problems were found in the abstract of the paper or in the introduction, and 26.57% of the papers presented predictions as a problem to be solved. On the other hand, 28.02% presented a need for detection and 22.22% for monitoring. This is consistent with the comment by Saoudi on the constant need for organizations in charge of firefighting to generate early detection [42]. It follows that the longer the time from its generation to its detection, the more difficult it is to control and fight it. The kinds of problems remaining focus mainly on management (8.7%) and the need for a simulation (5.8%) of the behavior based on different environmental factors. In addition, there was the need for prevention (7.73%) and the generation of access routes for the firefighters or organizations in charge of the rescue (0.97%). Figure 6 presents a graph of the number of studies found versus the problem to be solved.

It should be noted that other aspects and solutions to these problems are mentioned in the development of the papers that have not been considered in this study.

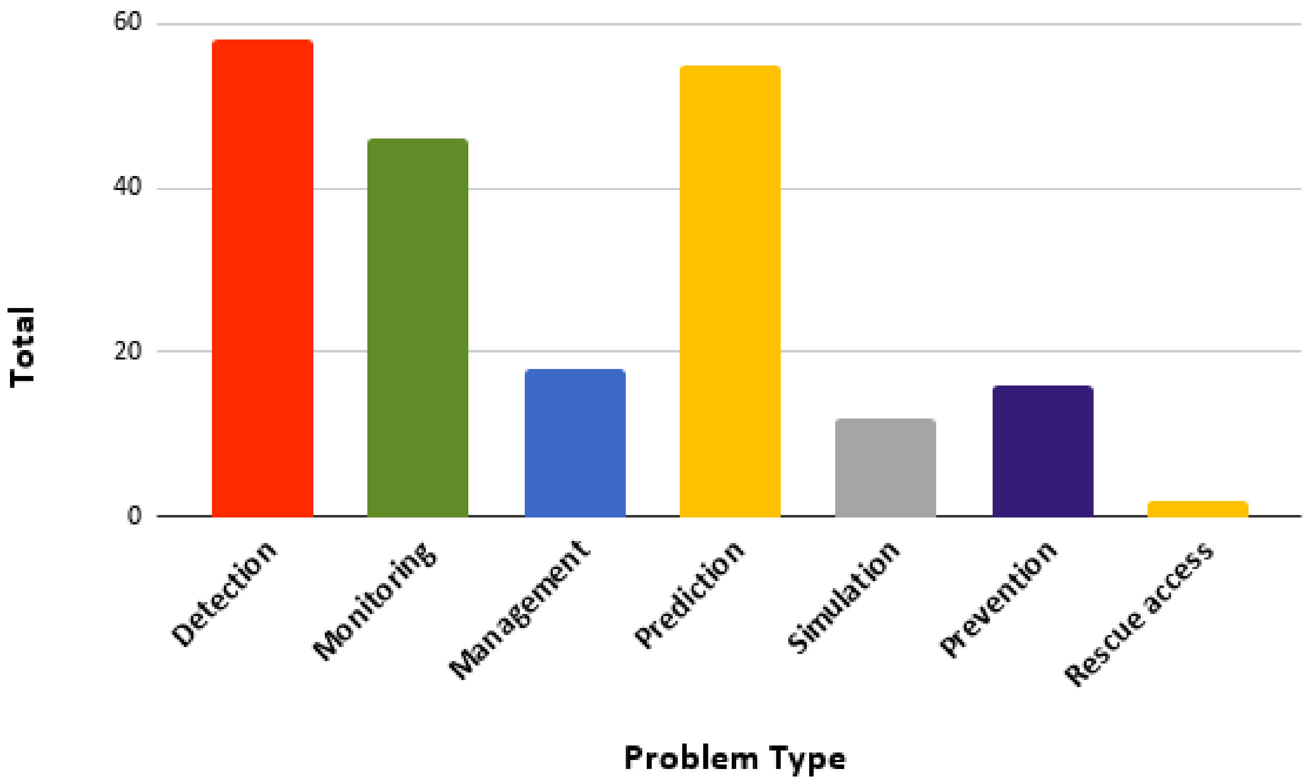


Figure 6. Number of studies found versus the problem to be solved.

RQ2. *What types of DSS were used*?

It was found that 5.46% of the works analyzed indicated the use of IDSS, 56.83% used PDSS, which included the use of GIS, 8.2% used BA, and finally, 5.46% used Big Data systems. Figure 7 summarizes these quantities. Table 8 presents the articles selected according to the type of DSS used.

Table 8. Classification of articles by DSS type.

DSS Type	References
PDSS	[2,8–11,42–140]
EIS	[10,49,67,93,94,111,112,118,126,141–173]
IDSS	[89,98,99,173–179]
GSS	[111,158]
BA	[77,86,90,149,172,180–189]
Big Data	[29,45,145,181,190–195]

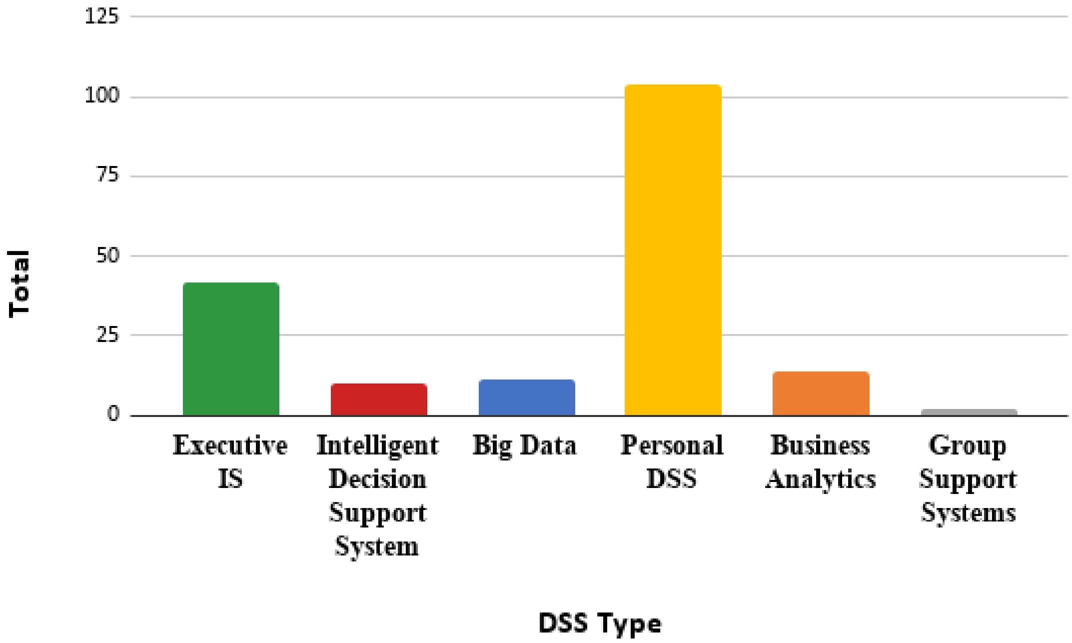


Figure 7. Number of studies by type of DSS.

It was observed that the most widely used type of DSS continued to be the traditional PDSS (including GIS). Despite technological advances, with the application of AI and Big Data, there is low use of these in the field of forest fires. In this sense, the authors Noble [33] and Finney [4] were right to discover that the practical use of DSS contemplates several challenges that have not yet been solved, such as ease of use and the way in which information is delivered to the different roles when facing a forest fire. On the other hand, the lack of qualified personnel implies little use for forest fire management.

RQ3. *What type of research was used, if it is a case study, experiment, or something else?*

Figure 8 shows that 36.3% of the analyzed works used a prototype as a solution to the problems detected. It can also be seen that the distribution was relatively equitable between the two remaining: case study (37.5%) and experiment (26.3%).

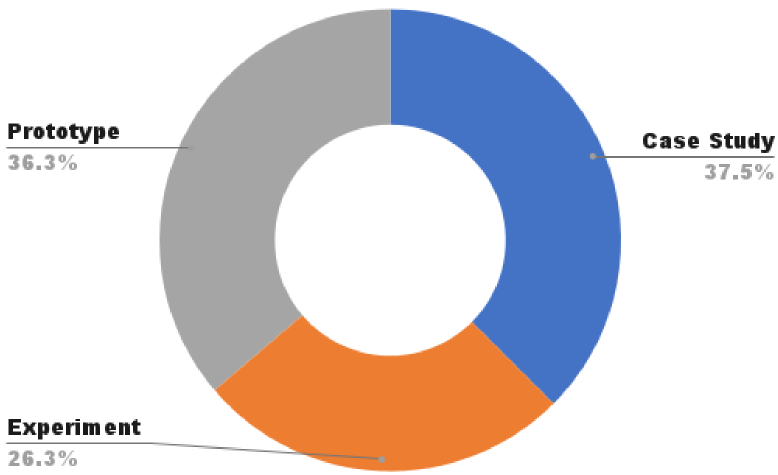


Figure 8. Types of research used.

RQ4. *What context were these DSS used in: academia or industry (real cases)?*

The majority (63.75%) of the papers come from academia, and the remaining (36.25%) from industry. This indicates that the research processes are developing, and technologies are constantly being tested that can more effectively support the management of wildland fires. This is beneficial from the point of view of continuous improvement.

RQ5. *What technologies were used in the systems found*?

Figure 9 presents a word cloud according to the technologies mentioned in the 183 studies analyzed. Both the wireless sensor networks and WSN tools were the most mentioned and outstanding. On the other hand, the use of cameras, GPS, IoT, GPRS, and Satellite Images was observed. The use of Cloud Computing and unstructured databases such as Hadoop is not yet massive.

Figure 9. Word cloud of the technologies.

Table 9 presents a summary of the main technologies used according to the papers' years of publication. It is observed that sensors and images have been used since 2010, which generate data to be processed by GIS. This data processing is usually slow due to the lack of smart technologies, and others that can work with a large volume of data. Cloud use is observed as an opportunity, since they are adequate services for the processing of a large volume of unstructured data at high speed. On the other hand, machine learning enables the development of smart systems to create predictions and self-learning.

Table 9. Technologies most frequently used between the periods of the defined years.

Years	Technologies
2018–2020	Cloud Computing, Machine Learning, Neural Networks, Sensors, Data Mining, real 3D image, Fuzzy Inference System, Big Data Tool
2016 and 2017	WSN, UAV, Satellite Images, aerial vehicles
2013–2015	ArcGIS, Sensores, Zigbee, MATLAB, MODIS
2011 and 2012	Sensors, Satellite Images, GPS, MODIS, Cámaras, GIS Tool
2010	Sensors, Satellite Images, GIS Tool

RQ6. *How has the development of DSS evolved over time*?

Figure 5 illustrates the constant presence of PDSS use (56.83%) and EIS (22.95%). On the other hand, it was observed that few studies were published in the period between

2014 and 2015. Although BA has been in use since 2011, only proposals were observed, unlike in recent years, in which it has been used for data analysis problem-solving and decision-making in the field. Big Data, on the other hand, has been used since 2016 as a solution for the analysis of unstructured data (data from experts). Only one paper was found in 2011 that proposed the use of Big Data for forest fire management.

It is worthy to note that there is a paucity of prediction systems employing complex algorithms, with a low number of publications between 2011 and 2015. This may be due to the small quantity and quality of the data used from the data sources, as is the case with sensors and images (see Figure 10).

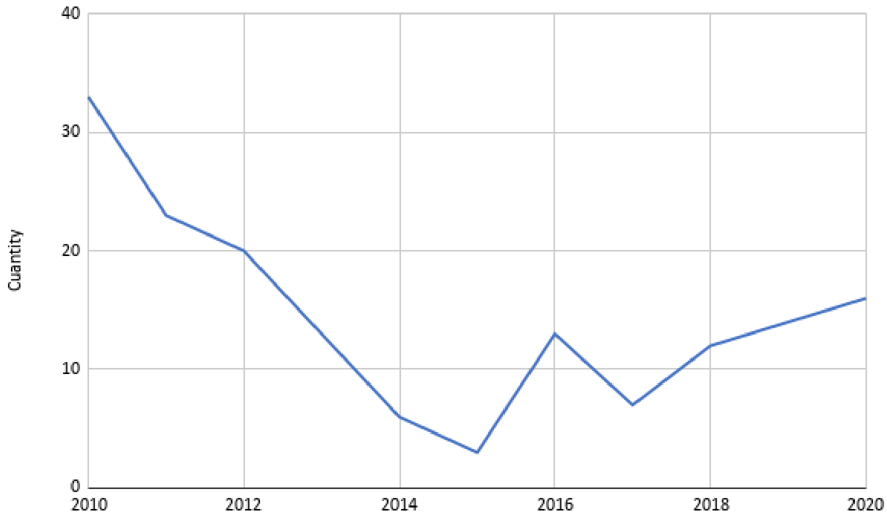


Figure 10. Studies per year.

It should be emphasized that, among the cited technologies of every era, sensors are a type of technology that is always present in a large number of the studies. This is due to its optimal application for recording environmental data. In recent years, technologies related to large amounts of data have also appeared, such as neural networks, machine learning, and the cloud, which is consistent with the need to produce predictive algorithms but in a more complex form, with algorithms and "smart" systems. In this sense, Big Data is a type of DSS that can integrate these technologies, fulfilling an important role in managing the wildland fire risk.

5. Discussion

This section examines the relevant aspects of the DSS types found. For this, the analysis included the most-cited studies (more than 30 citations), where the impacts and contributions stood out. On the other hand, studies published in recent years were included in order to search for technological advances, problems, challenges, and opportunities.

In the study by Calkin et al. [161], what stood out as the main feature of the DSS used was the generation of combat strategies prior to wildland fires. The use of behavior models, geospatial analysis, datasets generated through biological sensors, and climatological prediction helped improve the problem of decision-making under a large number of external factors that altered the initial combat conditions.

Two works focused on another type of problem, making reference to the provision of a real 3D image of a fire, facilitating its access. This aspect helps improve the decision-making regarding the follow-up and mitigation of a fire. The article by Rossi et al. [164] used a prototype of static cameras in a controlled environment, so stereovision images could be taken. These generated more reliable information to predict the behavior of the fire. On the other hand, the study by De Ríos et al. [118] used a system with static cameras and unmanned aerial vehicles to produce a more feasible image in real time without jeopardizing the people or equipment when mounting a static system near a real fire. The work by De Ríos was significant, because it created safety for the extraction of images.

Unlike the previous studies, Petropoulos et al. [10] compared two types of GIS, one combining neural networks with a satellite image analyzer and a spectral angle mapping system to improve the information for decision-making. The analysis performed on the topographies, vegetation, and soil conditions stands out for producing highly varied results according to the technology used. The authors used combinations of technologies to obtain more concrete results.

In Bianchini et al. [188], a DSS with high calculating power was used to generate results. On the other hand, Denham et al. [183] used a new genetic algorithm to improve on Bianchini's results. As a result, they achieved a significant improvement in wildland fire detection time, which is why the impact can be seen directly. In the same area of prediction, Iliadis et al. [89] are conspicuous for being the only study that used risk analysis models through dynamic algebra, being able to predict the behavior of a fire based on previous knowledge. This had a tremendous impact on Greek fire departments, where their estimations predicted 35–40% of the area to be affected by wildland fires. This may seem small, but knowing 40% of the zones affected by wildland fires beforehand can be a breakthrough in taking preventive measures for those areas.

The work by Soliman et al. [82] stands out, because it combined sensor networks and neural networks in order to generate a DSS that can detect a wildland fire even earlier. Through a neural network, a DSS makes it possible to detect fires in under 20 s. The authors reported that the system gets it right in 98% of cases, which can have a tremendous impact on fighting fires.

On the other hand, Almeida et al. [131] developed a commercial system called Bee2Fire, which allows the detection of forest fires. The system scans the landscape using regular cameras and deep artificial neural networks. Bee2Fire searches for plumes of smoke above the horizon with an image classification approach. Once these networks were trained, the system was deployed in the field, obtaining a sensitivity score of between 74% and 93%, a specificity of more than 99%, and an accuracy of around 82%.

Peng et al. [132] studied a computer vision-based forest fire early warning imaging system. First, a close-up detection of moving targets was performed. A mixed Gaussian model algorithm was then used to determine if there were moving objects in the video. The flames were then tracked and identified on video. Next, it was determined whether it was a flame. The purpose is to draw its outline and give an alarm to the supervisory office when the result is a fire. This early warning system waits for the appropriate personnel to take care of it.

Budiyanto et al. [140] created a forest fire monitoring system for a wide area of fire-prone areas using a WSN (Wireless Sensor Network). The study also used the FIS (Fuzzy Inference System) method as a decision-making method with mathematical calculations that can improve the precision in the fire detection system so that the output of this method is the level of the fire status. The IoT is also used so that information can be received by users in real time through the Internet network. Based on test results on the designed system, Sugeno's Fuzzy Inference System (FIS) calculations on SN1 and SN2 are 100% accurate compared to manual calculations.

Athanasis et al. [190] presented a cutting-edge approach to improving decision support tools for natural disaster management with information from the social network Twitter. The novelty of the approach lies in the integration of GIS modeling outputs with real-time information from Twitter. A first prototype was implemented that integrated georeferenced Twitter messages in a web GIS for forest fire risk management and earthquake monitoring in real time. Following a highly scalable architecture that was based on Big Data components, the proposed methodology could be applied in different geographical areas, different types of social networks, and a variety of natural disasters.

Another study of note was that of Lin et al. [181], because it used a mixture of wireless sensor networks, dynamic inference systems, and Big Data with the purpose of generating accurate fire predictions through risk indices. These different technologies were applied due to the number of factors that can influence the chance of a wildland fire in a study area, from humidity and wind speed to population density and time of year. The authors mentioned that, at festive times and during the day, the risk was much greater than at night or during normal work schedules. Although their experiment was applied and it produced results according to expectations, they also remarked that the area of prediction was one of the most complex [181].

Sayad et al. [194] combined Big Data, Remote Sensing, and Data Mining algorithms (Artificial Neural Networks and SVM) to process the data collected from satellite images in large areas and extracted ideas from them to predict the occurrence of forest fires and prevent these disasters. To do this, they implemented a dataset based on Remote Sensing data related to the status of crops (NDVI) and meteorological conditions (LST), as well as a fire indicator "Thermal Anomalies"; these data were acquired from "MODIS"(Moderate Resolution Imaging Spectroradiometer), a key instrument aboard the Terra and Aqua satellites. The experiments were carried out using the Big Data platform "Databricks". The experimental results offered a high prediction precision (98.32%).

Finally, the study of Bielski et al. [145] stands out, because it worked with Big Data technology to manage fires in a more general sphere, from educating the population to providing monitoring systems to distributing information in a timely manner when a fire occurred. The authors used information from multiple sources, obtaining climatological data, and from social networks. Once the data with which a fire is detected has been processed, the system generates information for decision-making. The system provides support with information relevant to the citizenry or inhabitants of the affected sector so as to avoid human losses. The greatest impact is ensuring the protection of human life. Bielski's work solved the challenges identified by Finney, since the DSS makes it possible to manage the risk more than simply preventing, monitoring, or reporting on a certain wildland fire.

In this discussion, we analyze the main technologies recently used in DSS systems for wildland fire management. State-of-the-art solutions are presented that combine various recent technologies, such as Big Data, Remote Sensing, AI, 3D image, and photo processing, as well as Cloud Computing and data from Social Networks. These solutions can produce real changes in forest fire management if we consider the aspects mentioned by Noble and Finney: friendly systems, staff training, and data analyzed in real time, among others.

Figure 11 represents the relationships that exist between the problems encountered when facing a forest fire versus the types of DSS used so far.

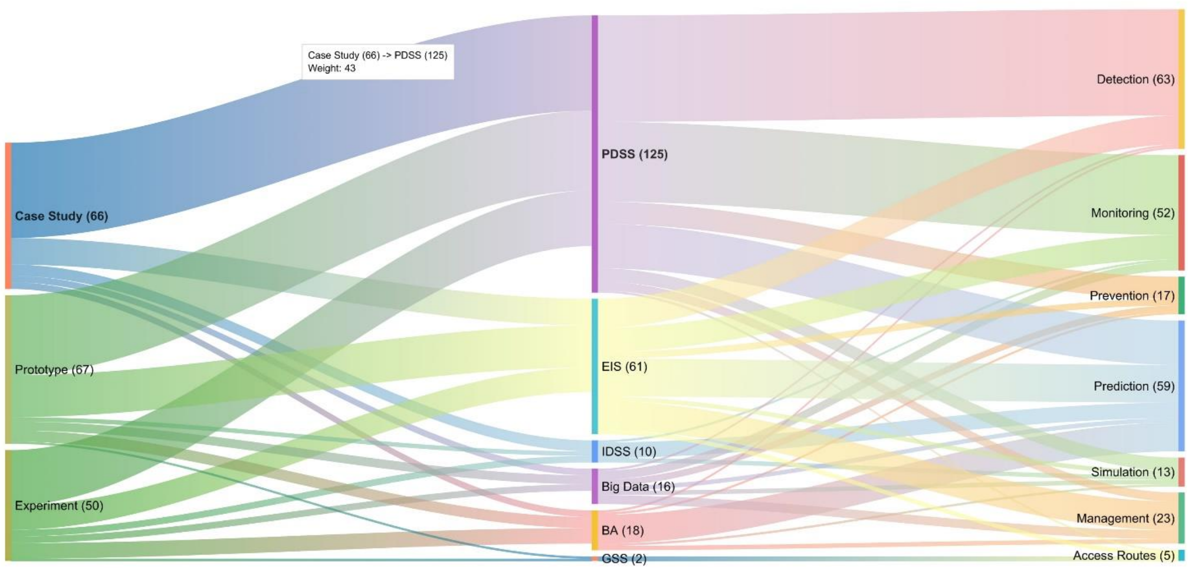


Figure 11. Relationship between the problems encountered and the use of DSS.

6. Limitations of the Study

There have been four kinds of threats to validity identified in this section [14]. The main limitations of the study are inherent to any research work, given that it is impossible to ensure absolute impartiality.

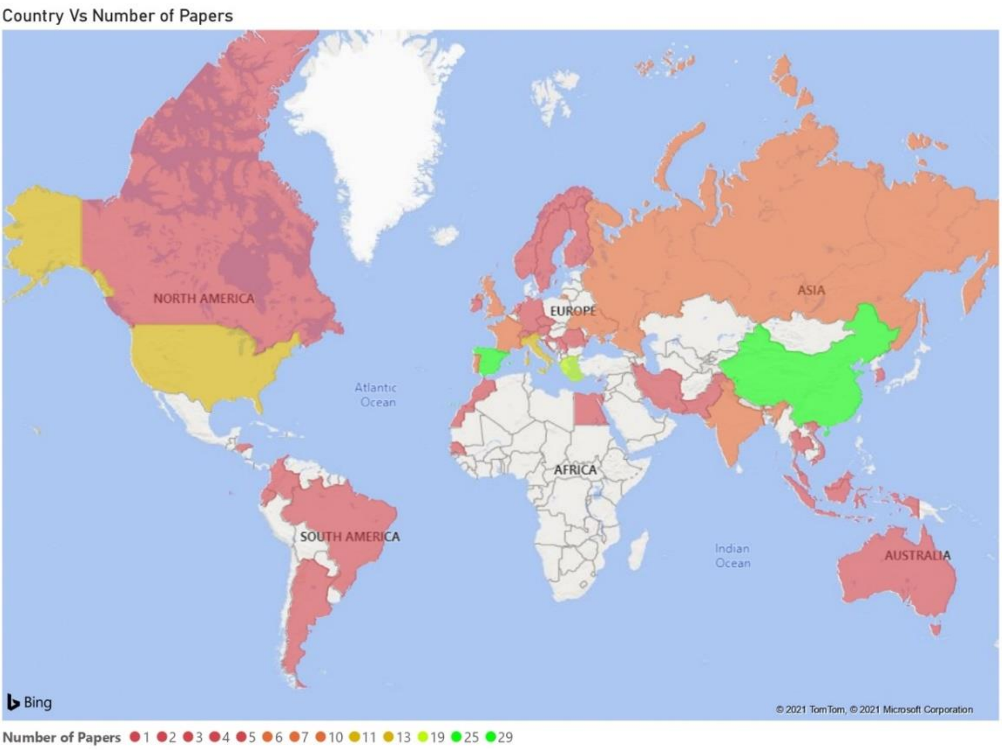
6.1. Construct Validity

In Systematic Mapping, threats to construct validity are relevant to the classification of selected studies. A search string was performed using IEEE Xplore, ACM, Science Direct, Springer, Elsevier, MDPI, WoS, and Scopus. Based on the search engine statistics, we found most of the research papers related to DSS and wildland fires. To mitigate the risk of losing essential and related publications, we searched the related articles from state-of-the-art reports and surveys.

The search string used is an important bias, since there are keywords that were not considered in order to obtain the largest possible set of studies. The string "system" AND ("Forest fire" OR "Wildland fire") was the one that yielded the largest number of studies to review. Examples of words not considered are wildfire, fire, "decision support", software, and application, because, by including them, the search engine reduced the number of documents to be reviewed, leaving out possible important studies.

Some papers that were not mentioned in this study, and that can be found using the wildfire AND system string, are references [196–198].

From the definition of the inclusion and exclusion criteria, leaving aside technical reports and works in languages other than English, it is possible that some studies in other languages were relevant or observed points that the selected ones did not. On the other hand, it is possible that papers from countries that are recognized in the field of wildland fires were not included. Figure 12 shows a map with the papers selected by country.



Country	Total
Argentina	2
Australia	2
Brazil	2
Canada	4
China	29
Croatia	3
Cyprus	2
Ecuador	2
Finland	2
France	7
Germany	4
Greece	19
India	10
Iran	3
Italy	11
Malaysia	5
Morocco	4
Netherlands	4
Not Defined	2
Portugal	7
Russian Federation	7
South Korea	4
Spain	25
Sweden	2
Turkey	5
Ukraine	6
United Kingdom	7
United States of America	13
Viet Nam	2
Total	**195**

Figure 12. Papers selected by country.

6.2. Internal Validity

This type of validity handles the extraction data analysis process, in which three authors identified the classification of the selected articles and the data extraction process while one author reviewed the results. The subjectivity when applying the aforementioned criteria for the selection of the studies was already applied by three reviewers. In order to minimize this bias, Cohen's kappa index was used [41], obtaining a value of 0.92, which is acceptable.

Another inherent bias is the initial filtering method. By only reviewing the titles and abstracts, the possibility remains that some of the discarded studies contained important information to answer the research questions.

6.3. External Validity

External validity is related to the generalizability of this study. The results of the systematic mapping were considered concerning the domain of Systems in Wildland Fires, and the validity of the results presented in this document referred only to the domain of DSS. The classification of the articles and the search string presented in this research can help professionals as a starting point for wildland fire research and the use of DSS.

6.4. Conclusion Validity

The threat of the validity of the conclusion is related to the identification of inappropriate relationships that can generate an incorrect conclusion. In the mapping study, a conclusion validity threat referred to the different elements, such as incorrect data extraction and missing studies. To lessen this threat, the data extraction and selection process were clearly defined in the previous paragraph on internal validity. Traceability between the extracted data and the conclusion was strengthened through the direct generation of frequency diagrams and bubble diagrams generated from the data collected through the application of a statistical analysis.

7. Conclusions

This paper presented a systematic mapping of studies on DSS for wildland fire management to obtain an overall view of the solutions presented by industry and the scientific community.

For this, a set of six research questions was designed, which were answered using different classifications from the selected works by type of problem addressed, the type of DSS used, the main technologies used, the type of contribution, and the context.

The studies described the use, development, and impact of DSS to solve these problems. One of the most important factors of those found was the need to apply correct technologies to suitable lands, since changes in the climatic or geographic factors can make it a more useful tool than in other situations, as well as the utility of the data and their correct management for these tools. In addition, within the studies themselves, the need for tools that generated responses in appropriate timeframes stood out, since it is one of the scarcest variables in combatting wildland fires.

There is a trend in the use of Big Data for the management of wildland fire risk, since this can provide systems with monitoring, prevention, and the management necessary to distribute information in a timely manner. We found 10 studies published in recent years that indicated the use of different data sources, such as climatological data, sensors, satellite images, data from social networks, photographs, and expert data. On the other hand, Machine Learning techniques have been incorporated to achieve systems that adapt to the context of the fire, pre-activating the use of alarms and schemes that represent the real situation of forest fires.

Big Data delivers relevant information to the citizenry or to the inhabitants of the affected sector to avoid human losses. Despite these advances, there are still many problems and challenges to be solved. More user-friendly systems are required for the use of all types of users in forest fires, greater training in the use and analysis of data, visualization systems that can be used in the field, providing relevant information for the equipment, and the integration of the DSS.

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Informed Consent Statement: Not applicable.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Selected Papers.

Reference	Title	Authors	P. Channel	Year	Citations
[178]	3D Fire Front Reconstruction in UAV-Based Forest-Fire Monitoring System	Sherstjuk V, Zharikova M, ...	IEEEXplore	2020	
[127]	A Novel Forest Fire Detection System Using Fuzzy Entropy Optimized Thresholding and STN-based CNN	Avula SB, Badri SJ, Reddy G	IEEEXplore	2020	
[128]	A Retrospective on ASPires: An Advanced System for the Prevention and Early Detection of Forest Fires	Peinl P.	ACM	2020	
[129]	An IoT-based forest fire detection system	Scicluna, D.	IJET	2020	
[130]	Architecture of embedded intelligent video analysis system for forest fire prevention	Zhang B., Zhang Z.	IOP	2020	
[131]	Bee2Fire: A deep learning powered forest fire detection system	de Almeida R.V., Crivellaro F., Narciso M., Sousa A.I., Vieira P.	SciTePress	2020	
[132]	Design of Forest Fire Warning System Based on Machine Vision	Peng J, Zhang H, Wu H, Wei Q	Springer	2020	
[189]	Development of an Intelligent System for Predicting the Forest Fire Development Based on Convolutional Neural Networks	Stankevich T.S.	Springer	2020	
[133]	Early Forest Fire Detection System using Wireless Sensor Network and Deep Learning	Benzekri W, Moussati A El, Moussaoui O, Berrajaa M	IJACSA	2020	
[134]	Efficient Forest Fire Detection System Based on Data Fusion Applied in Wireless Sensor Networks	Jilbab A, Bourouhou A	IJEEI	2020	
[135]	Fireanalyst: An effective system for detecting fire geolocation and fire behavior in forests using mathematical modeling	Güllüce Y., Çelik R.N.	TUBITAK	2020	
[136]	Forest Fire Detection and Alerting System	Minu O, Ramsiya M, Thasini A, Narayanan KV, Arun K	IEEEXplore	2020	
[137]	FOREST FIRE DETECTION SYSTEM USING IOT	Khan S., Jain S, MN Anusha, YP Kalyan	IJEAST	2020	
[138]	Forest Fire Detection System using LoRa Technology	Gaitan NC., P Hojbota	IJACSA	2020	
[139]	IoT-fog enabled framework for forest fire management system	Srividhya S., Sankaranarayanan S.	IEEEXplore	2020	
[140]	Optimization of Sugeno Fuzzy Logic Based on Wireless Sensor Network in Forest Fire Monitoring System	Budiyanto S., Silalahi LM., FA Silaban, ...	IEEEXplore	2020	
[45]	'Portugal Without Fires', A Data Visualization System to Help Analyze Forest Fire Data in Portugal	Gonçalves D., Lima B., Moura J.M., Ferreira L.	Springer	2019	

Table A1. *Cont.*

Reference	Title	Authors	P. Channel	Year	Citations
[44]	Fuzzy-Based Forest Fire Prevention and Detection by Wireless Sensor Networks	Toledo-Castro J., Santos-González I., Caballero-Gil P., Hernández-Goya C., Rodríguez-Pérez N., Aguasca-Colomo R.	Springer	2019	
[143]	Strategic and tactical planning to improve suppression efforts against large forest fires in the Catalonia region of Spain	Gonzalez-Olabarria J.R., Reynolds K.M., Larrañaga A., Garcia-Gonzalo J., Busquets E., Pique M.	ScienceDirect	2019	1
[141]	Mapping combined wildfire and heat stress hazards to improve evidence-based decision making	Vitolo C., Di Napoli C., Di Giuseppe F., Cloke H.L., Pappenberger F.	ScienceDirect	2019	
[92]	Spatial pattern analysis and prediction of forest fire using new machine learning approach of Multivariate Adaptive Regression Splines and Differential Flower Pollination optimization: A case study at Lao Cai province (Viet Nam)	Tien Bui D., Hoang N.-D., Samui P.	ScienceDirect	2019	
[173]	Data Mining Approach to Predict Forest Fire Using Fog Computing	Aakash R.S., Nishanth M., Rajageethan R., Rao R., Ezhilarasie R.	IEEEXplore	2019	
[180]	Scalability of a multi-physics system for forest fire spread prediction in multi-core platforms	Farguell A., Cortés A., Margalef T., Miró J.R., Mercader J.	Springer	2019	1
[2]	Design and development of forest fire monitoring terminal	Wu F., Lv X., Zhang H.	IEEEXplore	2019	
[43]	Development of forest fire early warning system based on the wireless sensor network in Lawu Mountain.	Yahya Dewangga Z., Koesuma S.	ICOPIA	2019	
[142]	Detection and monitoring of forest fires using Himawari-8 geostationary satellite data in South Korea	Jang E., Kang Y., Im J., Lee D.-W., Yoon J., Kim S.-K.	MDPI	2019	
[9]	Adaptive Neuro Fuzzy Inference System (ANFIS) based wildfire risk assessment	Kaur H., Sood S.K.	JETAI	2019	
[191]	COMBINING SOCIAL MEDIA AND AUTHORITATIVE DATA FOR CRISIS MAPPING: A CASE STUDY OF A WILDFIRE REACHING CROATIAN CITY OF SPLIT.	Tavra M, Racetin I, Peroš J	IAPRSSIS	2019	
[194]	Predictive modeling of wildfires: A new dataset and machine learning approach	Sayad YO, Mousannif H, Al Moatassime H	ScienceDirect	2019	
[195]	Studies on Big Data Mining Techniques in Wildfire Prevention for Power System	Zhou T, Li B, Wu C, Tan Y, Mao L, . . .	IEEEXplore	2019	
[144]	Prediction and management system for forest fires based on hybrid flower pollination optimization algorithm and adaptive neuro-fuzzy inference system	Ahmed K., Ewees A.A., Hassanien A.E.	IEEEXplore	2018	1

Table A1. *Cont.*

Reference	Title	Authors	P. Channel	Year	Citations
[174]	GIS-based spatial prediction of tropical forest fire danger using a new hybrid machine learning method	Tien Bui D., Le H.V., Hoang N.-D.	ScienceDirect	2018	3
[47]	Implementation of Information Technologies in the Organization of Forest Fire Suppression Process	Smotr O., Borzov Y., Burak N., Ljaskovska S.	IEEEXplore	2018	
[181]	A fuzzy inference and big data analysis algorithm for the prediction of forest fire based on rechargeable wireless sensor networks	Lin H., Liu X., Wang X., Liu Y.	ScienceDirect	2018	3
[145]	Coupling early warning services, crowdsourcing, and modelling for improved decision support and wildfire emergency management	Bielski C., O'Brien V., Whitmore C., Ylinen K., Juga I., Nurmi P., Kilpinen J., Porras I., Sole J.M., Gamez P., Navarro M., Alikadic A., Gobbi A., Furlanello C., Zeug G., Weirather M., Martinez J., Yuste R., Castro S., Moreno V., Velin T., Rossi C.	IEEEXplore	2018	1
[46]	An intelligent wireless system for field ecology monitoring and forest fire warning	Zheng Y., Zhao Y., Liu W., Liu S., Yao R.	MDPI	2018	
[94]	An INSPIRE-compliant open-source GIS for fire-fighting management	Grasso N., Lingua A.M., Musci M.A., Noardo F., Piras M.	Springer	2018	1
[93]	Forest Fire Monitoring System Based on UAV Team, Remote Sensing, and Image Processing	Sherstjuk V., Zharikova M., Sokol I.	IEEEXplore	2018	
[48]	Advancing early forest fire detection utilizing smart wireless sensor networks	Pokhrel P., Soliman H.	Springer	2018	
[190]	The emergence of social media for natural disasters management: a big data perspective	Athanasis N, Themistocleous M, Kalabokidis K, . . .	MDPI	2018	
[192]	An application framework for forest fire and haze detection with data acquisition using unmanned aerial vehicle	Saadat M.N., Husen M.N.	ACM	2018	
[193]	Big data analysis in UAV surveillance for wildfire prevention and management	Athanasis N, Themistocleous M, Kalabokidis K, . . .	Springer	2018	
[146]	An integrated approach for tactical monitoring and data-driven spread forecasting of wildfires	Valero M.M., Rios O., Mata C., Pastor E., Planas E.	ScienceDirect	2017	4
[49]	Forest fire information system using wireless sensor network	Devadevan V., Sankaranarayanan S.	ScienceDirect	2017	1
[8]	Situation awareness in the large forest fires response. A solution based on wireless mesh networks	Zambrano M., Esteve M., Pérez I., Carvajal F., Zambrano A.M.	IEEEXplore	2017	
[50]	Design and implementation of a Wireless Sensor Network to detect forest fires	Granda Cantuña J., Bastidas D., Solórzano S., Clairand J.-M.	IEEEXplore	2017	5

Table A1. *Cont.*

Reference	Title	Authors	P. Channel	Year	Citations
[147]	Forest fire monitoring system based on aerial image	Kim S., Lee W., Park Y.-S., Lee H.-W., Lee Y.-T.	IEEEXplore	2017	5
[148]	Sensor data monitoring and decision level fusion scheme for early fire detection	Rizogiannis C., Thanos K.G., Astyakopoulos A., Kyriazanos D.M., Thomopoulos S.C.A.	SPIE	2017	
[29]	Wildfire prevention in the era of big data	Athanasis N, Themistocleous M, . . .	Springer	2017	
[175]	Decentralized estimation of forest fire spread using mobile sensors	Schlotterbeck G., Raïevsky C., Lefèvre L.	Springer	2016	2
[150]	Forest fire modelling using cellular automata: application to the watershed Oued Laou (Morocco)	Jellouli O., Bernoussi A., Mâatouk M., Amharref M.	MCMDS	2016	4
[52]	The Greek national observatory of forest fires (NOFFi)	Tompoulidou M., Stefanidou A., Grigoriadis D., Dragozi E., Stavrakoudis D., Gitas I.Z.	SPIE	2016	3
[172]	A web based DSS for the management of floods and wildfires (FLIRE) in urban and periurban areas	Kochilakis G., Poursanidis D., Chrysoulakis N., Varella V., Kotroni V., Eftychidis G., Lagouvardos K., Papathanasiou C., Karavokyros G., Aivazoglou M., Makropoulos C., Mimikou M.	ScienceDirect	2016	4
[95]	Focused sunlight factor of forest fire danger assessment using Web-GIS and RS technologies	Baranovskiy N.V., Sherstnyov V.S., Yankovich E.P., Engel M.V., Belov V.V.	Elsevier	2016	1
[149]	FLIRE DSS: A web tool for the management of floods and wildfires in urban and periurban areas	Kochilakis G., Poursanidis D., Chrysoulakis N., Varella V., Kotroni V., Eftychidis G., Lagouvardos K., Papathanasiou C., Karavokyros G., Aivazoglou M., Makropoulos C., Mimikou M.	OP	2016	1
[96]	GWR-PM—Spatial variation relationship analysis with Geographically Weighted Regression (GWR)—An application at Peninsular Malaysia	Jamhuri J., Azhar B.M.S., Puan C.L., Norizah K.	IOP	2016	1
[98]	Web-GIS platform for forest fire danger prediction in Ukraine: Prospects of RS technologies	Baranovskiy N.V., Zharikova M.V.	SPIE	2016	1
[99]	Joint processing of RS and WWLLN data for forest fire danger estimation: New concept	Baranovskiy N.V., Krechetova S.Y., Belikova M.Y., Kocheeva N.A., Yankovich E.P.	SPIE	2016	2
[151]	An open service platform for multi-hazard in action—The PHAROS pilot demonstration	Barth B., Marchitti M.A., Mulero Chaves J., Raape U., Strobl C., Borràs M., Vilalta O., Ballart H., Vendrell J., Prat N., Mendes M., Ladoire T., Gardikis G., Pantazis S., Costicoglou S., Jäckel K., Van Setten W.	LNI	2016	
[51]	Forest environment monitoring application of intelligence embedded based on wireless sensor networks	Seo J.H., Park H.B.	KSII	2016	2

Table A1. *Cont.*

Reference	Title	Authors	P. Channel	Year	Citations
[97]	Forest Fire Warning System Based on GIS and WSNs	Wang M., Liu H., Chen F., Liu J.	IEEEXplore	2016	2
[42]	Data mining techniques applied to wireless sensor networks for early forest fire detection	Saoudi M., Bounceur A., Euler R., Kechadi T.	ACM	2016	5
[100]	PREFER: A European service providing forest fire management support products	Eftychidis G., Laneve G., Ferrucci F., Sebastian Lopez A., Lourenco L., Clandillon S., Tampellini L., Hirn B., Diagourtas D., Leventakis G.	SPIE	2015	1
[53]	Geoinformation monitoring of forest fire danger on the basis of remote sensing data of surface by the artificial earth satellite	Baranovskiy N.V., Yankovich E.P.	Elsevier	2015	12
[54]	Research and application of fire risk assessment based on satellite remote sensing for transmission line	Chen X., Li T., Ruan L., Xu K., Huang J., Xiong Y.	SemanticScholar	2015	1
[182]	Wildfire evacuation trigger buffers for sensitive areas: EVITA project	Kiranoudis C.T., Zachariadis E., Keramitsoglou I., Saini K., Kakaliagou O., Kleitsikas E.	IEEEXplore	2014	
[55]	Fuzzy logic based implementation for forest fire detection using wireless sensor network	Dutta M., Bhowmik S., Giri C.	Springer	2014	5
[103]	A web-oriented geoinformation system application for forest fire danger prediction in typical forests of the Ukraine	Baranovskiy N., Zharikova M.	Springer	2014	13
[101]	Mapping and analysis of forest and land fire potential using geospatial technology and mathematical modeling	Suliman M.D.H., Mahmud M., Reba M.N.M., S L.W.	IOP	2014	
[102]	ArcGIS for assessment and display of the probability of forest fire danger	Yankovich E.P., Baranovskiy N.V., Yankovich K.S.	IEEEXplore	2014	9
[56]	Firoxio: Forest fire detection and alerting system	Owayjan M., Freiha G., Achkar R., Abdo E., Mallah S.	IEEEXplore	2014	7
[105]	The research on forest fire simulation system	Huang Z., He S., Qiu L.	IEEEXplore	2013	
[59]	Forest fire detection in wireless sensor network using fuzzy logic	Bolourchi P., Uysal S.	IEEEXplore	2013	22
[60]	A tool for simulation and geo-animation of wildfires with fuel editing and hotspot monitoring capabilities	Bogdos N., Manolakos E.S.	ScienceDirect	2013	13
[109]	Modeling the spread of spatio-temporal phenomena through the incorporation of ANFIS and genetically controlled cellular automata: A case study on forest fire	Vahidnia M.H., Alesheikh A.A., Behzadi S., Salehi S.	IJDE	2013	4
[111]	A gis based assistant information system for forest fire prevention direction	Yu X., Zhang W., Yang Y., Lei Z., Zhang X.	Scientific.net	2013	2
[108]	The zoning of forest fire potential of Gulestan province forests using granular computing and MODIS images	Shadlouei A.J., Delavar M.R.	IAPRSSIS	2013	

Table A1. *Cont.*

Reference	Title	Authors	P. Channel	Year	Citations
[179]	A data-driven model for large wildfire behaviour prediction in Europe	Rodriguez-Aseretto D., De Rigo D., Di Leo M., Cortés A., San-Miguel-ayanz J.	ScienceDirect	2013	17
[104]	Design & application of forest fire monitoring system by remote sensing for Beijing, Tianjin & Hebei	Zhao C.L., Hou X.	MDPI	2013	
[57]	Design of optical electronic watch system based on multi-sensor	Wu C., Lu J.F., He B.G.	AMR	2013	
[58]	Design and function of the European forest fire information system	McInerney D., San-Miguel-Ayanz J., Corti P., Whitmore C., Giovando C., Camia A.	PERS	2013	3
[107]	Design and realization of forest fire monitoring system based on GIS in Henan Province, China	Liu X., Geng Y., He Z., Zhang J., Zhang L., Chen Z., Li D.	Scientific.net	2013	1
[199]	Forest fire detection system based on zigbee wireless sensor network	Zhu Y.L., Xie L.Q.	Scientific.net	2013	1
[62]	Wireless sensor network for forest fire detection	Hariyawan M.Y., Gunawan A., Putra E.H.	ScienceDirect	2013	17
[67]	Managing forest fires with i-protect fire simulation module	Filippopoulos I., Stamoulis G., Kikiras P.	IEEEXplore	2012	
[152]	Simulation and visualization of forest fire growth in an integrated 3D virtual geographical environment—A preliminary study	Huang H., Tang L., Li J., Chen C.	IEEEXplore	2012	4
[112]	Introducing GIS-based simulation tools to support rapid response in wildland fire fighting	Moreno A., Segura A., Zlatanova S., Posada J., García-Alonso A.	WITPRESS	2012	2
[111]	A GIS-based decision support system for determining the shortest and safest route to forest fires: A case study in Mediterranean Region of Turkey	Akay A.E., Wing M.G., Sivrikaya F., Sakar D.	Springer	2012	23
[65]	Forest fire hazard modeling using hybrid AHP and fuzzy AHP methods using MODIS sensor	Sharifi Hashjin S., Hoseinpoor Milaghardan A., Esmaeily A., Mojaradi B., Naseri F.	IEEEXplore	2012	3
[154]	Decision support system for forest fire protection in the Euro-Mediterranean region	Kalabokidis K., Xanthopoulos G., Moore P., Caballero D., Kallos G., Llorens J., Roussou O., Vasilakos C.	Springer	2012	16
[155]	PiroPinus: A spreadsheet application to guide prescribed burning operations in maritime pine forest	Fernandes P.M., Loureiro C., Botelho H.	ScienceDirect	2012	14
[183]	Dynamic Data-Driven Genetic Algorithm for forest fire spread prediction	Denham M., Wendt K., Bianchini G., Cortés A., Margalef T.	ScienceDirect	2012	30
[153]	Evaluating fuel complexes for fire hazard mitigation planning in the southeastern United States	Andreu A.G., Shea D., Parresol B.R., Ottmar R.D.	ScienceDirect	2012	12
[64]	Monitoring system for forest fire based on wireless sensor network	Zhu Y., Xie L., Yuan T.	IEEEXplore	2012	9

Table A1. *Cont.*

Reference	Title	Authors	P. Channel	Year	Citations
[71]	A mobility constraint model to infer sensor behaviour in forest fire risk monitoring	Ballari D., Wachowicz M., Bregt A.K., Manso-Callejo M.	ScienceDirect	2012	8
[156]	SIRIO: An integrated forest fire monitoring, detection and decision support system—performance and results of the installation in Sanremo (Italy)	Losso A., Corgnati L., Bertoldo S., Allegretti M., Notarpietro R., Perona G.	WITPRESS	2012	5
[157]	Monitoring network-based infrastructure for forest fire detection	Kharchenko V.S., Orekhov A.A., Kotchkar D.A., Bogomolov V.V.	WITPRESS	2012	
[72]	A wireless multi-sensor network deployment framework for wildland fire detection	Xiao D., Jiang X., Feng J., Hu Y.	ASABE	2012	
[70]	Intelligent forest fire monitoring system	Stula M., Krstinic D., Seric L.	Springer	2012	11
[63]	A new thermally activated battery cell-based forest fire detection and monitoring system	Neubauer B., Sidén J., Olofsson C., Gulliksson M., Koptyug A., Nilsson H.-E., Norgren M.	Elsevier	2012	1
[66]	Assessment of sparse forest and fire detection using threshold watershed algorithm	Menaka E., Suresh Kumar S., Parameshwari P.	IEEEXplore	2012	
[68]	Vision-based fire detection algorithm using optical flow	Ha C., Hwang U., Jeon G., Cho J., Jeong J.	IEEEXplore	2012	16
[69]	FireWatch: G.I.S.-assisted wireless sensor networks for forest fires	Andreou P.G., Constantinou G., Zeinalipour-Yazti D., Samaras G.	Springer	2012	1
[110]	Cluster recognition in spatial-temporal sequences: The case of forest fires	Vega Orozco C., Tonini M., Conedera M., Kanveski M.	Springer	2012	18
[158]	Assistant decision-making support system of forest grass fire based on GIS	Yanping J., Hongye Y., Yuefeng Z., Shuo W.	IEEEXplore	2011	2
[113]	Risk assessment for effective prevention and management of forest fires in Lijiang City	Zheng S., Li C., Su X., Qiu Q., Shao G.	SemanticScholar	2011	3
[75]	Study on forest fires recognition and moving target tracking in video surveillance system	Xiong X.-Y., Wang B.	IEEEXplore	2011	1
[160]	A data fusion framework with novel hybrid algorithm for multi-agent Decision Support System for Forest Fire	Elmas Ç., Sönmez Y.	ScienceDirect	2011	16
[117]	Regional forest-fire susceptibility analysis in central Portugal using a probabilistic ratings procedure and artificial neural network weights assignment	Dimuccio L.A., Ferreira R., Cunha L., Campar De Almeida A.	CSIRO	2011	4
[114]	Satellite data for detecting trans-boundary crop and forest fire dynamics in Northern Thailand	Bach N., simongkalcrtkal N.	SemanticScholar	2011	1

Table A1. *Cont.*

Reference	Title	Authors	P. Channel	Year	Citations
[73]	Fuzzy modeling of the climate change effect to drought and to wild fires in Cyprus	Papakonstantinou X., Iliadis L.S., Pimenidis E., Maris F.	Springer	2011	1
[184]	Machine learning and dataming algorithms for predicting accidental small forest fires	Iyer V., Iyengar S.S., Paramesh N., Murthy G.R., Srinivas M.B.	SemanticScholar	2011	6
[74]	Estimation of area burned by forest fires in Mediterranean countries: A remote sensing data mining perspective	Quintano C., Fernández-Manso A., Stein A., Bijker W.	ScienceDirect	2011	18
[76]	Discovery and integration of web 2.0 content into geospatial information infrastructures: A use case in wild fire monitoring	Núñez-Redó M., Díaz L., Gil J., González D., Huerta J.	Springer	2011	8
[118]	Automatic forest-fire measuring using ground stations and unmanned aerial systems	de Dios J.R.M., Merino L., Caballero F., Ollero A.	MDPI	2011	40
[161]	A real-time Risk Assessment tool supporting wildland fire decisionmaking	Calkin D.E., Thompson M.P., Finney M.A., Hyde K.D.	JOF	2011	62
[162]	Development of a decision support system for the study of an area after the occurrence of forest fire	Ioannou K., Lefakis P., Arabatzis G.	Inderscience	2011	9
[164]	On the use of stereovision to develop a novel instrumentation system to extract geometric fire fronts characteristics	Rossi L., Akhloufi M., Tison Y.	ScienceDirect	2011	33
[116]	Embedded forest fire monitoring and positioning system based on machine vision	Liu L., Shen M., Zhao X., Sun Y., Lu M., Xiong Y.	IEEEXplore	2011	1
[78]	A ground system for early forest fire detection based on infrared signal processing	Bosch I., Gómez S., Vergara L.	SemanticScholar	2011	3
[119]	Foogle: Fire monitoring tool for EUMETSAT's active fire product over Turkey using Google Earth	Sönmez I., Erdi E., Tekeli A.E., Demir F., Arslan M.	GNHR	2011	3
[115]	Intelligent GIS system of forest fire alarm and it's controlling strategy design	Duan Y.X., Cao J.Z., Luo Z.L.	IEEEXplore	2011	1
[159]	An effective technique to detect forest fire region through ANFIS with spatial data	Angayarkkani K., Radhakrishnan N.	IEEEXplore	2011	3
[77]	Research of an automatic forest fire detection system based on cooperative perception	Dong Z., Huang D.-G., Zhang D.-Y.	SemanticScholar	2011	1
[163]	Microwave radiometry imaging for forest fire detection: A simulation study	Bonafoni S., Alimenti F., Angelucci G., Tasselli G.	MDPI	2011	15
[120]	Modelling the probability of lightning-induced forest fire occurrence in the province of León (NW Spain) [Modelización de la probabilidad de ocurrencia de incendios forestales por rayo en la provincia de León (NO de España)]	Castedo-Dorado F., Rodriguez-Perez J.R., Marcos-Menendez J.L., Alvarez-Taboada M.F.	Unirioja	2011	3

Table A1. *Cont.*

Reference	Title	Authors	P. Channel	Year	Citations
[79]	Fire risk assessment in the Brazilian Amazon using MODIS imagery and change vector analysis	Maeda E.E., Arcoverde G.F.B., Pellikka P.K.E., Shimabukuro Y.E.	ScienceDirect	2011	13
[171]	Multisource data integration for fire risk management: The local test of a global approach	Diagne M., Drame M., Ferrão C., Marchetti P.G., Pinto S., Rivolta G.	IEEEXplore	2010	8
[165]	Forest fire autonomous decision system based on fuzzy logic	Lei Z., Lu J.	SPIE	2010	
[167]	Evolutionary intelligent system for input parameter optimisation in environmental modelling: A case study in forest fire forecasting	Wendt K., Cortés A., Margalef T.	IEEEXplore	2010	1
[168]	Forest fire evolution prediction using a hybrid intelligent system	Mata A., Baruque B., Pérez-Lancho B., Corchado E., Corchado J.M.	Springer	2010	2
[121]	Forest fire hazard rating assessment in peat swamp forest using Landsat thematic mapper image	Razali S.M., Nuruddin A.A., Malek I.A., Patah N.A.	SPIE	2010	6
[122]	GIS-based probability Assessment of natural hazards in forested landscapes of central and South-Eastern Europe	Lorz C., Fürst C., Galic Z., Matijasic D., Podrazky V., Potocic N., Simoncic P., Strauch M., Vacik H., Makeschin F.	Springer	2010	17
[123]	Modelling spatiotemporal variability of natural forest fire size class distribution in a boreal forest	Cui W., Perera A.H.	SemanticScholar	2010	
[11]	The research on forest fire prevention information system based on GIS	Liu X., Meng Y.	IEEEXplore	2010	
[176]	A fuzzy inference system using Gaussian distribution curves for forest fire risk estimation	Iliadis L., Skopianos S., Tachos S., Spartalis S.	Springer	2010	8
[185]	Data injection at execution time in grid environments using Dynamic Data Driven Application System for wildland fire spread prediction	Rodríguez R., Cortés A., Margalef T.	IEEEXplore	2010	4
[186]	Towards policies for data insertion in dynamic data driven application systems: A case study sudden changes in wildland fire	Rodríguez R., Cortés A., Margalef T.	ScienceDirect	2010	2
[187]	Forest fires prediction by an organization based system	Mata A., Pérez B., Corchado J.M.	Springer	2010	3
[188]	Wildland fire growth prediction method based on Multiple Overlapping Solution	Bianchini G., Denham M., Cortés A., Margalef T., Luque E.	SemanticScholar	2010	30
[86]	Analysis of forest potential fire environment based on GIS and RS	Liu W., Wang S., Zhou Y., Wang L., Zhang S.	IEEEXplore	2010	2
[89]	An intelligent system employing an enhanced fuzzy c-means clustering model: Application in the case of forest fires	Iliadis L.S., Vangeloudh M., Spartalis S.	ScienceDirect	2010	31
[90]	Prediction and simulation of Malaysian forest fires by random spread	Bin Suliman M.D.H., Serra J., Mahmud M.	ACM	2010	2

Table A1. *Cont.*

Reference	Title	Authors	P. Channel	Year	Citations
[170]	SIRIO high performance decision support system for wildfire fighting in alpine regions: An integrated system for risk forecasting and monitoring	Corgnati L., Losso A., Perona G.	SemanticScholar	2010	
[126]	Innovative image geo-referencing tool for decision support in wildfire fighting	Losso A., Corgnati L., Perona G.	SemanticScholar	2010	
[169]	A stereovision system for fire characteristics estimation	Rossi L., Akhloufi M., Molinier T., Tison Y.	SemanticScholar	2010	
[177]	Verification & validation of an agent-based forest fire simulation model	Niazi M.A., Siddique Q., Hussain A., Kolberg M.	ACM	2010	9
[80]	Forest fires mapping and monitoring of current and past forest fire activity from meteosat second generation data	Carvalheiro L.C., Bernardo S.O., Orgaz M.D.M., Yamazaki Y.	ScienceDirect	2010	10
[83]	An RFID Plug-n-Play smart sensors for monitoring forest fires	Ciancetta F., Bucci G., Fiorucci E., Landi C.	SemanticScholar	2010	1
[125]	A simulation-optimization model for selecting the location of fuel-breaks to minimize expected losses from forest fires	Rytwinski A., Crowe K.A.	ScienceDirect	2010	27
[87]	Scheduling in a multi-processor environment with deteriorating job processing times and decreasing values: The case of forest fires	Pappis C.P., Rachaniotis N.P.	Springer	2010	15
[91]	Early detection and monitoring of forest fire with a wireless sensor network system	Bayo A., Antolín D., Medrano N., Calvo B., Celma S.	ScienceDirect	2010	21
[166]	Forest fire sensing and decision support using large scale WSNs	Kolega E., Vescoukis V., Douligeris C.	SemanticScholar	2010	2
[124]	Design of automatic forest fire positioning system based on video monitoring system	Han N., Yang G.-Q., Wang Y.-Y.	IEEEXplore	2010	3
[10]	A comparison of spectral angle mapper and artificial neural network classifiers combined with landsat TM imagery analysis for obtaining burnt area mapping	Petropoulos G.P., Vadrevu K.P., Xanthopoulos G., Karantounias G., Scholze M.	MDPI	2010	60
[81]	Application of wireless sensor networks in forest fire detection under uncertainty	Mal-Sarkar S., Sikder I.U., Konangi V.K.	IEEEXplore	2010	4
[82]	A smart forest-fire early detection sensory system: Another approach of utilizing wireless sensor and neural networks	Soliman H., Sudan K., Mishra A.	IEEEXplore	2010	22
[84]	Research and implementation of forest fire early warning system based on UWB wireless sensor networks	Guo L., Wang W., Wang G., Cui J.	IEEEXplore	2010	3
[85]	Design and research of fire early warning system based on topological structure for forest	Wang J., Li Y., Chen P., Ma J., Lon C., Liu S.	IEEEXplore	2010	1
[88]	Adaptive weighted fusion algorithm for monitoring system of forest fire based on wireless sensor networks	Lu G., Xue W.	IEEEXplore	2010	13

References

1. Moayedi, H.; Mehrabi, M.; Bui, D.T.; Pradhan, B.; Foong, L.K. Fuzzy-metaheuristic ensembles for spatial assessment of forest fire susceptibility. *J. Environ. Manag.* **2020**, *260*. [CrossRef]
2. Wu, F.; Lv, X.; Zhang, H. Design and development of forest fire monitoring terminal. In Proceedings of the 2018 International Conference on Sensor Networks and Signal Processing (SNSP), Xi'an, China, 28–31 October 2018; pp. 40–44. [CrossRef]
3. Wu, Z.; He, H.S.; Keane, R.E.; Zhu, Z.; Wang, Y.; Shan, Y. Current and future patterns of forest fire occurrence in China. *Int. J. Wildl. Fire* **2020**, *29*, 104–119. [CrossRef]
4. Finney, M.A. The wildland fire system and challenges for engineering. *Fire Saf. J.* **2020**, *120*, 103085. [CrossRef]
5. Sakellariou, S.; Tampekis, S.; Samara, F.; Sfougaris, A.; Christopoulou, O. Review of state-of-the-art decision support systems (DSSs) for prevention and suppression of forest fires. *J. For. Res.* **2017**, *28*, 1107–1117. [CrossRef]
6. Chowdary, V.; Kumar Gupta, M.; Singh, R. A Review on Forest Fire Detection Techniques: A Decadal Perspective. *Int. J. Eng. Technol.* **2018**, *7*, 1312. [CrossRef]
7. Certini, G. Effects of fire on properties of forest soils: A review. *Oecologia* **2005**, *143*, 1–10. [CrossRef] [PubMed]
8. Zambrano, M.; Esteve, M.; Pérez, I.; Carvajal, F.; Zambrano, A.M. Situation awareness in the large forest fires response. A solution based on wireless mesh networks. In Proceedings of the 2017 IEEE 9th Latin-American Conference on Communications (LATINCOM), Guatemala City, Guatemala, 8–10 November 2017. [CrossRef]
9. Kaur, H.; Sood, S.K. Adaptive Neuro Fuzzy Inference System (ANFIS) based wildfire risk assessment. *J. Exp. Theor. Artif. Intell.* **2019**, *31*, 599–619. [CrossRef]
10. Petropoulos, G.P.; Vadrevu, K.P.; Xanthopoulos, G.; Karantounias, G.; Scholze, M. A comparison of spectral angle mapper and artificial neural network classifiers combined with landsat TM imagery analysis for obtaining burnt area mapping. *Sensors* **2010**, *10*, 1967–1985. [CrossRef] [PubMed]
11. Liu, X.; Meng, Y. The research on forest fire prevention information system based on GIS. In Proceedings of the 2010 International Forum on Information Technology and Applications, Kunming, China, 16–18 July 2010; Volume 2, pp. 168–171. [CrossRef]
12. Liu, S.; Duffy, A.H.; Whitfield, R.I.; Boyle, I.M. Integration of decision support systems to improve decision support performance. *Knowl. Inf. Syst.* **2010**, *22*, 261–286. [CrossRef]
13. Zimmerman, T. Wildland fire management decision making. *J. Agric. Sci. Technol. B* **2012**, *2*, 169.
14. Petersen, K.; Feldt, R.; Mujtaba, S.; Mattsson, M. Systematic Mapping Studies in Software Engineering. In Proceedings of the International Conference on Evaluation and Assessment in Software Engineering (EASE), Bari, Italy, 26–27 June 2008; pp. 1–10.
15. Kitchenham, B.; Charters, S. Guidelines for performing systematic literature reviews in software engineering. Keele University, UK. *Thechnical. Rep.* **2007**, *9*, 5.
16. Suzuki, K.; Tamada, H.; Doizaki, R.; Hirahara, Y.; Sakamoto, M. Women's negotiation support system—as affected by personal appearance versus use of language. In *Advances in Affective and Pleasurable Design*; Springer: Cham, Germany, 2017; pp. 221–230.
17. Aqel, M.J.; Nakshabandi, O.; Adeniyi, A. Decision support systems classification in industry. *Period. Eng. Nat. Sci.* **2019**, *7*, 774–785. [CrossRef]
18. Trianni, A.; Cagno, E.; Farne, S. Barriers, drivers and decision-making process for industrial energy efficiency: A broad study among manufacturing small and medium-sized enterprises. *Appl. Energy* **2016**, *162*, 1537–1551. [CrossRef]
19. Romiszowski, A.J. *Designing Instructional Systems: Decision Making in Course Planning and Curriculum Design*; Routledge Taylor & Francis Group: London, UK, 2016.
20. Samuel, O.W.; Asogbon, G.M.; Sangaiah, A.K.; Fang, P.; Li, G. An integrated decision support system based on ANN and Fuzzy_AHP for heart failure risk prediction. *Expert Syst. Appl.* **2017**, *68*, 163–172. [CrossRef]
21. Arnott, D.; Pervan, G. Arnott, D.; Pervan, G. A critical analysis of decision support systems research revisited: The rise of design science. In *Enacting Research Methods in Information Systems*; Palgrave Macmillan: Cham, Germany, 2016; pp. 43–103.
22. Zarate, P. Multi-criteria Group Decision Support System: Multi Cultural Experiments. In *Innovation for Systems Information and Decision Meeting*; Springer: Cham, Switzerland, 2020; pp. 47–61.
23. Cravero, A.; Sepúlveda, S. A chronological study of paradigms for data warehouse design. *Ing. Investig. Fac. Ing. Univ. Nac. Colomb.* **2012**, *32*, 58–62.
24. Hovorushchenko, T.; Herts, A.; Hnatchuk, Y. Concept of Intelligent Decision Support System in the Legal Regulation of the Surrogate Motherhood. *IDDM* **2019**, *2488*, 57–68.
25. Ajah, I.A.; Nweke, H.F. Big data and business analytics: Trends, platforms, success factors and applications. *Big Data Cogn. Comput. Multidiscip. Digit. Publ. Inst.* **2019**, *2*, 32. [CrossRef]
26. Mikalef, P.; Pappas, I.; Krogstie, J.; Giannakos, M. Big data analytics capabilities: A systematic literature review and research agenda. *Inf. Syst. E-Bus. Manag.* **2018**, *16*, 547–578. [CrossRef]
27. De Mauro, A.; Greco, M.; Grimaldi, M. A formal definition of Big Data based on its essential features. *Libr. Rev.* **2016**, *65*, 122–135. [CrossRef]
28. Negassa, M.D.; Mallie, D.T.; Gemeda, D.O. Forest cover change detection using Geographic Information Systems and remote sensing techniques: A spatio-temporal study on Komto Protected forest priority area, East Wollega Zone, Ethiopia. *Environ. Syst. Res.* **2020**, *9*, 1. [CrossRef]
29. Athanasis, N.; Themistocleous, M.; Kalabokidis, K. Wildfire Prevention in the Era of Big Data. In *European, Mediterranean, and Middle Eastern Conference on Information Systems*; Springer: Cham, Switzerland, 2017; pp. 111–118.

30. Cravero, A. Big data architectures and the internet of things: A systematic mapping study. *IEEE Lat. Am. Trans.* **2018**, *16*, 1219–1226. [CrossRef]
31. Acosta, M.; Corral, S. Multicriteria decision analysis and participatory decision support systems in forest management. *For. MDPI* **2017**, *8*, 116. [CrossRef]
32. Chuvieco, E.; Aguado, I.; Salas, J.; Garcia, M.; Yebra, M.; Oliva, P. Satellite Remote Sensing Contributions to Wildland Fire Science and Management. *Curr. For. Rep.* **2020**, *6*, 81–96. [CrossRef]
33. Noble, P.; Paveglio, T.B. Exploring Adoption of the Wildland Fire Decision Support System: End User Perspectives. *J. For.* **2020**, *118*, 154–171. [CrossRef]
34. Schultz, C.A.; Miller, L.F.; Greiner, S.M.; Kooistra, C. A Qualitative Study on the US Forest Service's Risk Management Assistance Efforts to Improve Wildfire Decision-Making. *Forests* **2021**, *12*, 344. [CrossRef]
35. Zaimes, G.; Tsioras, P.; Kiosses, C. Perspectives on protected are and wildfire management in the Black Sea region. *J. For. Res.* **2020**, *31*, 257–268. [CrossRef]
36. Martell, D.L. A Review of Recent Forest and Wildland Fire Management Decision Support Systems Research. *FIRE Sci. Manag.* **2015**, *1*, 128–137. [CrossRef]
37. Pacheco, A.P.; Claro, J.; Fernandes, P.M.; de Neufville, R.; Oliveira, T.M.; Borges, J.G.; Rodrigues, J.C. Cohesive fire management within an uncertain environment: A review of risk handling and decision support systems. *For. Ecol. Manag.* **2015**, *347*, 1–17. [CrossRef]
38. Francos, M.; Ubeda, X.; Pereira, P. Long-term forest management after wildfire (Catalonia, NE Iberian Peninsula). *J. For. Res.* **2020**, *31*, 269–278. [CrossRef]
39. James, K.; Randall, N.; Haddaway, N. A methodology for systematic mapping in environmental sciences. *Environ. Evid.* **2016**, *5*, 1–13. [CrossRef]
40. Dybå, T.; Dingsøyr, T. Empirical studies of agile software development: A systematic review. *Inf. Softw. Technol.* **2008**, *50*, 833–859. [CrossRef]
41. Kraemer, H. Kappa coefficient. In *Wiley StatsRef: Statistics Reference Online*; Wiley: Hoboken, NJ, USA, 2014; pp. 1–4.
42. Saoudi, M.; Bounceur, A.; Euler, R.; Kechadi, T. Data mining techniques applied to wireless sensor networks for early forest fire detection. In Proceedings of the International Conference on Internet of things and Cloud Computing, Cambridge, UK, 22–23 March 2016; pp. 1–7. [CrossRef]
43. Yahya Dewangga, Z.; Koesuma, S. Development of forest fire early warning system based on the wireless sensor network in Lawu Mountain. *J. Phys. Conf. Ser.* **2019**, *1153*. [CrossRef]
44. Toledo-Castro, J.; Santos-Gonzáles, I.; Caballero-Gil, P.; Hernandez-Goya, C.; Rodríguez-Perez, N.; Aguasca-Colomo, R. Fuzzy-Based Forest Fire Prevention and Detection by Wireless Sensor Networks. In *The 13th International Conference on Soft Computing Models in Industrial and Environmental Applications*; Springer: Cham, Switzerland, 2018. [CrossRef]
45. Gonçalves, D.; Lima, D.; Martinho moura, J.; Ferreira, L. "Portugal Without Fires", A Data Visualization System to Help Analyze Forest Fire Data In Portugal. *Interactivity Game Creat. Des. Learn. Innov.* **2019**, *265*, 385–394. [CrossRef]
46. Zheng, Y.; Zhao, Y.; Liu, W.; Liu, S.; Yao, R. An intelligent wireless system for field ecology monitoring and forest fire warning. *Sensors* **2018**, *18*, 4457. [CrossRef] [PubMed]
47. Smotr, O.; Borzov, Y.; Burak, N.; Ljaskovska, S. Implementation of Information Technologies in the Organization of Forest Fire Suppression Process. In Proceedings of the 2018 IEEE Second International Conference on Data Stream Mining & Processing (DSMP), Lviv, Ukraine, 21–25 August 2018; pp. 157–161. [CrossRef]
48. Pokhrel, P.; Soliman, H. *Advancing Early Forest Fire Detection Utilizing Smart Wireless Sensor Networks*; Springer International Publishing: New York, NY, USA, 2018; Volume 11249, ISBN 9783030030612.
49. Devadevan, V.; Sankaranarayanan, S. Forest fire information system using wireless sensor network. *Int. J. Agric. Environ. Inf. Syst.* **2017**, *8*, 52–67. [CrossRef]
50. Granda Cantuña, J.; Bastidas, D.; Solórzano, S.; Clairand, J.M. Design and implementation of a Wireless Sensor Network to detect forest fires. In Proceedings of the 2017 Fourth International Conference on eDemocracy & eGovernment (ICEDEG), Quito, Ecuador, 19–21 April 2017; pp. 15–21. [CrossRef]
51. Seo, J.H.; Park, H.B. Forest environment monitoring application of intelligence embedded based on wireless sensor networks. *KSII Trans. Internet Inf. Syst.* **2016**, *10*, 1555–1570. [CrossRef]
52. Tompoulidou, M.; Stefanidou, A.; Grigoriadis, D.; Dragozi, E.; Stavrakoudis, D.; Gitas, I.Z. The Greek National Observatory of Forest Fires (NOFFi). *Fourth Int. Conf. Remote Sens. Geoinf. Environ.* **2016**, *9688*. [CrossRef]
53. Baranovskiy, N.V.; Yankovich, E.P. Geoinformation monitoring of forest fire danger on the basis of remote sensing data of surface by the artificial earth satellite. *J. Autom. Inf. Sci.* **2015**, *47*, 11–23. [CrossRef]
54. Chen, X.; Li, T.; Ruan, L.; Xu, K.; Huang, J.; Xiong, Y. Research and application of fire risk assessment based on satellite remote sensing for transmission line. *Proc. World Congr. Eng. Comput. Sci.* **2015**, *2219*, 284–287.
55. Dutta, M.; Bhowmik, S.; Giri, C. Fuzzy Logic Based Implementation for Forest Fire Detection Using Wireless Sensor Network. In *Advanced Computing, Networking and Informatics-Volume 1: Advanced Computing and Informatics Proceedings of the Second International Conference on Advanced Computing, Networking and Informatics (ICACNI-2014)*; Springer: Berlin, Germany, 2014; Volume 27, pp. 319–327. ISBN 9783319073521.

56. Owayjan, M.; Freiha, G.; Achkar, R.; Abdo, E.; Mallah, S. Firoxio: Forest fire detection and alerting system. In Proceedings of the MELECON 2014—2014 17th IEEE Mediterranean Electrotechnical Conference, Beirut, Lebanon, 13–16 April 2014; pp. 177–181. [CrossRef]
57. Wu, C.; Lu, J.F.; He, B.G. Design of optical electronic watch system based on multi-sensor. *Adv. Mater. Res.* **2013**, *753–755*, 2232–2234. [CrossRef]
58. McInerney, D.; San-Miguel-Ayanz, J.; Corti, P.; Whitmore, C.; Giovando, C.; Camia, A. Design and function of the European forest fire information system. *Photogramm. Eng. Remote Sens.* **2013**, *79*, 965–973. [CrossRef]
59. Bolourchi, P.; Uysal, S. Forest fire detection in wireless sensor network using fuzzy logic. In Proceedings of the 2013 Fifth International Conference on Computational Intelligence, Communication Systems and Networks, Madrid, Spain, 5–7 June 2013; pp. 83–87. [CrossRef]
60. Bogdos, N.; Manolakos, E.S. A tool for simulation and geo-animation of wildfires with fuel editing and hotspot monitoring capabilities. *Environ. Model. Softw.* **2013**, *46*, 182–195. [CrossRef]
61. Zhang, J.; Li, W.; Han, N.; Kan, J. Forest fire detection system based on a ZigBee wireless sensor network. *Front. For. China* **2008**, *3*, 369–374. [CrossRef]
62. Hariyawan, M.Y.; Gunawan, A.; Putra, E.H. Wireless sensor network for forest fire detection. *Telkomnika* **2013**, *11*, 563–574. [CrossRef]
63. Neubauer, B.; Sidén, J.; Olofsson, C.; Gulliksson, M.; Koptyug, A.; Nilsson, H.E.; Norgren, M. A new thermally activated battery cell-based forest fire detection and monitoring system. *WIT Trans. Ecol. Environ.* **2012**, *158*, 113–124. [CrossRef]
64. Zhu, Y.; Xie, L.; Yuan, T. Monitoring system for forest fire based on wireless sensor network. In Proceedings of the 10th World Congress on Intelligent Control and Automation, Beijing, China, 6–8 July 2012; Volume 694–697, pp. 4245–4248.
65. Sharifi Hashjin, S.; Hoseinpoor Milaghardan, A.; Esmaeily, A.; Mojaradi, B.; Naseri, F. Forest fire hazard modeling using hybrid AHP and fuzzy AHP methods using MODIS sensor. *Int. Geosci. Remote Sens. Symp.* **2012**, 931–934. [CrossRef]
66. Menaka, E.; Suresh Kumar, S.; Parameshwari, P. Assessment of sparse forest and fire detection using threshold watershed algorithm. In Proceedings of the IET Chennai 3rd International Conference on Sustainable Energy and Intelligent Systems (SEISCON 2012), Tiruchengode, India, 27–29 December 2012; pp. 89–94. [CrossRef]
67. Filippopoulos, I.; Stamoulis, G.; Kikiras, P. Managing forest fires with i-protect fire simulation module. In Proceedings of the 2012 16th Panhellenic Conference on Informatics, Piraeus, Greece, 5–7 October 2012; pp. 283–289. [CrossRef]
68. Ha, C.; Hwang, U.; Jeon, G.; Cho, J.; Jeong, J. Vision-based fire detection algorithm using optical flow. In Proceedings of the 2012 Sixth International Conference on Complex, Intelligent, and Software Intensive Systems, Palermo, Italy, 4–6 July 2012; pp. 526–530. [CrossRef]
69. Andreou, P.G.; Constantinou, G.; Zeinalipour-Yazti, D.; Samaras, G. FireWatch: G.I.S.-assisted wireless sensor networks for forest fires. *Int. Conf. Sci. Stat. Database Manag.* **2012**, *7338*, 618–621. [CrossRef]
70. Stula, M.; Krstinic, D.; Seric, L. Intelligent forest fire monitoring system. *Inf. Syst. Front.* **2012**, *14*, 725–739. [CrossRef]
71. Ballari, D.; Wachowicz, M.; Bregt, A.K.; Manso-Callejo, M. A mobility constraint model to infer sensor behaviour in forest fire risk monitoring. *Comput. Environ. Urban Syst.* **2012**, *36*, 81–95. [CrossRef]
72. Xiao, D.; Jiang, X.; Feng, J.; Hu, Y. A wireless multi-sensor network deployment framework for wildland fire detection. *Am. Soc. Agric. Biol. Eng. Annu. Int. Meet.* **2012**, *5*, 4157–4162. [CrossRef]
73. Papakonstantinou, X.; Iliadis, L.S.; Pimenidis, E.; Maris, F. Fuzzy modeling of the climate change effect to drought and to wild fires in Cyprus. *Eng. Appl. Neural Netowrks* **2011**, *363*, 516–528. [CrossRef]
74. Quintano, C.; Fernández-Manso, A.; Stein, A.; Bijker, W. Estimation of area burned by forest fires in Mediterranean countries: A remote sensing data mining perspective. *For. Ecol. Manag.* **2011**, *262*, 1597–1607. [CrossRef]
75. Xiong, X.Y.; Wang, B. Study on forest fires recognition and moving target tracking in video surveillance system. In Proceedings of the 2011 International Conference on Electronic & Mechanical Engineering and Information Technology, Harbin, China, 12-14 August 2011; Volume 6, pp. 2853–2856. [CrossRef]
76. Núñez-Redó, M.; Díaz, L.; Gil, J.; González, D.; Huerta, J. Discovery and integration of web 2.0 content into geospatial information infrastructures: A use case in wild fire monitoring. *Int. Conf. Availab. Reliab. Secur.* **2011**, *690*, 50–68. [CrossRef]
77. Dong, Z.; Huang, D.G.; Zhang, D.Y. Research of an automatic forest fire detection system based on cooperative perception. *Appl. Mech. Mater.* **2011**, *48–49*, 916–919. [CrossRef]
78. Bosch, I.; Gómez, S.; Vergara, L. A ground system for early forest fire detection based on infrared signal processing. *Int. J. Remote Sens.* **2014**, *32*, 4857–4870. [CrossRef]
79. Maeda, E.E.; Arcoverde, G.F.B.; Pellikka, P.K.E.; Shimabukuro, Y.E. Fire risk assessment in the Brazilian Amazon using MODIS imagery and change vector analysis. *Appl. Geogr.* **2011**, *31*, 76–84. [CrossRef]
80. Carvalheiro, L.C.; Bernardo, S.O.; Orgaz, M.D.M.; Yamazaki, Y. Forest fires mapping and monitoring of current and past forest fire activity from meteosat second generation data. *Environ. Model. Softw.* **2010**, *25*, 1909–1914. [CrossRef]
81. Mal-Sarkar, S.; Sikder, I.U.; Konangi, V.K. Application of wireless sensor networks in forest fire detection under uncertainty. In Proceedings of the 2010 13th International Conference on Computer and Information Technology (ICCIT), Dhaka, Bangladesh, 23–25 December 2010; pp. 193–197. [CrossRef]
82. Soliman, H.; Sudan, K.; Mishra, A. A smart forest-fire early detection sensory system: Another approach of utilizing wireless sensor and neural networks. *Proc. IEEE Sens.* **2010**, 1900–1904. [CrossRef]

83. Ciancetta, F.; Bucci, G.; Fiorucci, E.; Landi, C. An RFID Plug-n-Play smart sensors for monitoring forest fires. In Proceedings of the IMEKO TC-4 and TC-19 Symposium and IWADC Instrumentation for the ICT Area, Kosice, Slovakia, 8–10 September 2010; pp. 531–536.
84. Guo, L.; Wang, W.; Wang, G.; Cui, J. Research and Implementation of Forest Fire Early Warning System Based on UWB Wireless Sensor Networks. In Proceedings of the 2010 Second International Conference on Communication Systems, Networks and Applications, Hong Kong, China, 29 June–1 July 2010; pp. 176–179.
85. Wang, J.; Li, Y.; Chen, P.; Ma, J.; Lon, C.; Liu, S. Design and research of fire early warning system based on topological structure for forest. In Proceedings of the Third International Workshop on Advanced Computational Intelligence, Suzhou, China, 25–27 August 2010; pp. 579–582. [CrossRef]
86. Liu, W.; Wang, S.; Zhou, Y.; Wang, L.; Zhang, S. Analysis of forest potential fire environment based on GIS and RS. In Proceedings of the 2010 18th International Conference on Geoinformatics, Beijing, China, 18–20 June 2010. [CrossRef]
87. Pappis, C.P.; Rachaniotis, N.P. Scheduling in a multi-processor environment with deteriorating job processing times and decreasing values: The case of forest fires. *J. Heuristics* **2010**, *16*, 617–632. [CrossRef]
88. Lu, G.; Xue, W. Adaptive weighted fusion algorithm for monitoring system of forest fire based on wireless sensor networks. In Proceedings of the 2010 Second International Conference on Computer Modeling and Simulation, Sanya, China, 22–24 January 2010; Volume 4, pp. 414–417. [CrossRef]
89. Iliadis, L.S.; Vangeloudh, M.; Spartalis, S. An intelligent system employing an enhanced fuzzy c-means clustering model: Application in the case of forest fires. *Comput. Electron. Agric.* **2010**, *70*, 276–284. [CrossRef]
90. Bin Suliman, M.D.H.; Serra, J.; Mahmud, M. Prediction and simulation of Malaysian forest fires by random spread. *Int. J. Remote Sens.* **2010**, *31*, 6015–6032. [CrossRef]
91. Bayo, A.; Antolín, D.; Medrano, N.; Calvo, B.; Celma, S. Early detection and monitoring of forest fire with a wireless sensor network system. *Procedia Eng.* **2010**, *5*, 248–251. [CrossRef]
92. Tien Bui, D.; Hoang, N.D.; Samui, P. Spatial pattern analysis and prediction of forest fire using new machine learning approach of Multivariate Adaptive Regression Splines and Differential Flower Pollination optimization: A case study at Lao Cai province (Viet Nam). *J. Environ. Manag.* **2019**, *237*, 476–487. [CrossRef]
93. Sherstjuk, V.; Zharikova, M.; Sokol, I. Forest Fire Monitoring System Based on UAV Team, Remote Sensing, and Image Processing. In Proceedings of the 2018 IEEE Second International Conference on Data Stream Mining & Processing (DSMP), Lviv, Ukraine, 21–25 August 2018; pp. 590–594. [CrossRef]
94. Grasso, N.; Lingua, A.M.; Musci, M.A.; Noardo, F.; Piras, M. An INSPIRE-compliant open-source GIS for fire-fighting management. *Nat. Hazards* **2018**, *90*, 623–637. [CrossRef]
95. Baranovskiy, N.V.; Sherstnyov, V.S.; Yankovich, E.P.; Engel, M.V.; Belov, V.V. Focused sunlight factor of forest fire danger assessment using Web-GIS and RS technologies. *Fourth Int. Conf. Remote Sens. Geoinf. Environ.* **2016**, *9688*, 968823. [CrossRef]
96. Jamhuri, J.; Azhar, B.M.S.; Puan, C.L.; Norizah, K. GWR-PM—Spatial variation relationship analysis with Geographically Weighted Regression (GWR)—An application at Peninsular Malaysia. *IOP Conf. Ser. Earth Environ. Sci.* **2016**, *37*. [CrossRef]
97. Wang, M.; Liu, H.; Chen, F.; Liu, J. Forest Fire Warning System Based on GIS and WSNs. In Proceedings of the 2015 4th International Conference on Advanced Information Technology and Sensor Application (AITS), Harbin, China, 21–23 August 2015; pp. 3–6. [CrossRef]
98. Baranovskiy, N.V.; Zharikova, M.V. Web-GIS platform for forest fire danger prediction in Ukraine: Prospects of RS technologies. In Proceedings of the Proceedings SPIE 10001, Remote Sensing of Clouds and the Atmosphere XXI, Edinburgh, UK, 26–29 September 2016. [CrossRef]
99. Baranovskiy, N.V.; Krechetova, S.Y.; Belikova, M.Y.; Kocheeva, N.A.; Yankovich, E.P. Joint processing of RS and WWLLN data for forest fire danger estimation: New concept. *Remote Sens. Clouds Atmos.* **2016**, *10001*, 1000113. [CrossRef]
100. Eftychidis, G.; Laneve, G.; Ferrucci, F.; Sebastian Lopez, A.; Lourenco, L.; Clandillon, S.; Tampellini, L.; Hirn, B.; Diagourtas, D.; Leventakis, G. PREFER: A European service providing forest fire management support products. *Third Int. Conf. Remote Sens. Geoinf. Environ.* **2015**, *9535*, 953517. [CrossRef]
101. Suliman, M.D.H.; Mahmud, M.; Reba, M.N.M. Mapping and analysis of forest and land fire potential using geospatial technology and mathematical modeling. *IOP Conf. Ser. Earth Environ. Sci.* **2014**, *18*. [CrossRef]
102. Yankovich, E.P.; Baranovskiy, N.V.; Yankovich, K.S. ArcGIS for assessment and display of the probability of forest fire danger. In Proceedings of the 2014 9th International Forum on Strategic Technology (IFOST), Cox's Bazar, Bangladesh, 21–23 October 2014; pp. 222–225. [CrossRef]
103. Baranovskiy, N.; Zharikova, M. A Web-Oriented Geoinformation System Application for Forest Fire Danger Prediction in Typical Forests of the Ukraine. In *Thematic Cartography for the Society*; Springer International Publishing: Berlin, Germany, 2014; pp. 13–22. ISBN 978-3-319-08179-3.
104. Zhao, C.L.; Hou, X. Design & application of forest fire monitoring system by remote sensing for Beijing, Tianjin & Hebei. *Adv. Mater. Res.* **2013**, *760–762*, 1043–1047. [CrossRef]
105. Huang, Z.; He, S.; Qiu, L. The research on forest fire simulation system. In Proceedings of the 2013 Fourth International Conference on Digital Manufacturing & Automation, Cox's Bazar, Bangladesh, Shinan, China, 29–30 June 2013; pp. 1528–1531. [CrossRef]
106. Yu, X.; Zhang, W.; Yang, Y.; Lei, Z.; Zhang, X. A gis based assistant information system for forest fire prevention direction. *Appl. Mech. Mater.* **2013**, *303–306*, 2215–2218. [CrossRef]

107. Liu, X.; Geng, Y.; He, Z.; Zhang, J.; Zhang, L.; Chen, Z.; Li, D. Design and realization of forest fire monitoring system based on GIS in Henan Province, China. *Adv. Mater. Res.* **2013**, *610–613*, 3665–3669. [CrossRef]
108. Jalilzadeh Shadlouei, A.; Delavar, M.R. The Zoning of Forest Fire Potential of Gulestan Province Forests Using Granular Computing and MODIS Images. *ISPRS Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2013**, *XL-1/W3*, 365–370. [CrossRef]
109. Vahidnia, M.H.; Alesheikh, A.A.; Behzadi, S.; Salehi, S. Modeling the spread of spatio-temporal phenomena through the incorporation of ANFIS and genetically controlled cellular automata: A case study on forest fire. *Int. J. Digit. Earth* **2013**, *6*, 51–75. [CrossRef]
110. Vega Orozco, C.; Tonini, M.; Conedera, M.; Kanveski, M. Cluster recognition in spatial-temporal sequences: The case of forest fires. *Geoinformatica* **2012**, *16*, 653–673. [CrossRef]
111. Akay, A.E.; Wing, M.G.; Sivrikaya, F.; Sakar, D. A GIS-based decision support system for determining the shortest and safest route to forest fires: A case study in Mediterranean Region of Turkey. *Environ. Monit. Assess.* **2012**, *184*, 1391–1407. [CrossRef] [PubMed]
112. Moreno, A.; Segura, A.; Zlatanova, S.; Posada, J.; García-Alonso, A. Introducing GIS-based simulation tools to support rapid response in wildland fire fighting. *WIT Trans. Ecol. Environ.* **2012**, *158*, 163–176. [CrossRef]
113. Zheng, S.; Li, C.; Su, X.; Qiu, Q.; Shao, G. Risk assessment for effective prevention and management of forest fires in Lijiang City. *Int. J. Sustain. Dev. World Ecol.* **2011**, *18*, 509–514. [CrossRef]
114. Bach, N.L.; Simongkalertkal, N. Satellite Data for Detecting Trans-Boundary Crop and Forest Fire Dynamics in Northern Thailand. *Int. J. Geoinform.* **2011**, 47–54.
115. Duan, Y.X.; Cao, J.Z.; Luo, Z.L. Intelligent GIS system of forest fire alarm and it's controlling strategy design. In Proceedings of the 2011 International Conference on Machine Learning and Cybernetics, Guilin, China, 10–13 July 2011; Volume 4, pp. 1809–1814. [CrossRef]
116. Liu, L.; Shen, M.; Zhao, X.; Sun, Y.; Lu, M.; Xiong, Y. Embedded forest fire monitoring and positioning system based on machine vision. In Proceedings of the 2011 International Conference on Machine Learning and Cybernetics, Guilin, China, 10–13 July 2011; Volume 2, pp. 631–635. [CrossRef]
117. Dimuccio, L.A.; Ferreira, R.; Cunha, L.; Campar De Almeida, A. Regional forest-fire susceptibility analysis in central Portugal using a probabilistic ratings procedure and artificial neural network weights assignment. *Int. J. Wildl. Fire* **2011**, *20*, 776–791. [CrossRef]
118. de Dios, J.R.M.; Merino, L.; Caballero, F.; Ollero, A. Automatic forest-fire measuring using ground stations and unmanned aerial systems. *Sensors* **2011**, *11*, 6328–6353. [CrossRef] [PubMed]
119. Sönmez, I.; Erdi, E.; Tekeli, A.E.; Demir, F.; Arslan, M. Foogle: Fire monitoring tool for EUMETSAT's active fire product over Turkey using Google Earth. *Geomat. Nat. Hazards Risk* **2011**, *2*, 1–13. [CrossRef]
120. Castedo-Dorado, F.; Rodríguez-Pérez, J.R.; Marcos-Menéndez, J.L.; Álvarez-Taboada, M.F. Modelling the probability of lightning-induced forest fire occurrence in the province of León (NW Spain). *For. Syst.* **2011**, *20*, 95. [CrossRef]
121. Razali, S.M. Forest fire hazard rating assessment in peat swamp forest using Landsat thematic mapper image. *J. Appl. Remote Sens.* **2010**, *4*, 043531. [CrossRef]
122. Lorz, C.; Fürst, C.; Galic, Z.; Matijasic, D.; Podrazky, V.; Potocic, N.; Simoncic, P.; Strauch, M.; Vacik, H.; Makeschin, F. GIS-based probability Assessment of natural hazards in forested landscapes of central and South-Eastern Europe. *Environ. Manag.* **2010**, *46*, 920–930. [CrossRef]
123. Cui, W.; Perera, A.H. Modelling spatiotemporal variability of natural forest fire size class distribution in a boreal forest. *Model. Environ.* **2010**, *1*, 262–271.
124. Ning, H.; Guang-qun, Y.; Yuan-yuan, W. Design of Automatic Forest Fire Positioning System Based on Video Monitoring System. In Proceedings of the 2010 Second IITA International Conference on Geoscience and Remote Sensing, Qingdao, China, 28–31 August 2010; pp. 532–535. [CrossRef]
125. Rytwinski, A.; Crowe, K.A. A simulation-optimization model for selecting the location of fuel-breaks to minimize expected losses from forest fires. *For. Ecol. Manag.* **2010**, *260*, 1–11. [CrossRef]
126. Losso, A.; Corgnati, L.; Perona, G. Innovative image geo-referencing tool for decision support in wildfire fighting. *WIT Trans. Ecol. Environ.* **2010**, *137*, 173–183. [CrossRef]
127. Avula, S.B.; Badri, S.J.; Reddy, G. A Novel Forest Fire Detection System Using Fuzzy Entropy Optimized Thresholding and STN-based CNN. In Proceedings of the 2020 International Conference on COMmunication Systems and NETworkS, COMSNETS 2020, Bengaluru, India, 7–11 January 2020; pp. 750–755.
128. Peinl, P. A Retrospective on ASPires: An Advanced System for the Prevention and Early Detection of Forest Fires. In Proceedings of the 12th International Conference on Management of Digital EcoSystems, MEDES 2020, Virtual Event, United Arab Emirates, 2–4 November 2020; pp. 30–37.
129. Scicluna, D. An IoT-Based Forest Fire Detection System. Bachelor's Thesis, University of Malta, Msida, Malta, 2020.
130. Zhang, B.; Zhang, Z. Architecture of embedded intelligent video analysis system for forest fire prevention. In *Journal of Physics: Conference Series*; Institute of Physics Publishing: London, UK, 2020; Volume 1544, p. 12052.
131. de Almeida, R.V.; Crivellaro, F.; Narciso, M.; Sousa, A.I.; Vieira, P. Bee2Fire: A deep learning powered forest fire detection system. In Proceedings of the ICAART 2020—12th International Conference on Agents and Artificial Intelligence, Valletta, Malta, 22–24 February 2020; SciTePress: Setúbal, Portugal, 2020; Volume 2, pp. 603–609.

132. Peng, J.; Zhang, H.; Wu, H.; Wei, Q. Design of Forest Fire Warning System Based on Machine Vision. In *International Conference on Computer Engineering and Networks*; Springer Science and Business Media Deutschland GmbH: Berlin, Germany, 2020; Volume 1274, pp. 352–363.
133. Moussati, A.E.; Moussaoui, O.; Benzekri, W.; El Moussati, A.; Berrajaa, M. Early Forest Fire Detection System using Wireless Sensor Network and Deep Learning. *Artic. Int. J. Adv. Comput. Sci. Appl.* **2020**, *11*. [CrossRef]
134. Anas, M.; Abbassi, E.; Jilbab, A.; Bourouhou, A. Efficient Forest Fire Detection System Based on Data Fusion Applied in Wireless Sensor Networks. *Int. J. Electr. Eng. Inform.* **2020**, *12*. [CrossRef]
135. Güllüce, Y.; Çelik, R.N. Fireanalyst: An effective system for detecting fire geolocation and fire behavior in forests using mathematical modeling. *Turkish J. Agric. For.* **2020**, *44*, 127–139. [CrossRef]
136. Minu, O.; Ramsiya, M.; Thasini, A.; Narayanan, K.V.; Arun, K. Forest Fire Detection and Alerting System. *Int. J. Res. Eng. Sci. Manag.* **2020**, 8–10.
137. Pavitra, M.; Khan, S.; Jain, S.; Mn, A.; Kalyan, P. *Forest Fire Detection System Using Iot*; Springer: Singapore, 2020; Volume 5.
138. Gaitan, N.-C.; Cel, S.; Hojbota, P. Forest Fire Detection System using LoRa Technology Article in. *Int. J. Adv. Comput. Sci. Appl.* **2020**. [CrossRef]
139. Srividhya, S.; Sankaranarayanan, S. IoT-fog enabled framework for forest fire management system. In Proceedings of the World Conference on Smart Trends in Systems, Security and Sustainability, WS4 2020, London, UK, 27–28 July 2020; pp. 273–276.
140. Budiyanto, S.; Silalahi, L.M.; Silaban, F.A.; Darusalam, U.; Andryana, S.; Fajar Rahayu, I.M. Optimization of Sugeno Fuzzy Logic Based on Wireless Sensor Network in Forest Fire Monitoring System. In Proceedings of the 2020 2nd International Conference on Industrial Electrical and Electronics, ICIEE 2020, Lombok, Indonesia, 20–21 October 2020; pp. 126–134.
141. Vitolo, C.; Di Napoli, C.; Di Giuseppe, F.; Cloke, H.L.; Pappenberger, F. Mapping combined wildfire and heat stress hazards to improve evidence-based decision making. *Environ. Int.* **2019**, *127*, 21–34. [CrossRef]
142. Jang, E.; Kang, Y.; Im, J.; Lee, D.W.; Yoon, J.; Kim, S.K. Detection and monitoring of forest fires using Himawari-8 geostationary satellite data in South Korea. *Remote Sens.* **2019**, *11*, 271. [CrossRef]
143. Gonzalez-Olabarria, J.R.; Reynolds, K.M.; Larrañaga, A.; Garcia-Gonzalo, J.; Busquets, E.; Pique, M. Strategic and tactical planning to improve suppression efforts against large forest fires in the Catalonia region of Spain. *For. Ecol. Manag.* **2019**, *432*, 612–622. [CrossRef]
144. Ahmed, K.; Ewees, A.A.; Hassanien, A.E. Prediction and management system for forest fires based on hybrid flower pollination optimization algorithm and adaptive neuro-fuzzy inference system. In Proceedings of the 2017 Eighth International Conference on Intelligent Computing and Information Systems (ICICIS), Cairo, Egypt, 5–7 December 2017; pp. 299–304. [CrossRef]
145. Bielski, C.; O'Brien, V.; Whitmore, C.; Ylinen, K.; Juga, I.; Nurmi, P.; Kilpinen, J.; Porras, I.; Sole, J.M.; Gamez, P.; et al. Coupling early warning services, crowdsourcing, and modelling for improved decision support and wildfire emergency management. In Proceedings of the 2017 IEEE International Conference on Big Data (Big Data), Boston, MA, USA, 11–14 December 2017; pp. 3705–3712. [CrossRef]
146. Valero, M.M.; Rios, O.; Mata, C.; Pastor, E.; Planas, E. An integrated approach for tactical monitoring and data-driven spread forecasting of wildfires. *Fire Saf. J.* **2017**, *91*, 835–844. [CrossRef]
147. Kim, S.; Lee, W.; Park, Y.; Lee, Y.; Lee, H. Forest Fire Monitoring System Based on Aerial Image. In Proceedings of the 2016 3rd International Conference on Information and Communication Technologies for Disaster Management (ICT-DM), Vienna, Austria, 13–15 December 2016; pp. 5–10.
148. Rizogiannis, C.; Thanos, K.G.; Astyakopoulos, A.; Kyriazanos, D.M.; Thomopoulos, S.C.A. Sensor data monitoring and decision level fusion scheme for early fire detection. In *Signal Processing, Sensor/Information Fusion, and Target Recognition XXVI*; International Society for Optics and Photonics: Bellingham, WA, USA, 2017; Volume 10200. [CrossRef]
149. Kochilakis, G.; Poursanidis, D.; Chrysoulakis, N.; Varella, V.; Kotroni, V.; Eftychidis, G.; Lagouvardos, K.; Papathanasiou, C.; Karavokyros, G.; Aivazoglou, M.; et al. FLIRE DSS: A web tool for the management of floods and wildfires in urban and periurban areas. *Open Geosci.* **2016**, *8*, 711–727. [CrossRef]
150. Jellouli, O.; Bernoussi, A.; Mâatouk, M.; Amharref, M. Forest fire modelling using cellular automata: Application to the watershed Oued Laou (Morocco). *Math. Comput. Model. Dyn. Syst.* **2016**, *22*, 493–507. [CrossRef]
151. Barth, B.; Marchitti, M.A.; Mulero Chaves, J.; Raape, U.; Strobl, C.; Borràs, M.; Vilalta, O.; Ballart, H.; Vendrell, J.; Prat, N.; et al. An Open Service Platform for Multi-Hazard in Action—The PHAROS Pilot Demostration. In *Lecture Notes in Informatics (LNI), Proceedings-Series of the Gesellschaft fur Informatik (GI)*; Kollen Druck+ Verlag GmbH: Bonn, Germany, 2016; Volume 259, pp. 1775–1789.
152. Huang, H.; Tang, L.; Li, J.; Chen, C. Simulation and visualization of forest fire growth in an integrated 3D virtual geographical environment—A preliminary study. In Proceedings of the 2012 20th International Conference on Geoinformatics, Hong Kong, China, 15–17 June 2012; pp. 1–6. [CrossRef]
153. Andreu, A.G.; Shea, D.; Parresol, B.R.; Ottmar, R.D. Evaluating fuel complexes for fire hazard mitigation planning in the southeastern United States. *For. Ecol. Manag.* **2012**, *273*, 4–16. [CrossRef]
154. Kalabokidis, K.; Xanthopoulos, G.; Moore, P.; Caballero, D.; Kallos, G.; Llorens, J.; Roussou, O.; Vasilakos, C. Decision support system for forest fire protection in the Euro-Mediterranean region. *Eur. J. For. Res.* **2012**, *131*, 597–608. [CrossRef]
155. Fernandes, P.M.; Loureiro, C.; Botelho, H. PiroPinus: A spreadsheet application to guide prescribed burning operations in maritime pine forest. *Comput. Electron. Agric.* **2012**, *81*, 58–61. [CrossRef]

156. Losso, A.; Corgnati, L.; Bertoldo, S.; Allegretti, M.; Notarpietro, R.; Perona, G. SIRIO: An integrated forest fire monitoring, detection and decision support system—Performance and results of the installation in Sanremo (Italy). *WIT Trans. Ecol. Environ.* **2012**, *158*, 79–90. [CrossRef]
157. Kharchenko, V.S.; Orekhov, A.A.; Kotchkar, D.A.; Bogomolov, V.V. Monitoring network-based infrastructure for forest fire detection. *WIT Trans. Ecol. Environ.* **2012**, *158*, 91–99. [CrossRef]
158. Yanping, J.; Hongye, Y.; Yuefeng, Z.; Shuo, W. Assistant decision-making support system of forest grass fire based on GIS. In Proceedings of the 2011 IEEE 3rd International Conference on Communication Software and Networks, Xi'an, China, 27–29 May 2011; pp. 619–622. [CrossRef]
159. Angayarkkani, K.; Radhakrishnan, N. An effective technique to detect forest fire region through ANFIS with spatial data. In Proceedings of the 2011 3rd International Conference on Electronics Computer Technology, Kanyakumari, India, 8–10 April 2011; pp. 24–30. [CrossRef]
160. Elmas, Ç.; Sönmez, Y. A data fusion framework with novel hybrid algorithm for multi-agent Decision Support System for Forest Fire. *Expert Syst. Appl.* **2011**, *38*, 9225–9236. [CrossRef]
161. Calkin, D.E.; Thompson, M.P.; Finney, M.A.; Hyde, K.D. A real-time Risk Assessment tool supporting wildland fire decisionmaking. *J. For.* **2011**, *109*, 274–280. [CrossRef]
162. Ioannou, K.; Lefakis, P.; Arabatzis, G. Development of a decision support system for the study of an area after the occurrence of forest fire. *Int. J. Sustain. Soc.* **2011**, *3*, 5–32. [CrossRef]
163. Bonafoni, S.; Alimenti, F.; Angelucci, G.; Tasselli, G. Microwave Radiometry Imaging for Forest Fire Detection: A Simulation Study. *Prog. Electromagn. Res.* **2011**, *112*, 77–92. [CrossRef]
164. Rossi, L.; Akhloufi, M.; Tison, Y. On the use of stereovision to develop a novel instrumentation system to extract geometric fire fronts characteristics. *Fire Saf. J.* **2011**, *46*, 9–20. [CrossRef]
165. Lei, Z.; Lu, J. Forest fire autonomous decision system based on fuzzy logic. *Sixth Int. Symp. Digit. Earth Model. Algorithms Virtual Real.* **2009**, *7840*, 78400T. [CrossRef]
166. Kolega, E.; Vescoukis, V.; Douligeris, C. Forest fire sensing and decision support using large scale WSNs. *Model. Environ.* **2010**, *3*, 1820–1827.
167. Wendt, K.; Cortés, A.; Margalef, T. Evolutionary intelligent system for input parameter optimisation in environmental modelling: A case study in forest fire forecasting. In Proceedings of the IEEE Congress on Evolutionary Computation, Barcelona, Spain, 18–23 July 2010. [CrossRef]
168. Mata, A.; Baruque, B.; Pérez-Lancho, B.; Corchado, E.; Corchado, J.M. Forest fire evolution prediction using a hybrid intelligent system. *IFIP Adv. Inf. Commun. Technol.* **2010**, *322*, 64–71. [CrossRef]
169. Rossi, L.; Akhloufi, M.; Molinier, T.; Tison, Y. A stereovision system for fire characteristics estimation. In Proceedings of the 14th World Multiconference on Systemics, Cybernetics and Informatics (WMSCI 2010), mage, Acoustic, speech and signal processing, Orlando, FL, USA, 29 June–2 July 2010; Volume 2, pp. 104–109.
170. Corgnati, L.; Losso, A.; Perona, G. SIRIO high performance decision support system for wildfire fighting in alpine regions: An integrated system for risk forecasting and monitoring. *WIT Trans. Ecol. Environ.* **2010**, *137*, 163–172. [CrossRef]
171. Diagne, M.; Drame, M.; Ferrão, C.; Marchetti, P.G.; Pinto, S.; Rivolta, G. Multisource data integration for fire risk management: The local test of a global approach. *IEEE Geosci. Remote Sens. Lett.* **2010**, *7*, 93–97. [CrossRef]
172. Kochilakis, G.; Poursanidis, D.; Chrysoulakis, N.; Varella, V.; Kotroni, V.; Eftychidis, G.; Lagouvardos, K.; Papathanasiou, C.; Karavokyros, G.; Aivazoglou, M.; et al. A web based DSS for the management of floods and wildfires (FLIRE) in urban and periurban areas. *Environ. Model. Softw.* **2016**, *86*, 111–115. [CrossRef]
173. Aakash, R.S.; Nishanth, M.; Rajageethan, R.; Rao, R.; Ezhilarasie, R. Data Mining Approach to Predict Forest Fire Using Fog Computing. In Proceedings of the 2018 Second International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 14–15 June 2018; pp. 1582–1587. [CrossRef]
174. Tien Bui, D.; Van Le, H.; Hoang, N.D. GIS-based spatial prediction of tropical forest fire danger using a new hybrid machine learning method. *Ecol. Inform.* **2018**, *48*, 104–116. [CrossRef]
175. Schlotterbeck, G.; Raïevsky, C.; Lefèvre, L. Decentralized estimation of forest fire spread using reactive and cognitive mobile sensors. *Nat. Comput.* **2018**, *17*, 537–551. [CrossRef]
176. Iliadis, L.; Skopianos, S.; Tachos, S.; Spartalis, S. A Fuzzy Inference System Using Gaussian Distribution Curves for Forest Fire Risk Estimation. *IFIP Int. Conf. Artif. Intell. Appl. Innov.* **2010**, 376–386. [CrossRef]
177. Niazi, M.A.; Siddique, Q.; Hussain, A.; Kolberg, M. Verification & validation of an agent-based forest fire simulation model. *Spring Simul. Multiconf.* **2010**, 1–8. [CrossRef]
178. Sherstjuk, V.; Zharikova, M.; Dorovskaja, I. 3D Fire front reconstruction in UAV-Based Forest-Fire Monitoring System. In Proceedings of the 2020 IEEE 3rd International Conference on Data Stream Mining and Processing, DSMP 2020, Lviv, Ukraine, 21–25 August 2020; pp. 243–248.
179. Rodriguez-Aseretto, D.; De Rigo, D.; Di Leo, M.; Cortés, A.; San-Miguel-ayanz, J. A data-driven model for large wildfire behaviour prediction in Europe. *Procedia Comput. Sci.* **2013**, *18*, 1861–1870. [CrossRef]
180. Farguell, A.; Cortés, A.; Margalef, T.; Miró, J.R.; Mercader, J. Scalability of a multi-physics system for forest fire spread prediction in multi-core platforms. *J. Supercomput.* **2019**, *75*, 1163–1174. [CrossRef]

181. Lin, H.; Liu, X.; Wang, X.; Liu, Y. A fuzzy inference and big data analysis algorithm for the prediction of forest fire based on rechargeable wireless sensor networks. *Sustain. Comput. Inform. Syst.* **2018**, *18*, 101–111. [CrossRef]
182. Kiranoudis, C.T.; Zachariadis, E.; Keramitsoglou, I.; Saini, K.; Kakaliagou, O.; Kleitsikas, E. Wildfire evacuation trigger buffers for sensitive areas: EVITA project. In Proceedings of the 2014 Third International Workshop on Earth Observation and Remote Sensing Applications (EORSA), Changsha, China, 11–14 June 2014; pp. 121–125. [CrossRef]
183. Denham, M.; Wendt, K.; Bianchini, G.; Cortés, A.; Margalef, T. Dynamic Data-Driven Genetic Algorithm for forest fire spread prediction. *J. Comput. Sci.* **2012**, *3*, 398–404. [CrossRef]
184. Iyer, V.; Iyengar, S.S.; Paramesh, N.; Murthy, G.R.; Srinivas, M.B. Machine learning and dataming algorithms for predicting accidental small forest fires. In Proceedings of the Fifth International Conference on Sensor Technologies and Applications, Nice/Saint Laurent du Var, France, 21–27 August 2011; pp. 116–121.
185. Rodríguez, R.; Cortés, A.; Margalef, T. Data injection at execution time in grid environments using Dynamic Data Driven Application System for wildland fire spread prediction. In Proceedings of the 2010 10th IEEE/ACM International Conference on Cluster, Cloud and Grid Computing, Melbourne, Australia, 17–20 May 2010; pp. 565–568. [CrossRef]
186. Rodríguez, R.; Cortés, A.; Margalef, T. Towards policies for data insertion in dynamic data driven application systems: A case study sudden changes in wildland fire. *Procedia Comput. Sci.* **2010**, *1*, 1267–1276. [CrossRef]
187. Mata, A.; Pérez, B.; Corchado, J.M. Forest fires prediction by an organization based system. *Adv. Intell. Soft Comput.* **2010**, *70*, 135–144. [CrossRef]
188. Bianchini, G.; Denham, M.; Cortés, A.; Margalef, T.; Luque, E. Wildland fire growth prediction method based on Multiple Overlapping Solution. *J. Comput. Sci.* **2010**, *1*, 229–237. [CrossRef]
189. Stankevich, T.S. Development of an Intelligent System for Predicting the Forest Fire Development Based on Convolutional Neural Networks. In *International Conference of Artificial Intelligence, Medical Engineering, Education*; Springer: Cham, Switzerland, 2020; Volume 1126, pp. 3–12.
190. Athanasis, N.; Themistocleous, M.; Kalabokidis, K.; Papakonstantinou, A.; Soulakellis, N.; Palaiologou, P. The emergence of social media for natural disasters management: A big data perspective. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. ISPRS Arch.* **2018**, *42*, 75–82. [CrossRef]
191. Tavra, M.; Racetin, I.; Peroš, J. Combining social media and authoritative data for crisis mapping: A case study of a wildfire reaching croatian city of split. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2019**. [CrossRef]
192. Saadat, M.N.; Husen, M.N. An application framework for forest fire and haze detection with data acquisition using unmanned aerial vehicle. In Proceedings of the ACM International Conference Proceeding Series, Langkawi, Malaysia, 5–7 January 2018.
193. Athanasis, N.; Themistocleous, M.; Kalabokidis, K.; Chatzitheodorou, C. Big data analysis in uav surveillance for wildfire prevention and management. In *European, Mediterranean, and Middle Eastern Conference on Information Systems*; Springer: Cham, Switzerland, 2019; Volume 341, pp. 47–58.
194. Sayad, Y.O.; Mousannif, H.; Al Moatassime, H. Predictive modeling of wildfires: A new dataset and machine learning approach. *Fire Saf. J.* **2019**, *104*, 130–146. [CrossRef]
195. Zhou, T.; Li, B.; Wu, C.; Tan, Y.; Mao, L.; Wu, W. Studies on Big Data Mining Techniques in Wildfire Prevention for Power System. In Proceedings of the 2019 3rd IEEE Conference on Energy Internet and Energy System Integration: Ubiquitous Energy Network Connecting Everything, EI2 2019, Changsha, China, 8–10 November 2019; pp. 866–871.
196. Kalabokidis, K.; Ager, A.; Finney, M.; Athanasis, N.; Palaiologou, P.; Vasilakos, C. AEGIS: A wildfire prevention and management information system. *Nat. Hazards Earth Syst. Sci.* **2016**, *16*, 643–661. [CrossRef]
197. D'Andrea, M.; Fiorucci, P.; Gaetani, F.; Negro, D. RISICO: A Decision Support System (DSS) for dynamic wildfire risk evaluation in Italy. In Proceedings of the EGU General Assembly 2010, Vienna, Austria, 2–7 May 2010; p. 11102.
198. Carroll, M.; Weber, K.; Schnase, J.L.; Gill, R.L. Post-Wildfire Decision Support with NASA RECOVER. *AGU Fall Meet. Abstr.* 2018. NH23C–0855. Available online: https://ui.adsabs.harvard.edu/abs/2018AGUFMNH23C0855C (accessed on 24 May 2021).
199. Zhu, Y.; Xie, L.Q. Forest fire detection system based on ZigBee wireless sensor network. *Adv. Mater. Res.* **2013**, *694*, 961–965. [CrossRef]