



Patents and forest fire control



GOBIERNO
DE ESPAÑA

MINISTERIO
DE INDUSTRIA, COMERCIO
Y TURISMO



Oficina Española
de Patentes y Marcas



instituto nacional
da propriedade industrial

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Oficina Española
de Patentes y Marcas

inpi instituto nacional
da propriedade industrial

Paseo de la Castellana, 75 - 28071 Madrid
Tel. 902 157 530 - 910 780 780
información@oepm.es www.oepm.es

Campo das Cebolas, s/n. 1149-035 Lisboa
Tel. 218 818 100 - Fax: 218 869 859
servico.publico@inpi.pt <https://inpi.justica.gov.pt>

Portuguese Institute of Industrial Propriety, I.P



Guilherme Távora
Fedra Oliveira
Luísa Silvério
Sofia Antunes
Inês Cristóvão da Silva

Spanish Patent and Trademark Office, O.A.



Patricia López Calvo
Fernando Olalquiaga del Prado
Blanca Vila Riudavets
Carmen Toledo de la Torre

Authors and technical-scientific experts



Javier Madrigal Olmo. Instituto Nacional de Investigación y Tecnología Agrarias y Alimentaria, Centro Nacional-Consejo Superior de Investigaciones Científicas (INIA-CSIC)



Rubén Laina Relaño y Yolanda Ambrosio Torrijos. Escuela Técnica Superior de Ingeniería de Montes, Forestal y del Medio Natural. Universidad Politécnica de Madrid



Alfonso Andrade Otero. Ministerio para la Transición Ecológica y el Reto Demográfico



Tiago Martins de Oliveira e Arlindo Pinto dos Santos. Agência para a Gestão Integrada de Fogos Rurais, I.P.



Carlos Fonseca. Laboratório Colaborativo para Gestão Integrada da Floresta e do Fogo

Photography

Javier Madrigal. Laboratorio de incendios forestales, Centro de Investigación Forestal (INIA-CSIC)
J. Félix Mateo. COP Cuenca. Consejería de Desarrollo Sostenible JCCM. Plan INFOCAM

INSTITUTIONAL PRESENTATION



The Portuguese Institute of Industrial Propriety, I.P. (INPI) and the Spanish Patent and Trademark Office, O.A. (OEPM) have been collaborating over the past few years in several fields, sharing the vision that Industrial Propriety, by stimulating and protecting the investments in innovation, is a strategic instrument for the scientific and technological development, as well as for a sustainable and integrative development of the economy. The aforementioned cooperation between the two entities has consisted, mainly, on the exchange of experiences and best practices, with the achievement of very positive results in projects with Iberian impact and in the bilateral organization of several events.

This fruitful collaboration provided an opportunity to carry out a study, using the technical information provided by patents on the sustainable management of the forest, the fight against desertification, the prevention of the soil degradation and the loss of biodiversity, and it was then decided that the focus of that study would be on the analysis of the evolution of patents related to the control of forest fires.

This is a matter of great importance for Portugal and Spain and represents a permanent challenge for both countries and, even on a global scale, it is undeniably a matter of current affairs, as it is closely associated to climate change, which has been identified as one of the biggest environmental, social and economic threats that the planet and mankind are facing.

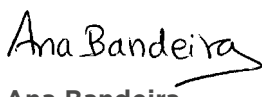
Forest fires are, by themselves, a scourge with the most varied repercussions, corresponding in the Iberian Peninsula to a complex problem that entails high risks for the population as well as for the environment.

To minimize this general negative impact, innovation, through the knowledge resulting from scientific research and technologic development, has key potential. The emergence of technologies in the field of prevention, detection and fire extinguishing, as well as protection and post-fire restoration soil equipment, is a key ally to establish effective policies and to operate the firefight and control of wildfires.

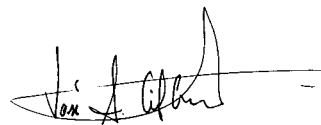
Industrial Propriety can play a highly relevant role in this context, since it secures the financial outcome of the high investments inherent to the Research and Development (R&D). On the other hand, the patent system, given its own nature, promotes innovation and attracts mores investments thus encouraging the invention of technologies consecutively more advanced in the fight against wildfires.

In this study —which usefulness seems to us indisputable— the aim is precisely to present the most promising technologies in the field of firefight and control of wildfires, which have an associated patent document. However, it also offers a broader perspective, revealing the main initiatives and policies related to the fight and control of forest fires, adopted by the Iberian institutions.

We sincerely hope that this study helps to ensure that firefighting, a cross-border key-challenge, is approached from a broader perspective and that it benefits the Iberian population as a whole.



Ana Bandeira
President of the Directive
Council at Portuguese Institute
of Industrial Propriety, I.P



José Antonio Gil Celedonio
Director General at Spanish Patent
and Trademark Office, O.A.

EXECUTIVE SUMMARY





The number of patent applications related to forest fires has progressively increased in the last decade throughout the world.



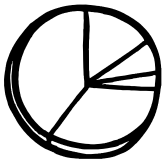
In particular, in the past 5 years, patent applications related to forest fires have increased at an accelerated pace.



Spain is the leading country in the European Union in the filing of patent applications regarding forest fires. In Portugal, there are several awareness campaigns put in place such as «Portugal Chama», which aims to raise people's awareness to the problem of severe forest fires.



Most of the patent applications filed regarding forest fires are not internationalised. Only a small percentage files for protection in other countries.



Russia, Australia and Spain are not the top patent filing offices globally; however, they do stand out in the field of forest fires, ahead of other offices such as Japan or the European Patent Office (EPO).



More and more inventions are related to the use of artificial intelligence and the use of drones in fighting and controlling forest fires. Portugal has several R&D projects in the field of prevention and detection of rural fires. These projects involve different technologies that meet the ones mentioned in patent documents identified in this study, such as aerial technologies, artificial intelligence and sensors.



The fire extinguishing field is the sector with the highest number of patent applications filed, ahead of the detection and prevention field or the protection equipment field.



Post-fire restoration is the least patented sector and therefore presents many opportunities for innovation.



There is a link between the countries where more patents related to forest fires are filed and those where more fires occur, reflecting the fact that patents are a good indicator of the technologic development generated by social needs.

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01

INTRODUCTION



1.1. Forest fires in the Iberian Peninsula

Undoubtedly rural and forest fires have a very significant impact on citizens and on natural heritage. It is also clear that the effects of climate change, such as heat waves, desertification and other extreme meteorological phenomena, are increasingly visible and contribute in a large extent to the increased risk of forest fires. Climate change even adds to the longer risky season and to the prolonged heat and drought phenomena a bigger and faster accumulation of the fuel available to burn, which adds more obstacles to the management of this scourge.

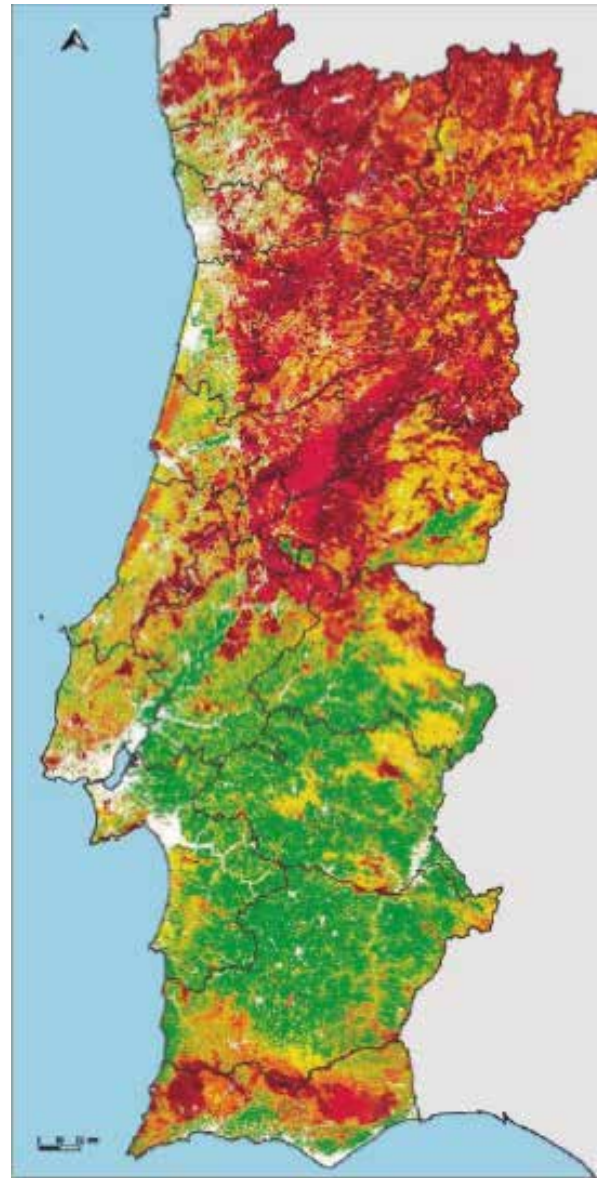
Therefore, there is a growing and clearly perceptible trend towards the rise of fire risk, of longer fire seasons and intense «mega fires» that rapidly spread and for which the traditional firefighting methods can do little. In the European Union, nine to ten fires are caused by man, either intentionally or by negligence or accident. Hence, the raising of public awareness and the use of educational campaigns about fire risk are fundamental to prevent such catastrophes.

In Portugal, the Institute for Nature Conservation and Forests (ICNF, I.P.) produces every year, and at the beginning of each year, maps of fire risk, which indicate the areas that are most likely to be exposed to forest fires. These maps not only hold information on the risk of fire on a scale 1-5, but also indicate which areas over 500 ha have not burned for more than 10 years, in hazard classes «High» or «Very High» (Figure 1).

With the same purpose of monitoring, prevention and risk analysis, the Portuguese Institute for Sea and Atmosphere (IPMA, I.P.)

also publishes a daily evaluation of fire risk, that combines the information of the annual map of fire risk with the daily weather forecast.

Figure 1. Fire risk map for 2020¹



The 21st annual report on forest fires in Europe, Middle East and North Africa 2020, produced

¹ 21st annual report on forest fires in Europe, Middle East and North Africa 2020, produced by the Cross-border cooperation - European Commission in the prevention and forest fire extinguishing in the Atlantic axis (https://www.eixoatlantico.com/images/informes/secretaria_general/informe-incendios-ea_pt.pdf)

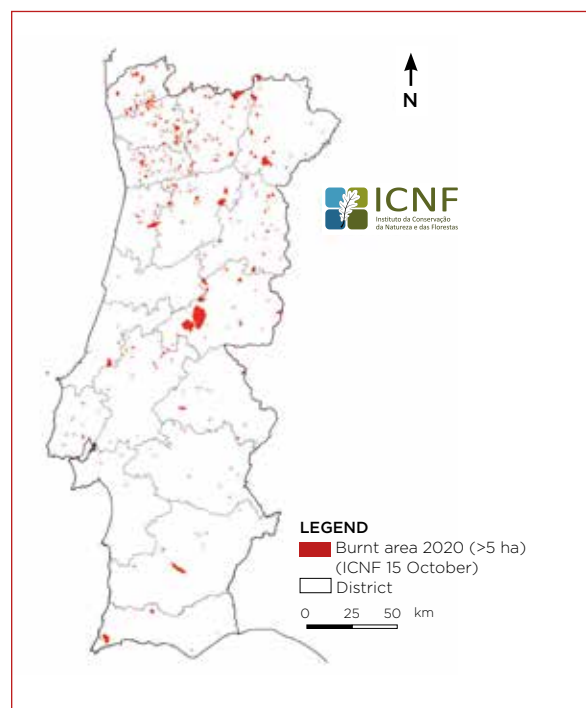


by the European Commission, shows that Romania was the most affected country, followed by Portugal, Spain and Italy.

Specifically, in mainland Portugal the burnt surface in 2020 was 67,170 ha, which represented about half the average of the last decade, which was 138,083 ha. In this timeframe, 2017 is a year worth noting, as it was the year in which fires in Portugal had an impact of unprecedented severity. This catastrophe triggered several structural, organising and operative measures, as well as the development of policy instruments related to the prevention and fight against rural fires, which have shown specific results. From the outset, it was approved in an extraordinary meeting of the Council of Ministers, the change from the system that existed since 2006 into an Integrated Management System of Rural Fires (SGIFR). The Agency for Integrated Rural Fire Management (AGIF), a public Institute, was also created, which is responsible for the integrated analysis, planning, evaluation and strategic coordination of the SGIFR, including the qualified intervention in high-risk events.

In 2020, the most affected area in Portugal was the central region, with a total burnt area of about 32,000 ha, which represents around half of the total registered in the Portuguese territory (Figure 2). In fact, the biggest fire of 2020 was yield exactly in this region, with a burnt area of about 15,000 ha. Of fires with a specific cause, 38% were caused by intentional acts (arson), while 50% were caused by accident or negligence. The use of fire for grassland renewal continues to have a considerable impact on the total area burned.

Figure 2. Distribution of burnt areas in Portugal in 2020²

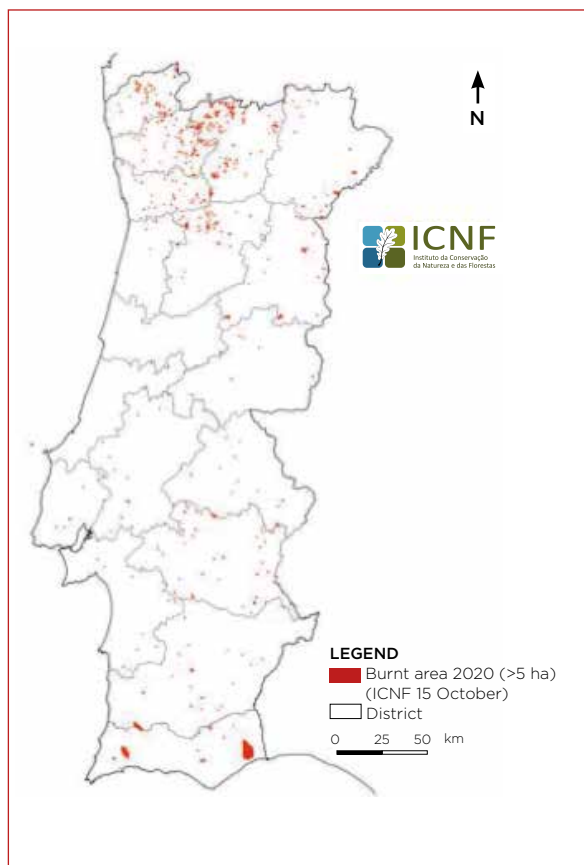


Comparing 2021 figures with the history of the previous ten years, it is noted that there were 54% fewer rural fires and 79% fewer burnt area, comparing the annual average over the same period. 2021 had, until 15 October, the lowest number of fires and the second lowest number of burnt area, since 2011. A change in the most affected geographical regions is also highlighted, compared to 2020. From the district analysis, stood out with the highest number of fires, and in descending order, Porto (1,297), Braga (688) and Lisbon (667). In either case, the fires were mostly of small dimension (less than 1 ha of burnt area). Regarding burnt area, the most affected district was Faro, with 9,268 ha, about 34% of the total burnt area until 15 October 2021, followed by Vila Real, with 4,041 ha (15% total) and Braga with 2,117 ha (8% total) (Figure 3).

2 8th Provisional Report on Rural Fires – 2020 (<https://www.icnf.pt/api/file/doc/7218b448c991d725>)

Of the total of 7,610 rural fires in 2021, 6,438 were investigated (85% of the total number of fires, responsible for 96% of the total burnt area). Of these, the research allowed the attribution of a cause to 4,327 fires (67% of the investigated fires – responsible for 90% of the total burnt area). The most frequent causes in 2021 were: negligent use of fire (47%) and arson – attributable (23%), with relevance to the burning of forest or agricultural surplus (20%), burning of heaps of forestry or agricultural waste (10%) and burning for cattle grazing management (14%). The reignitions represented 4% of the total of established causes, a lower figure compared to the average of the previous ten years (17%).³

Figure 3. Distribution of burnt areas in Portugal in 2021



Prevention is one of the main actions in the fight against rural fires. Therefore, it is worth mentioning a series of measures which were carried out with the goal of preventing and minimizing the impact of fires, such as renovation and development of new water reservoirs, the creation of new forest paths and awareness-raising campaigns such as «Portugal Chama»⁴ (Figure 4). The main goal of the latter is to warn about risky behaviour and to raise public awareness in order to help and protect the country from serious rural fires. The work that is carried out in close cooperation with the population, through the local authorities, in «Aldeia Segura» and «Pessoas Seguras» programs, is also very important to create structural measures for the protection of people and goods and to raise awareness about the prevention of risky behaviour and self-protection measures.

Figure 4. Portugal Chama Campaign⁵



Also, in the context of «Portugal Chama» National Campaign, the project «Raposas Chama» was developed. It is a collective and inclusive movement, designed for reaching all children and young people, aged 5 to 12, through school, teachers, family and all community. With the seal of the Portuguese Republic and the collaboration of the Ministry of Education, the aim is to raise awareness and educate children and young people about fire

³ 8th Provisional Report on Rural Fires – 2020 – 2021 (<https://www.icnf.pt/api/file/doc/504914cdd1a211bb>)

⁴ Campaign video at <https://www.youtube.com/watch?v=k4wb-EH4poY>

⁵ Image taken from <https://portugalchama.pt/>



risk behaviour, believing that in the present they can play a crucial role in raising awareness among adults, mainly through their family network.

In Portugal, *The National Plan of Integrated Management of Rural fires 20-30* (PNGIFR) also stands out. The Plan introduces an innovative governance model of risk, identifying the strategic goal and the measures to apply, clarifying the roles and responsibilities of the different entities cooperating to achieve the goals set. It intends to achieve a vision of a Portugal that is protected from severe rural fires, defining a strategy to achieve such goal, to which action programs will be associated, on national and regional levels, with the annual setting of necessary goals and indicators, on which the PNGIFR monitoring will focus.

In Spain, the 2020 figures were also lower than the average of the last decade. Specifically, the total number of fires decreased in about 30% (from 11,684 to 8,068), while the total burnt area decreased in about 32% (123,944 ha to 84,257 ha). In terms of geographical regions, the Northwest region was the most affected, both as regards the number of large fires and total area burnt, followed by Mediterranean and interior regions and Canary Islands.

As aforementioned, prevention and firefight measures are essential to minimise the impact that fires have on people and on environmental ecosystems. Community awareness has a key role in the prevention of fires. During 2020, the travelling exhibition «50 years of knowledge and prevention of forest fires», created to celebrate the 50th anniversary *General Statistics of Forest Fires*, crossed the Spanish territory. *Wildfire Prevention Teams (EPRIF)*, the *Preventive Work Brigades* and the *Wildfire*

Reinforcement Brigades (BRIF) also perform a very important job not only in raising public awareness but also in acting in situ, by carrying out actions aimed at fire prevention and extinguishing in the forest. Regarding BRIF (Figure 5), these highly specialised squads of helicopter transport can operate in any part of the country. These teams receive constant training and coaching, which allows them to act in the most demanding situations and the most complicated fires. The mastery of all fire extinguishing techniques, including backfiring, is essential to their performance.

Figure 5. Reinforcement Squad against forest fires of Tabuyo del Monte, at the extinguishing of a fire in Lobios (Ourense) on 08-08-2020⁶



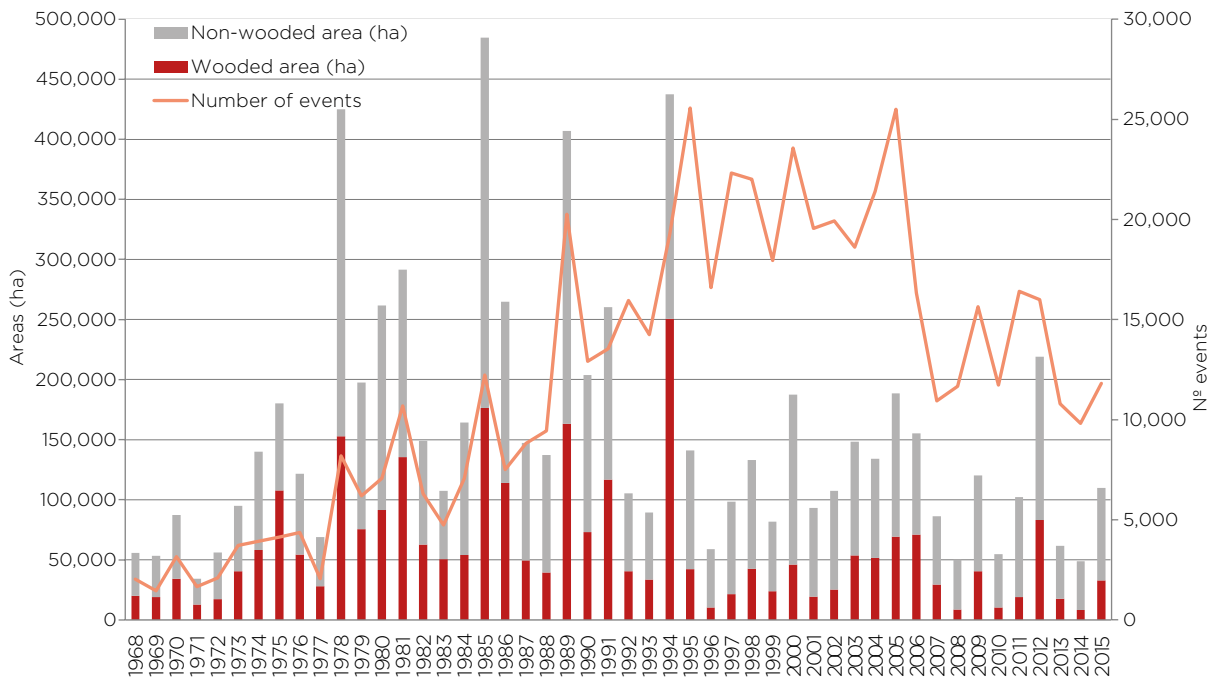
In the case of Spain, according to data of the *General Statistics of Forest Fires* (EGIF), which is the national database integrating forest fire reports from all over the country since 1968, the annual average, in approximate figures, of forest affected area is 100,000 ha, from which, 2/3 are accidents (casualties of less than 1 ha). Likewise, the fire scheme in Spain is characterised by the following indicators, among others:

- A high interannual and regional variability related to affected areas and number of casualties (Figures 6, 7 and 8).

6 21st Annual Report on Forest Fires in Europe, Middle East and North Africa 2020, developed by the European Commission; Transborder Cooperation on the prevention and suppression of forest fires in the Atlantic axis (https://www.eixoatlantico.com/images/informes/secretaria_general/informe-incendios-ea_pt.pdf)

- A high percentage of fires whose causes are associated with human action, where more than 50% of fires are intentional, while fires due to natural causes account for less than 5% of the total (Figure 9).
- A small number of events is responsible for a very significant part of the total of forest area affected. Specifically, less than 0.2% of events comprise more than 40% of the total forest area affected.

Figure 6. Evolution of the number of events and affected area. Period 1968-2015. Source: The forest fires in Spain. Decade 2006-2015⁷. Page 6



7 https://www.miteco.gob.es/es/biodiversidad/estadisticas/incendios-decenio-2006-2015_tcm30-521617.pdf



Figure 7. Evolution of the affected area by geographical area. Source: The forest fires in Spain. Decade 2006-2015⁸. Page 18

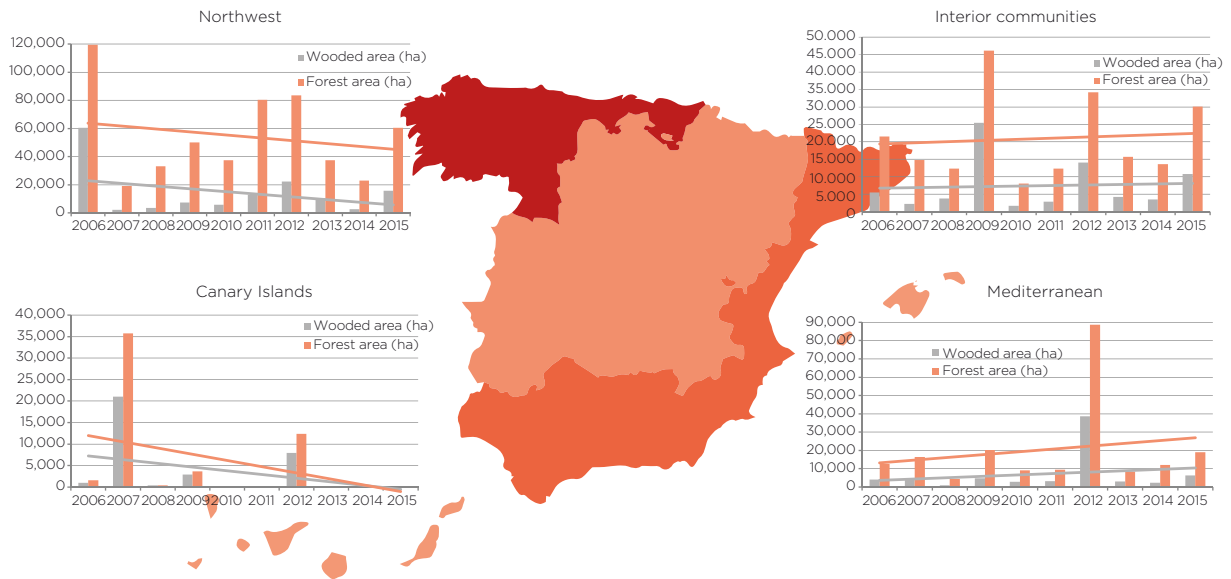
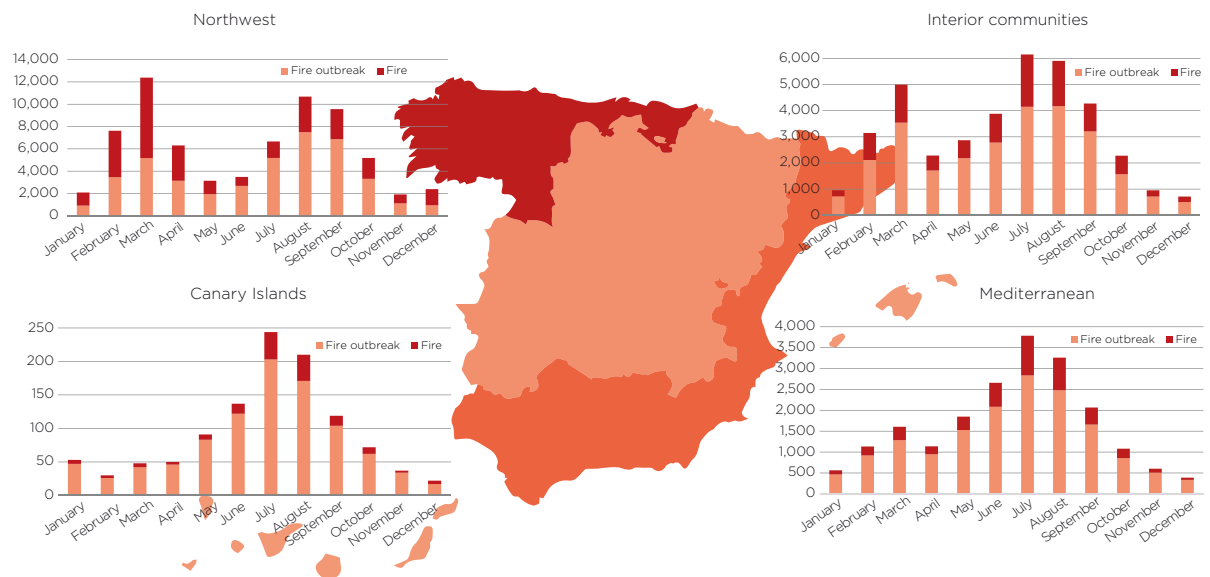
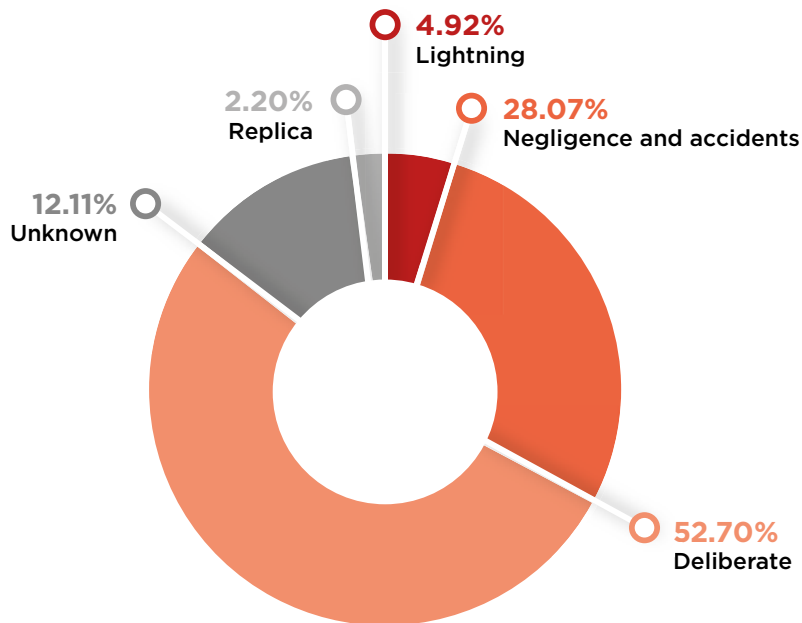


Figure 8. Monthly distribution of the total number of events throughout all decade, 2006-2015. Source: The forest fires in Spain⁸. Decade 2006-2015. Page 51



8 https://www.miteco.gob.es/es/biodiversidad/estadisticas/incendios-decenio-2006-2015_tcm30-521617.pdf

Figure 9. Forest fires by group of causes, 2006-2015. Source: The forest fires in Spain. Decade 2006-2015⁹. Page 56



Furthermore, an increase of the risk indices and of the intensity and dangerousness for society of forest fires is foreseen in the upcoming decades, as a consequence of the Global Change (climate change and change in the uses of territory), thus becoming more and more complex, dangerous and difficult to manage causalities, although the statistical trends reflected in the *General Statistics of Forest Fires* indicate, at present, a reduction of the number of fires and of the affected forest area.

As a consequence of the aforementioned, and responding to the legal mandate reflected in forest fires and in civil protection legislation, Spain has developed, since the 1970s, a national system for prevention and extinguishing of forest fires. It is professionalised, standardised and with a high number of personal and material resources, including the Autonomous Communities

(CCAA) resources, which are responsible for fire prevention and firefighting tasks, as well as the General Administration of the State (AGE) resources, which supports the former with a national coverage system.

Also, in the past years, the AGE as well as the CCAA have made a commitment to improve management of forest fires through the contracting of IT development, communication platforms and technological resources, such as fire spread simulators, risk index calculation programs, big data analytics systems, day and night forest fire monitoring platforms, etc.

An example is the ARBARIA project, which started to be implemented in 2020. This project consists of a computer system for forest fires analysis and forecasting, using artificial intelligence techniques associated to machine learning and deep learning. ARBARIA uses historical data from forest fires

⁹ https://www.miteco.gob.es/es/biodiversidad/estadisticas/incendios-decenio-2006-2015_tcm30-521617.pdf



that occurred in Spain in the last decades, as well as weather data and socioeconomical elements. Through two algorithmic models, ARBARIA allows to explain and predict the weekly occurrence of fires regionally, as well as to identify causal socioeconomical patterns, providing very valuable information for fire extinguishing and prevention actions.

From the outset this project shows the importance of technological development in fire control. As it is well known, the innovation and the Research and Development (R&D) are inseparable partners of Industrial Propriety, and play a key role in the ability to adapt quickly and effectively to the challenges humanity systematically faces.

Given the high level of uncertainty in the short, medium and long term that the Global Change casts, the Forest Fires Fight Commission approved, in 2019, the *Strategic guidelines for the management of forest fires in Spain*. These guidelines set out general, specific goals and priority courses of action that should inform the activities of all public administrations with competence in this area. In particular, the need for improvement of the technology used in the prevention and extinguishing of forest fires, identifying, among others, the systems of «fleet tracking, remote detection through satellite or aero transported elements as well as spectral image processing, simulation of fire behaviour, risk indices associated with forest, phenological and atmospheric variables, creation of fuel models, vulnerability, danger or habitability indices associated to the urban-forest interface, large historical series of data analysis (Big Data), improvement of the technical requirements for the use of fire in both fire extinguishing and fire prevention», among others. These institutional demands assume a motivation for innovation in the field of forest fires.

1.2. Spanish-Portuguese collaboration in the control of fires

The forest ecosystems and the fires that threatens them are the same reality on both sides of the Spanish-Portuguese border. Fires that start at one country and cross the border causing severe damage in the neighbouring country are not rare. For example, the cross-border area between Galicia and the north of Portugal represents one of the geographical areas with the largest forest fire concentration of the Iberia Peninsula (see Figure 10), which prompts the authorities of both countries to underline the importance of reinforcing the cross-border operations in the fight against forest fires.

Therefore, the collaboration between Portugal and Spain in the fight and prevention of forest fires is of great importance. For example, in 2020, the same as preceding years, the Protocol of Technical Cooperation and Mutual Assistance regarding Civil Protection and the Additional Protocol on mutual help in border areas between Portugal and Spain were activated on several occasions, both in Portuguese and Spanish territory, with firefighting resources made available.

Figure 10. Location of extinguished fires by the Ministry for the Ecological Transition and Demographic Right in 2020¹⁰



¹⁰ 21st Annual Report on Forest Fires in Europe, Middle East and North Africa 2020, developed by the European Commission; Transborder Cooperation on the prevention and suppression of forest fires in the Atlantic axis (https://www.eixoatlantico.com/images/informes/secretaria_general/informe-incendios-ea_pt.pdf)

The Common Strategy of Cross-border development also includes several measures aimed at fire-fighting and prevention of fires, such as:

- Reinforce the coordination of border resources linked to civil protection; sign agreements between Civil Protection National Authorities to continue on developing the ARIEM project related to the Civil Protection and Emergencies; adapt the action protocols between the firefighting and emergency teams on both sides of the border; facilitate the coordination of fire management, with the creation of the *Iberian Center for the Investigation and Fighting of Forest Fires (CILIFO)*.
- Continue the cooperation on forest fires in the framework of existing protocols (Évora Protocol) and through the already established national and regional channels.

The *Iberian Center for the Investigation and Fighting of Forest Fires (CILIFO)* is a good

example of how a Spanish-Portuguese association can work. It is a project that intends, through the expected results of its activities, to become a permanent centre for development and promotion of training, awareness, research and cooperation in the fight against forest fires. Its main goals are:

- To reinforce and promote cooperation, working procedures and training between the Devices of Prevention and Extinguishing of Forest Fires in the cooperation field of the Euroregion Alentejo - Algarve - Andalusia).
- To promote the creation of sustainable and quality employment in the area of influence of the project; reduce the economic cost of fires by promoting the forest economy linked to the landscape.
- To improve the responsiveness to forest fires of entities and authorities involved in the fight against them in the three participant regions.

Business incubator: FOIL-CILIFO



The Firefighting Open Innovation Lab-CILIFO (FOIL-CILIFO)¹¹ is the first worldwide business and technology accelerator/incubator focused on the prevention and extinguishing of forest fires, adaptation and mitigation of climate change, created in the framework of the *Iberian Center for the Investigation and Fighting of Forest Fires (CILIFO)*¹² project, financed by the European Union FEDER fund in 75% through the Cross-border Cooperation Programme Interreg VA Spain-Portugal 2014-2020 (POCTEP). The CILIFO project has a 24.6-million-euro budget. The incubator FOIL/CILIFO is managed by the Fundación Finnova as one of the beneficiary entities of the project¹³.

The FOIL/CILIFO, besides representing an efficient work space, offers services in multiple fields. The accelerator not only offers the possibility to test innovative technologies with pilot tests, supporting the implementation of new ideas in the framework of euro-projects, but also allows consultancy and mentoring through experts, enabling the search of international partners and providing legal advice.

The FOIL/CILIFO currently has 30 accelerated entities at a European level and three at an intercontinental level (México, Chile and Brazil). These initiatives are presented in «Innovative solutions catalogue».

Since the 16 June 2021, the FOIL-CILIFO takes part in the EIT Climate KIC Open Accelerator - The ClimAccelerator, the accelerator of climate change accelerators, which enables that entities accelerated and mentored by FOIL-CILIFO, through Finnova, can have an international networking space with entities that are working on adaptation and mitigation of climate change, and other environmental issues. EIT Climate KIC is a European community of knowledge and innovation, supported and powered by the European Commission, to work on the transition to a carbon-neutral economy. In this context FOIL-CILIFO and EIT Climate KIC Open Accelerator are boosting several initiatives and project proposals where the prevention and extinguishing of forest fires is a priority issue.

Furthermore, FOIL-CILIFO has been selected as the representative of Spain in the *European Business Promotion Awards* (EEPA) in category 4: «Support for the internationalisation of companies» and on the 16 November 2021 it was proclaimed the winner in this category at European level by the European Commission, in association with the Committee of Regions.

11 <https://innovation.cilifo.eu/startups>

12 <https://cilifo.eu/>

13 <https://finnova.eu/>



1.3. Purpose of the study

Intended for both public and private organisations related to the prevention, control and fight against forest fires, as well as the management and post fire restoration of the affected ecosystems, this study aims to analyse the evolution of patent applications filed in this technological field that have been published worldwide between 2010-2021.

The report was elaborated by patent examiners from the Portuguese Institute of Industrial Propriety, I.P. (INPI) and from the Spanish Patents and Trademarks Office O.A. (OEPM), with the scientific-technical advice from experts in the Academic sector as well as relevant national bodies with competence in the fight and control of fires in Spain and Portugal.

Four relevant technological fields were identified, each of which is the subject of a separate section in this report:

- Detection and prevention of fires.
- Fire extinguishing.
- Protection equipment.
- Post-fire restoration.

Each section includes a detailed analysis of the most innovative patent applications published between 2019-2021, as well as statistic analysis on the development of the sector in the past 10 years, reflected by patent applications published worldwide. Furthermore, a list of patents considered to be the most relevant has been included, meaning those related to inventions which protection has been extended to more than one country (2010-2021), and are therefore expected to have a greater commercial and technological impact.

The report also includes explicit references to other subjects related to the control of fires in the Iberian Peninsula, such as research projects, public-private partnership initiatives, innovative companies or the recently published UNE standard on long-term retardants, pioneer in Europe.

1.4. Using patent information

Patents are industrial propriety titles that grant its owner the right to prevent unauthorized third parties to use their invention, whenever this invention is new, inventive and industrially applicable. Nevertheless, in order for an inventor to obtain such right, in addition to following a certain administrative procedure and paying annual maintenance fees for up to 20 years, he must disclose the invention in the corresponding patent application.

Therefore, patent documents constitute a source of technological information with extraordinary value, since they are a means of dissemination in which an enormous number of inventions are recorded every year. Considering only the five most important patent offices in the world (European, American, Chinese, Japanese and Korean), the number of applications filed in 2020 rose to 2.8 million.¹⁴

Patent databases, many of them free of charge, enable the access to the global patent collection estimated in more than 130 million documents. The statistical analysis of all this information provides indicators on technological innovation in a specific field, shows where the obtained research results are protected or who the main actors are, hence enabling to ascertain the competitors and those with whom one should alliances. On the other hand, a detailed analysis of published patent applications enables to discover

14 <https://www.fiveipoffices.org/statistics/statisticsreports/2020edition>. IP5 Statistics Report 2020 Edition.

the most innovative technology and spot technological trends.

The information contained in patents provides knowledge of great utility for decision making in innovative companies, research public entities, other parties related to the commercialisation and transfer of technology, as well as organisations responsible for innovative public policies.

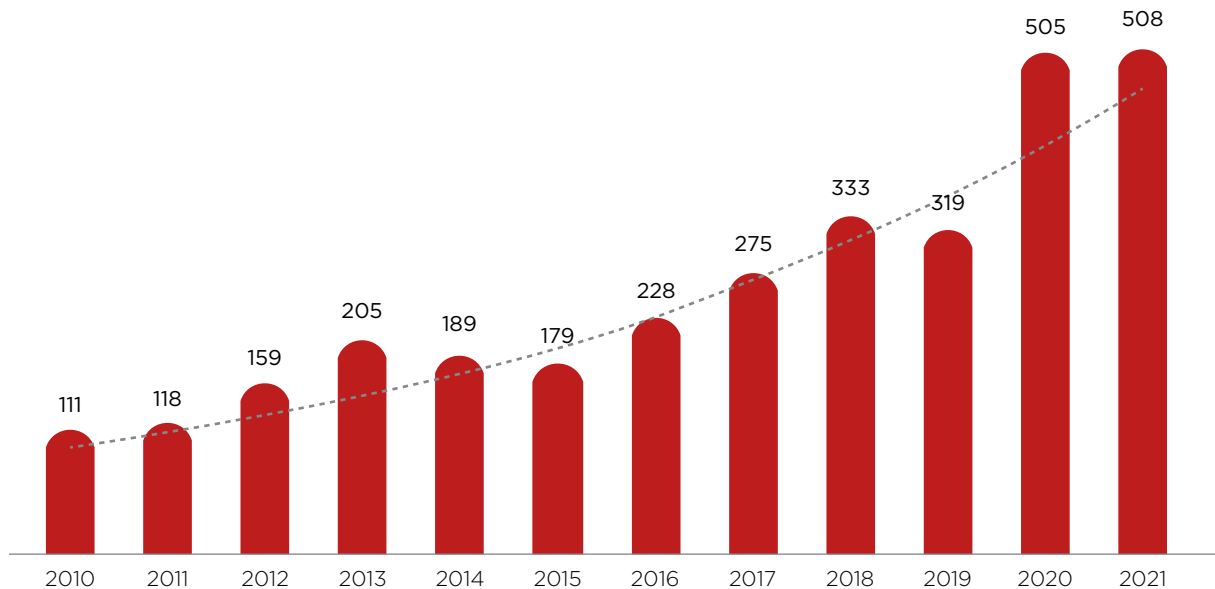
For the analysis of the obtained data, every patent and utility model retrieved have been considered, without limiting it to those forming part of International Patent Families, given that the documents published in the PCT system (Patent Cooperation Treaty), in the European Patent Office (EPO) or in more than one national office¹⁵, i.e., those that fall under the definition of the International Patent Families, are only 378. This amount of publications does not seem

relevant to conduct a study from which significative conclusions may be obtained and, consequently, as noted above, it was decided to include in the report all the retrieved documents that meet the search requirements.

Between 2010 and 2021, 3,137 patent or utility model documents have been published in the world, directly related to forest fires. In general terms (Figure 11), it is noted that the number of published documents has been progressively increasing throughout the decade. In 2015, 61.26% more documents were published than in 2010, and from that year onwards the number rises at an accelerated pace: in 2021, 357.66% more documents were published than in 2011.

In 2020, a year marked by the COVID-19 pandemic, 58.30% more documents were retrieved than in 2019.

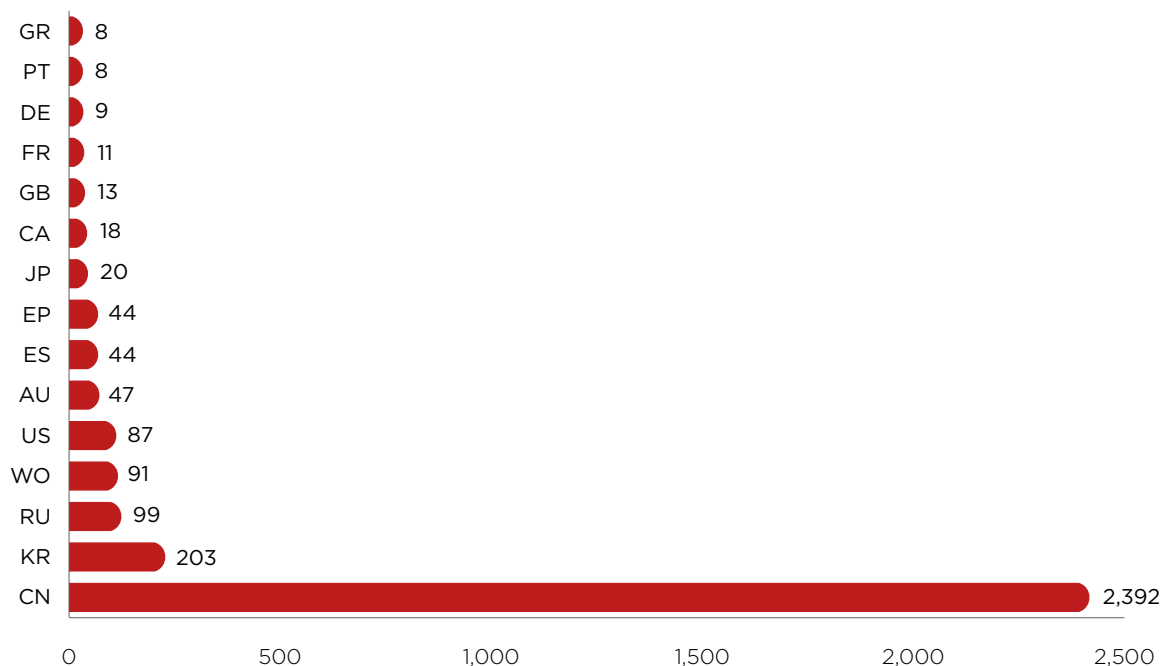
Figure 11. Total patent documents on forest fires 2010-2021



¹⁵ Dervis *et al.*, 2001; Harhoff *et al.*, 2003; Van Pottelsberghe and van Zeebroeck, 2008; Frietsch and Schmoch, 2010; Martinez, 2011; Squicciarini *et al.*, 2013; Dechezleprêtre *et al.*, 2017).



Figure 12. Publishing Offices 2010-2021



76.25% of documents (patents and utility models) were published by the Chinese Patent Office (China National Intellectual Property Administration, CNIPA), which corresponds to a total of 2,392 documents. South Korea published 6.47%, Russia 3.16% and USA 2.77%. PCT international publications were 2.90%. The total number of shared documents by these offices can be seen in Figure 12.

Over the past few years, the Chinese government has been implementing different types of measures aimed at supporting the country's innovation. That can explain the high number of patent applications filed to CNIPA, related to several types of technology. However, the great majority of these patent applications are «domestic applications», that is, national requests which are not subsequently internationally extended.

Specifically, in the field of forest fires, the consulted databases¹⁶ reveal that 97.41% of retrieved Chinese applications refer to innovations protected only in China.

The country where the first application of a patent's invention was filed is, frequently, the home country of that invention. Thus, the data about the countries where the patent or utility model application was filed, from which ulterior applications claim priority, offers information on the geographical origin of the invention. In the field of forest fires, it is possible to observe that China is the country where most inventions have been filed between 2010-2021. Thus, it is of interest to study the data related to the country that claims priority excluding the documents published in China, due to the reason mentioned in the previous paragraphs.

¹⁶ GPI (Global Patent Index).

Figure 13. Countries and Offices that claim priority of patent documents. China excluded

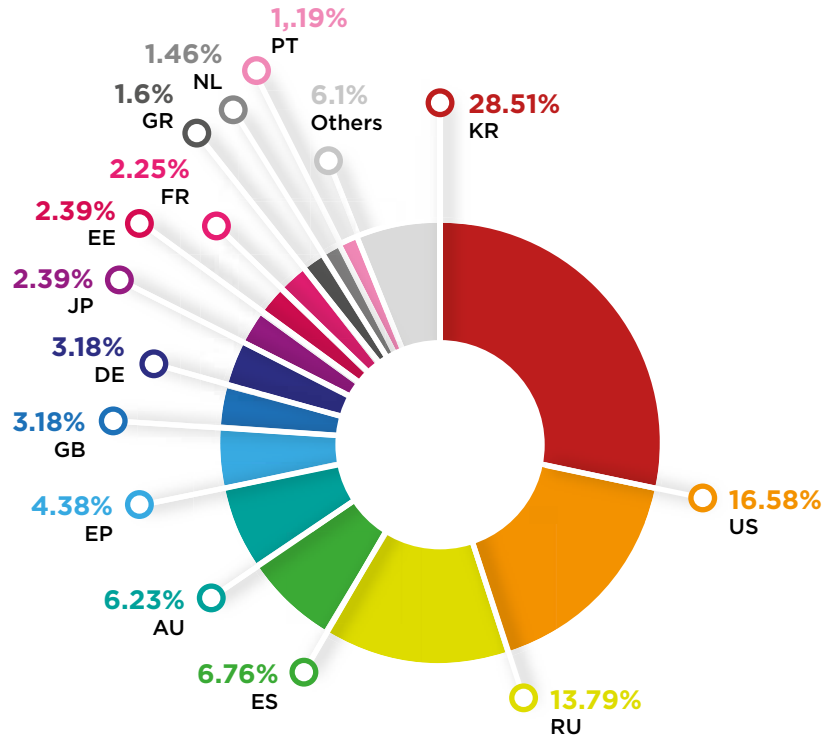


Figure 13 shows that the countries with the highest number of inventions (after China) are South Korea (28.51%), USA (16.58%), Russia (13.79%), Spain (6.76%) and Australia (6.23%). As to Portugal, the obtained number is 1.19%.

The three applicants that have filed the highest number of published patent or utility model applications have their headquarters in China as shown in Table 1.

Table 1. Applicants with the highest number of patent applications

Applicant	Publications
STATE GRID CORP CHINA	77
NANJING FOREST POLICE COLLEGE	47
UNIV NORTHEAST FORESTRY	45



Table 2. Applicants with the highest number of patent documents. China excluded

Applicant	Publications
TYCO FIRE PRODUCTS LP (US)	17
FRS GROUP LLC (US)	14
NAT INST FOREST SCIENCE (KR)	10
JABE BEHEER B V (NL)	10
FEDERAL NOE G BJUDZHETNOE OBRAZOVATEL NOE UCHREZHDENIE VYSSHEGO PROFESSIONAL NOGO OBRAZOVANIJA MO GU (RU)	9
ARVILLE TEXTILES LTD (GB)	8
WILKENING DAVID W (US)	7
STS DEFENCE LTD (GB)	7
SMART PACKAGING SOLUTIONS SPS (FR)	7
SCHNARR MICHAEL S (US)	7
NIKOLAJEVA IRINA (RU)	7
MCLELLAN JOSEPH (US)	7
HULBERT DENNIS (US)	7

Excluding China, eight companies and one individual are among the top nine applicants. After the 10th, the proportion of individual applicants rises (Table 2).

It should be noted that the applicant's country of origin does not always correspond to the country where the patent application has been filed.

1.5. Methodology

The following steps were followed in the preparation of the report:

- Definition of a search strategy with key words and patent classification codes concerning technologies related to forest fires.
- Search on worldwide-specialized patent databases, to which INPI and OEPM have access.

- Classification of the information retrieved in four technological fields: detection and prevention, extinguishing, protection and post-fire restoration equipment.

- Analysis of the information in patent documents to spot the relevant technologies of each field.

- Statistical analysis

The patent classification systems used were the International Patent Classification (IPC) and the Cooperative Patent Classification (CPC). Both specific and less specific classifications of forest fires have been taken into consideration. These have been combined with key words to limit the search results obtained on the subject of the report.¹⁷

The search has been concluded in full-text databases and patent documents that were not specifically aimed at forest fires have been discarded.

¹⁷ For more information on methodology, see Annex II.

The statistics have been performed with the Global Patent Index (GPI) tool of the European Patent Office (EPO). These statistics cover a larger period (2010-2021) than the analysis of patent documents (2019-2021) and reflect the number of inventions assigned to each technological field, regardless of the fact that some of these inventions are also classified in other fields.

Furthermore, a list of patents relating to inventions whose protection was extended to more than one country between 2010-2021 has been included.

Both for the establishment of the technological fields to be analysed, as to the tracking of relevant patents, scientific and technical advice has been provided by national experts on the control of forest fires in the Iberian Peninsula.

02

DETECTION AND PREVENTION OF FIRES



2.1. Detection and prevention technologies

Detection and prevention technologies concern the identification of a fire outbreak or determining the risk of a fire event.

The interest in developing early warning systems and, therefore, investigate and develop equipment and software to alert about these extraordinary events, should be taken into consideration in risk management.

Seven technologies for the detection and prevention of fires are highlighted. These technologies are, in most cases, interconnected, and the cases where only one of them shows up alone in a patent document are rare. Since there is not a complete partitioning of technologies, it was decided to select the most determining technology in each of the applications. Nevertheless, a subsection was created comprising applications where several technological fields stand out, referred to as combined technologies.

Application [EP2741264A1](#) (BOEING CO [US]) regards the «Forest sensor deployment and monitoring system», wherein soil sensor units are deployed in a forest from aerial vehicles and the collected information is transmitted to a remote location for analysis. The application [PT110537A](#) (UNIV DE TRAS OS MONTES E ALTO DOURO [PT]), with the title «System for remote detection of risk situations», that comprises monitoring points distributed by sensor units that transmit data to an unmanned aerial vehicle, also efficiently illustrates the relevance of these technologies.

Artificial Intelligence and Machine learning

There are several applications where data analysis and processing in fire detection is processed, with artificial intelligence and machine learning technologies standing out.

Many technologies use artificial intelligence and machine learning to detect fire events through data analysis. For example, patent



Monitoring

Monitoring is the field that stands out the most in fire detection and prevention, and there is a high incidence of this innovation, specially detection. Technologies concern the supervision of a certain region with risk of forest fire.

application [WO2019048604A1](#) (FCM DIENSTLEISTUNGS AG [CH]) concerns an «Automatic early detection of smoke, soot and fire with increased detection reliability using machine learning» wherein an analysis is made from a smoke coloured-optimised pixel region by a detection algorithm that uses a machine learning calculation model.



Still in this field, «An emergency response system and method» is disclosed in application [WO2021174291A1](#) (STEPHEN CHRISTOPHER COLIN [AU] *et al.*), that comprises sensors which sense emergency variables that communicate with a server which analyses and determines how to respond to an emergency situation. A sensor is also disclosed which, through artificial intelligence or machine learning, predicts the probability of ignition after a lightning.

As to patent application [US2021260421A1](#) (RAYA GIDEON [IL]), with the title «Fire control and prevention», it uses sensors that detect certain parameters of animal activity and an analysis is made by a computerized module in order to identify fire escape behaviours, wherein that identification can be made by artificial intelligence.

Risk analysis

Data analysis and processing is often used for purposes of performing a risk analysis, estimating the likelihood of a forest fire event.

Application [WO2021091021A1](#) (ALCHERA INC [KR]) describes a «Fire detection system», capable of detecting in a quick and precise way the beginning of a fire in a certain region, using images and light flows captured by analysis modules that estimate the likelihood or the presence of fire, by resorting to a classification system. Patent application [US2014027131A1](#) (BOEING CO [US]), titled «Wildfire arrest and prevention system», claims an apparatus, operation controller and method, that enables the control of unmanned aerial vehicles for detection, prevention and suppression of fires in a designated area, through information gathering and analysis, fire risk estimation and its extinction using the use of retardants. Patent application [WO2021174291A1](#) (STEPHEN CHRISTOPHER COLIN [AU] *et al.*), mentioned previously, is

also disclosed, concerning «An emergency response system and method», that consists of several sensors which, when sensing several emergency variables, communicate that information, through a communication channel, to a server, which analyses those variables, estimates the risk and determines the best way to respond to the emergency situation, by resorting, specially, to the use of drones.

On the other hand, patent application [US2021142537A1](#) (GEN ELECTRIC [US]), with the title «Multi source geographic information system (GIS) web based data visualization and interaction for vegetation management», consists of a system and method that receives the data from images about the vegetation of a certain region and assigns scores to the fire risk of that region.

Sensors and cameras

Technologies relating to sensors have as main goal the fire detection at an early stage.

Patent application [WO2019244094A1](#) (LADEIRA JOAO [PT]) with the title «Wildfire detection system and method using array of CO₂ sensors and artificial intelligence», describes a sensorial unit for retransmitting the data, a server and a software with an algorithm projected for processing the incoming data and trigger the fire detection alarms at an early stage. The application [AU2021105697A4](#) (ACADEMY OF WATER RESOURCES CONSERVATION FOREST OF QILIAN MOUNTAINS GANSU PROVINCE [CN]), with the epigraph «A Monitoring Device for Forest Ecological Environment» discloses a broader monitoring with high accuracy of the air in forests, with an automatic video and rapid positioning. Patent application [WO2021038407A1](#) (UNIV KING ABDULLAH SCI & TECH [SA]), refers to a «Versatile optical fibre sensor and method for

detecting red palm weevil, farm fires, and soil moisture» and consists of an integrated system which includes an optical fibre to be applied on trees and an acoustic sensor connected to the optical fibre, configured to process three optical signals, one to determine the presence of red palm weevil, the second to determine the temperature of the location and the third to determine the humidity, thus allowing to identify the presence of a fire.

Camera image technologies are essentially connected to detection and monitoring of smoke and flames in forests.

Patent application [WO2018226128A1](#) (GORYACHENKOV DMITRY ANATOLYEVICH [RU]), with the title «Video camera for the early detection of a wildfire» comprises a housing with a rotating mechanism, an image capturing sensor and a lens, which in turn are connected to a data transmission unit and to a remote monitoring console, capable of identifying smoke and/or flames from wildfires. As to patent application [WO2020089541A1](#) (UNIV DE CORSE P PAOLI [FR] *et al.*), it refers to a «Device for characterizing a fire and associated method for determining radiant fluxes», that comprises at least one stereovision system, comprising a first and second image capturing unit and at least one processing unit configured to determine at least one geometrical feature of the fire at an early stage.

Stationary Platforms

Stationary platforms are associated with structures or barriers that have as main goal to hold and/or to stop the spread of forest fires.

The application titled «Canopy For Climate And Solar Mitigation», [US2021332604A1](#) (AINTABI JASON [US]), discloses a reflective sunshade connected to a

collapsible web or frame structure, placed above the ground by a combination of lifting balloons and positioning machines for managing the elevation, the shape and the geolocation of the sunshade device. A sunshade management system controls the said device, collapsing in the evening, or on rainy or cloudy days, or when severe weather-related events are detected (thunderstorms, earthquakes, etc.).

Also worth mentioning the application [WO2021091473A1](#) (HUGNORA INVEST & TJAENSTEPRODUKTION [SE]), with the title «System and method for limiting spread of wildfire», that defines a fire limiting area, positioning a plurality of droplet generating units along the fire limiting area and connecting the units to a liquid source, forming a mist which is applied along the fire limiting boundary.

Aerial Technologies

Aerial technologies are present in the spectrum of fire detection and prevention through information gathering and transmission.

Patent application [KR20210072954](#) (KOREA ELECTRONICS TECHNOLOGY [KR]), named «Disposable IoT System for distribution of Disposable IoT Terminal using drone» sets a disposable IoT (Internet of Things) device, equipped with one or more sensors, at the lower end of a drone which is used to predict the spread of forest fires and monitoring reignitions.

A «Fire-fighting prevention and response system and method for using such a system» is described in patent application [WO2020064923A1](#) (AIRBUS DEFENCE & SPACE SAS [FR]), in which drones that communicate with a central station have a fire detection unit comprising a thermal camera and a fire response unit comprising a container with gas. The drones also have



monitoring modules for a certain path and a control module to trigger the response unit and communicate with the central station.

Document [US2021283439A1](#) (RAPIDDEPLOY INC [US]) concerning the «Dispatching UAVs for Wildfire Surveillance», discloses an «interface» of unmanned aerial vehicles, wherein at least one of said UAV has wildfire detection means. The UAV interface transmits an instruction so that an UAV moves to the location of the potential wildfire, and receives data captured by, at least, one sensor. The system is capable of processing the received data and sending a wildfire alert.

Retardant Products

Technologies related to fire retardants have as main goal to slow down or to stop the spread of flames. Patent applications that were found about fire retardants describe, mostly, retardants that are used separately or that are part of the chemical composition of the coating of buildings and structures which are intended to protect from possible fires.

Regarding isolated retardants, it is worth mentioning patent application [US2021154502A1](#) (M FIRE HOLDINGS LLC [US]), which refers to a «Method of and system network for managing the application of fire and smoke inhibiting compositions on ground surfaces before the incidence of wild-fires, and also thereafter, upon smoldering ambers and ashes to reduce smoke and suppress fire re-ignition», namely, a wireless mobile information network, that manages the application of a slurry composed of fire retardants and cellulose or wood fibre, mixed with water and other additives.

Patent application [WO2020109654A1](#) (XPYRO OY [FI]) is also worth noting, which discloses a «Method and aqueous

composition for preventing wildfires», where the aqueous composition consists of a fire retardant and fibrillar cellulose.

Combined Technologies

This subchapter addresses retrieved patent applications that encompass, in synergy, several technologies, described previously, related to the detection and prevention of forest fires.

Patent application [US2019176987A1](#) (BEECHAM JAMES E [US]), with the title «System and method for fire suppression via artificial intelligence» describes a computer enabled with artificial intelligence connected to several stationary and mobile sensors, that collect data and communicate it to the system, which indicates possible fires and takes action for the extinguishing of those fires by resorting, namely, to drones. Patent application [WO2021010912A1](#) (TAYSI OLCAY [TR]), whose title is «Early fire detection system and a detector suitable thereof», enables early detection of fires in different environments, through one or more detectors thrown from the aerial vehicles, which are configured to analyse collected data about humidity, temperature, smoke, carbon/carbon dioxide and wind direction, and that obtain energy from a solar panel. Finally, patent application [US2021232818A1](#) (AIDASH INC [US]), with the title «System and method of intelligent vegetation management» claims a system that enables image data collection with aerial technologies, determining the fire risk on a given area, by resorting to a convolutional neural network.

2.2. Evolution of the industry

Over the study period, 1,737 patent or utility model documents were published

Figure 14. Patent documents related to detection and prevention – 2010-2021

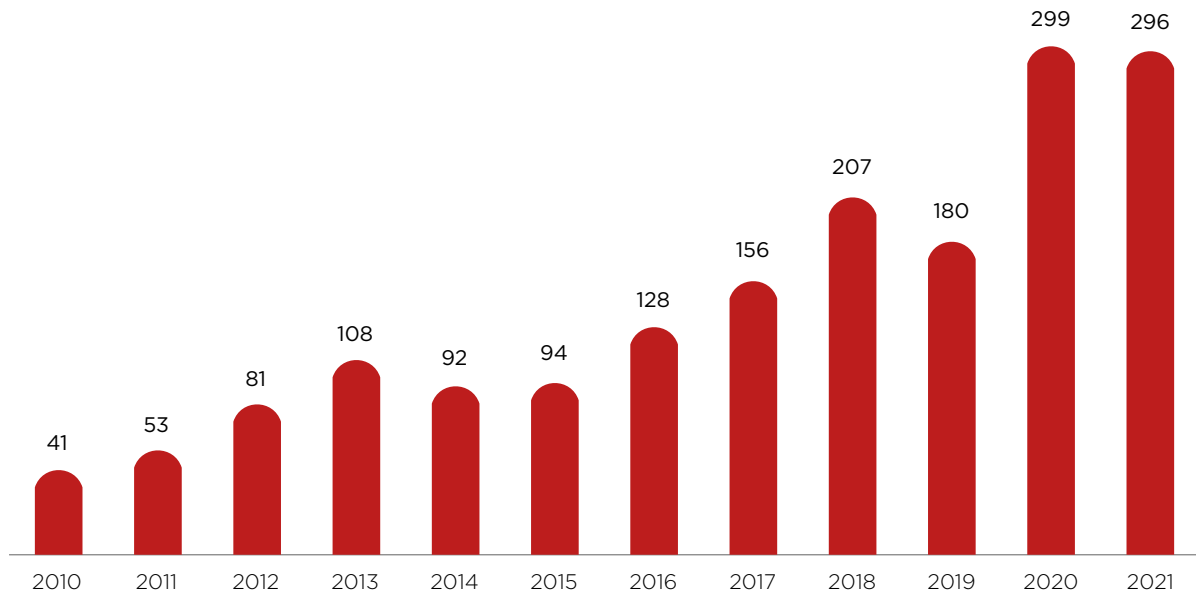
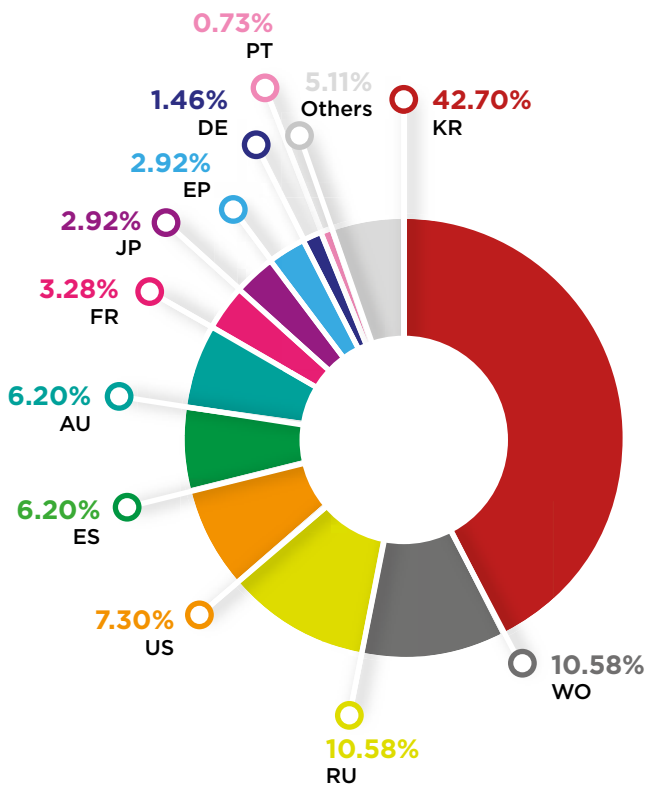


Figure 15. Publication Institutes. Detection and prevention of fires, excluding China



worldwide, related to the detection and prevention of forest fires. Except for the years 2014 and 2019, and a very slight decrease in 2021, an annual increase of published documents is noted. The average indicates an annual increase of 56.54% for 11 years, although the sharpest increase occurs from 2015 onwards, as it can be seen in Figure 14.

If China is not considered, as previously suggested, the offices that publish the highest number of patent documents in the field of the prevention and detection of forest fires can be seen in Figure 15.

South Korea is the country which publishes the most applications - 42.70% - followed by the World Intellectual Property Organization (WIPO) with 10.58% PCT international applications. Russia also has the latter percentage. The United States of America and Spain published 7.30% and 6.20% of applications respectively. Regarding Portugal, the percentage of published patent documents in the field of the prevention and detection of forest fires was 0.73%.



2.3. Relevant technologies

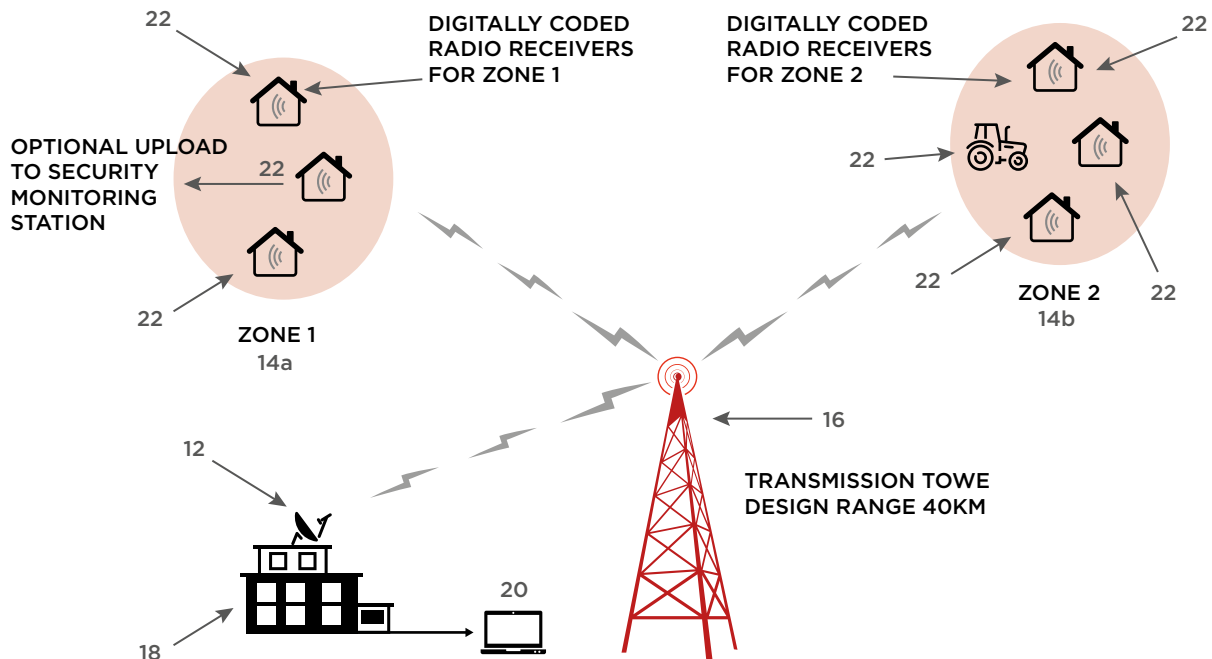
In this section, the inventions between 2010-2021 that were protected in at least two countries will be commented. Together with the publication number of the commented document and its applicant, the country codes where the patent was applied are indicated. This analysis is made for a broader period (2010-2021) than for the applications discussed in section 2.1., given that in order to ascertain to which countries the inventions were internationally extended, it becomes necessary a broader period.

Patent **WO2011000060** (DATODI RAYMOND FRANCIS [AU]), (AU,CA, EP, US) discloses a radio-activated warning system that has a receptor which receives coded signals from the corresponding geographical area and triggers an alarm which warns about upcoming danger. The system is comprised of a transmitter that transmits a coded signal to several attributed geographical

areas having a unique code. Thereby, areas under fire threat can be remotely controlled and managed via Internet. Furthermore, the signal of upcoming danger can be efficiently supplied to the residents of remote areas, even during a power outage.

Document **WO2015094014** (OBSHESTVO [RU]), (WO, EA, RU, US) discloses a process for determining the optimum configuration of a forest video monitoring system that improves the efficacy of installing and determining the optimum configuration of the system on the basis of accurate evaluations. The method consists of collecting parameters related to the characteristics of the monitoring sites and of the territory and setting a system performance indicator. The options for the location of the monitoring sites are then examined and compared to the location option with the best performance indicator value is selected. The result from the comparison determines the optimum configuration of the system.

Figure 16. Scheme from patent application WO2011000060



In turn, patent [WO2012167609](#) (GUANGZHOU SAT INFRARED TECHNOLOGY CO LTD [CN] *et al.*), (WO, CN, EP, US) describes a forest fire early warning system that generates and transmits an alarm signal based on received data from an infrared camera. A mathematical model calculates the alarm temperature value, so that the system can guarantee accuracy about the causes of the transmitted alarm, and automatically supervises and alerts about the complex environmental conditions.

The technology described in patent [WO2020146927](#) (POLE GRAHAM [AU]), (AU, CA, EP) consists of a fire detector device that includes an infrared sensor to detect reflected photons. Furthermore, a hygrometer detects ambient humidity and an electronic controller receives the infrared sensor outputs and the hygrometer

output signal, which are compared to a predetermined value. If relevant, an alert signal is provided based on those comparisons.

Lastly, patent [WO2013030497](#) (NOVELTIS [FR] *et al.*), (WO, FR) discloses a device for the early detection of forest fires. A computer processing unit applies a threshold filter to detect and track the beginning of the fire using satellite data. The filter is based on the histogram of a temperature image, taking into consideration the glow masked by vegetation. In this way, it isolates the values and constructs a spatial indicator. The system applies a cloud mask on the glow temperature chart at a moment and at a previous moment, isolates the pixels and generates a bitemporal indicator to provide informations to rapidly detect and locate the beginning of the fire.

Figure 17. Scheme from patent application WO2015094014

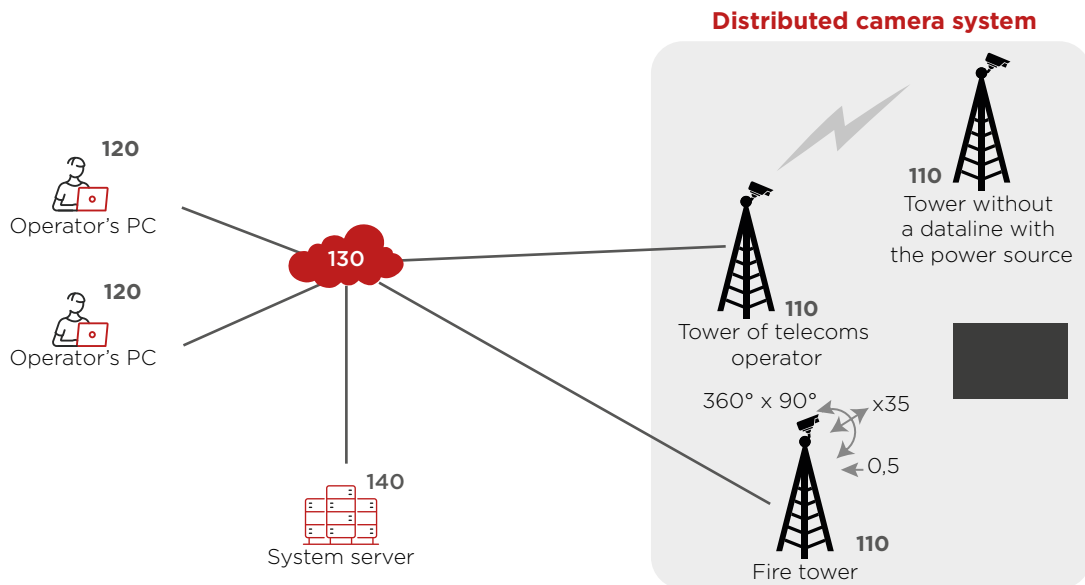




Figure 18. Scheme from patent document WO2012167609

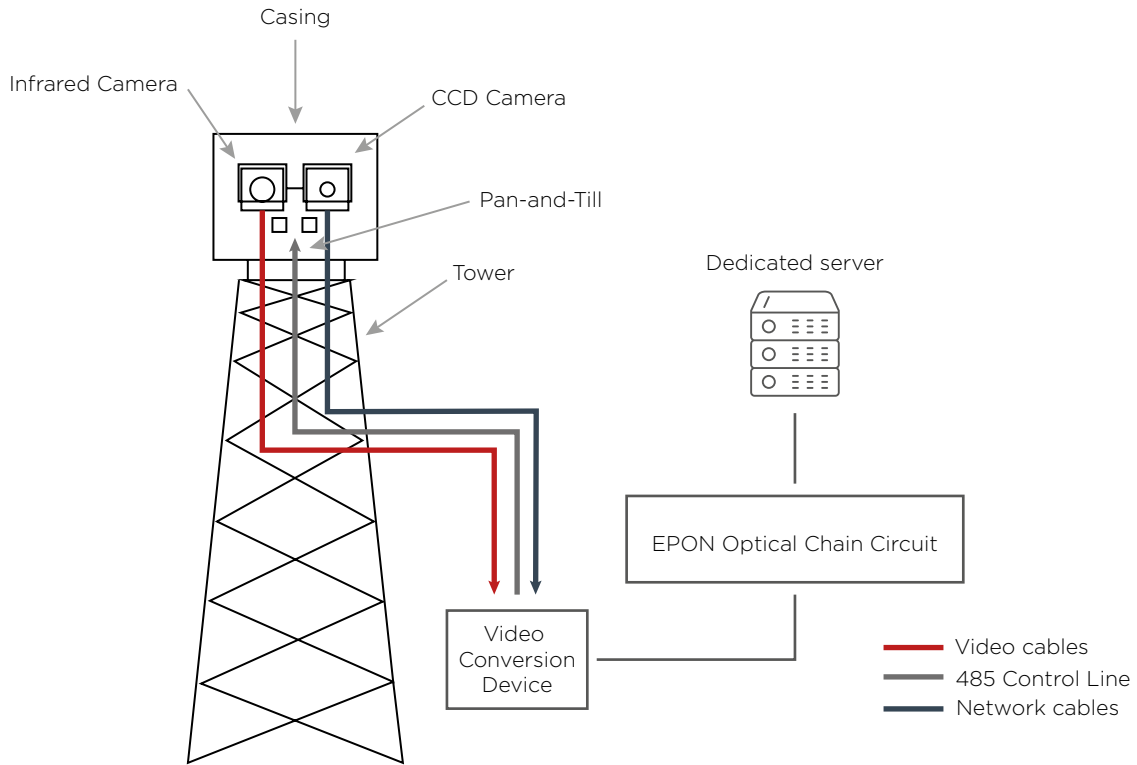
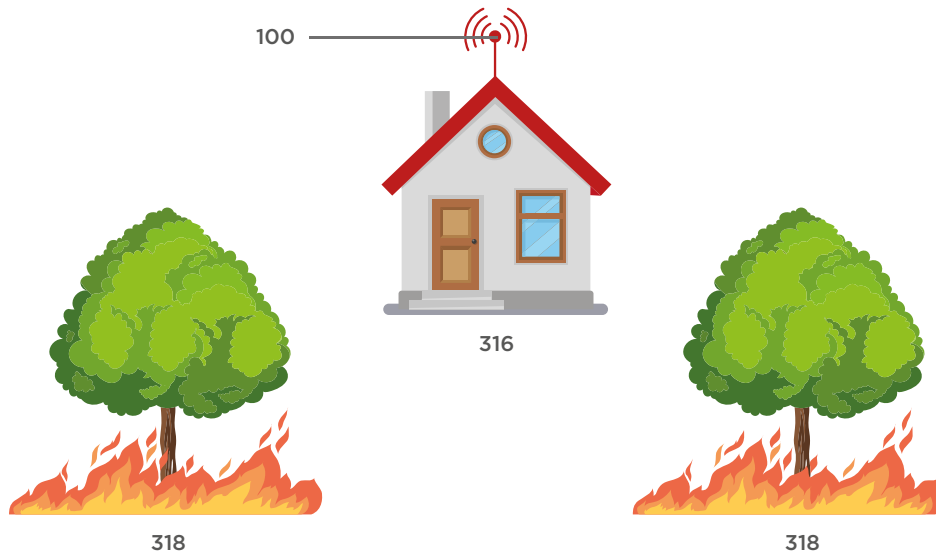


Figure 19. Scheme from patent application WO2020146927



Institution in the sector: Forestwise



forestwise

The Collaborative Lab for the Integrated Management of Forest and Fire (CoLAB) ForestWISE is a private non-profit Association, with legal personality¹⁸. ForestWISE aims to promote the integrated management of the forest and forest fire through activities such as (co)research, innovation and knowledge and technology transfer, so as to contribute to the sustainable forest management in Portugal, to the valuation of forest services and products, to the reduction of negative consequences of major rural fires, to the increase of the competitiveness of Portuguese forestry industry, to the dynamization of the sustainable development in the low density territories and to the promotion of scientific employment.

CoLAB ForestWISE responds to the aims of the Resolution of the Council of Ministers n.º 159/2017, by the combined efforts of universities, of the public sector and industry, on a holistic and multidisciplinary approach to fire questions, forest valorisation and sustainable development of forest-based industry. ForestWISE leverages existing knowledge in knowledge centres, applying it on solving specific, current and emerging business problems and meeting the major society challenges.

ForestWISE has been recognised with CoLAB stamp on 30 January 2018 and was legally constituted on 29 September 2018.¹⁹ At its current configuration, it integrates 15 associates, among which are companies, academia and public entities. The companies associated are *Altri Florestal*, *Amorim Florestal*, *E-REDES*, *DS Smith Kraft Viana*, *REN*, *Sonae Arauco Portugal* and *The Navigator Company*. The academia associates are *INESC-TEC*, *Instituto Superior de Agronomia da Universidade de Lisboa*, *Universidade de Aveiro*, *Universidade de Évora*, *Universidade de Trás-Os-Montes e Alto Douro* and *Universidade de Coimbra*. The public entities associated are *AGIF - Agência para a Gestão Integrada de Fogos Rurais* and *INIAV - Instituto Nacional de Investigação Agrária e Veterinária*.

CoLAB ForestWISE works in coordination with partners and national networks, namely *ICNF - Instituto da Conservação da Natureza e das Florestas*, *DGT - Direção-Geral do Território*, *ANEPC - Autoridade Nacional de Emergência e Proteção Civil* and *GNR - Guarda Nacional Republicana* and with international partners, such as *Fundação CESEFOR*, *CTFC - Centre de Ciència i Tecnologia Forestal de Catalunya*, *SLU - Swedish University of Agricultural Sciences* and *Copernicus*, which is the Earth observation program of the European Union, and is part of the European network of Copernicus Relays. These partnerships and national and international networks assure the adoption of best practices by ForestWISE and its positioning in high TRL and with great focus on knowledge and technology transfer.

In its internal organization, CoLAB ForestWISE is composed of four work lines (LT): LT1: Forest and Fire Management; LT2: Risk Management; LT3: Circular Economy and Value Chains and LT4: People and Policies, from which several (co)research and transfer activities and projects are developed. Currently, twelve projects funded by several sources (public and private) are underway and the executive team is involved in more than thirty proposals, some of which hold high relevance regarding Forest and Forest Fire and also for the country.

Currently, ForestWISE multidisciplinary team consists of nineteen people, including Senior Investigators, Project Managers, Project Technicians, Administrative and Account Staff, and is regularly recruiting new members.



¹⁸ <https://www.forestwise.pt/>

¹⁹ <https://www.ambientemagazine.com/laboratorio-colaborativo-paraa-gestao-integrada-da-floresta-e-fogo-contrata-investigadores/>



**R&D Projects on Detection and
Prevention of rural fires in Portugal**



Portugal has several R&D projects in the field of prevention and detection of rural fires, funded by the *Fundação para a Ciência e a Tecnologia* (FCT).²⁰ These projects involve several technologies that meet, from mentioned in patent applications that have been identified in this study, in particular, monitoring, aerial technologies, artificial intelligence and sensors.

Of the projects mentioned, the following deserve special mention on the field of fire prevention:

A sustainable model of land use planning for the prevention of rural fires – SCAPE FIRE

SCAPE Fire project from the *Instituto Superior de Agronomia da Universidade de Lisboa (ISA)* and aims to propose a rural land use model that contributes to the prevention of rural fires, in compliance with the ecological, economic and social sustainability of the landscape. The goal is to create a landscape protection framework against rural fires, assuring the conservation of soil, water and biodiversity. The methodology elaborates a conceptual model based on the ecology of the landscape and on fire behaviour.

This model is applied to landscape typologies, determined from their vulnerability to rural fires and its consequences in soil loss, by using socioeconomic and ecological parameters. This results in a gradation of intervention priorities that inform about the selection of case studies. For each case study, a proposal of rural area use model will be elaborated, linking the conservation of nature (water, soil and biodiversity), familiar and commercial agriculture, forestry, pastoralism, rural and nature tourism and other activities that contribute to population settlement in rural areas.²¹

Regarding forest fire detection, the following projects are highlighted:

Where is the fire? – Identification, positioning and monitoring of forest fires with data supplied by citizens – Fireloc

Fireloc project, from the *Instituto de Engenharia de Sistemas e Computadores de Coimbra (INESC Coimbra)*. It seeks to develop an innovating system that will enable:

1. Any citizen with a smartphone to report that he/she is spotting a fire outbreak, automatically sending its location coordinates (observation spot), an image of what he/she is seeing (photo taken with the smartphone) and data that will allow to georeference the phenomenon that he/she is watching (namely the orientation in relation to the north, automatically collected by the smartphone, and the approximate distance from the event that he/she is seeing, indicated by the observer).

²⁰ FCT (2019). R&D projects on forest fires prevention and detection in Portugal. <<https://www.fct.pt/>, (4 January 2022)>

²¹ <https://www.isa.ulisboa.pt/proj/scapefire/>

2. For each contribution, to identify the approximate geographical location of the observed event and the level of trust in the received data, using information about the volunteer (his credibility being related to his/her profile and contribution track record) and on what there is at the observation and event spot (using information about the soil use and occupation and a land digital model).
3. To integrate and process the data provided by all contributing citizens, identifying the geographical location and the extension of the observed phenomenon in near-real time. The developed system will be available in an independent way and will be integrated in the App FireRisk. The information provided will be integrated in the portal «Exploring VGI».²²

The use of autonomous aerial vehicles for supporting controlled fires and detection detecting reignitions in the management of forest fires – FoCoR

The use of an automatic system based on the development of Unmanned Aerial Vehicles (UAV) for the support of controlled fires and detection of reignitions is the aim of project FoCoR, from the *Instituto de Desenvolvimento de Novas Tecnologias (FCT/UNL)*. The mission control software to be developed will allow to choose the different operation methods, to delimit the operation area and to configure and control the mission. For prescribed fires, the system will support three main activities:

1. Area coverage and analysis – The UAV covers the area foreseen for the Controlled Fire, in order to analyse the biomass levels, to build a 3D map and to make a weather map of the temperature and wind of that area. For these tasks, UAV will use an anemometer and a multispectral and temperature sensor on board.
2. Ignition – on board of the UAV a weapon will be used to ignite the fire at precise spots, following a burn plan suggested by an algorithm or created by the operator of the platform's mission.
3. Monitoring over the Controlled Fire – The UAV will be used to search the area of the Controlled Fire, identified in the mission plan, so as to keep the situation under global control. It will provide information on the perimeter of the fire and temperature and wind record, alerting the operator about unusual conditions. For this task, the UAV will use a thermal sensor on board and sensors for measuring temperature and wind speed. In reignitions, the main mission is to identify areas that overcome a certain temperature, by using the sensors installed on board of the UAV (for example, thermal cameras).²³

²² <https://www.uc.pt/en/org/inescc/Projects/projects/FireLoc>

²³ <http://www.isa.ulisboa.pt/ceabn/projecto/1/105/focor-a-utiliza-ccedil-atilde-o-de-ve-iacute-culos-a-eacute-reos-aut-oacute-nomos-no-apoio-a-fogos-controlados-e-dete-ccedil-atilde-o-de-reacendimentos-na-gest-atilde-o-de-inc-ecirc-ndios-florestais>

Early automatic detection of forest fires, by using neuronal networks of residual learning – ResNetDetect

The INOV INESC Inovação - *Instituto de Novas Tecnologias (IST/ULisboa)*, from **ResNetDetect**, has developed the CICLOPE system, which has been commercialised in Portugal, Italy and Greece since 2001, and that covers 25% of the Portuguese mainland and uses visible video monitoring for smoke detection. However, the automatic detection algorithm is prone to high rates of false alarms. With technological progress, new promising and universal algorithms were developed, for pattern detection and image classification, based on artificial intelligence techniques. However, smoke detection in forests is still very challenging due to the landscape (the wind on trees changes the landscape), to the sky (clouds are mistaken for smoke) and to the light conditions, among others. The goals of the project are:

1. To create a forest fires image database, big enough to train deep learning algorithms, collecting images with CICLOPE system and on the Internet, making experiences with fires and creating images with advanced Adversarial Generating Networks.
2. To study and compare the efficiency of different ResNetArc on the automatic detection of smoke patterns.
3. To discover ResNetArc optimized hyperparameters for fire detection by using global optimization based on Sequential Model (SMBO) and to create a dedicated network.
4. To incorporate the new knowledge on CICLOPE and demonstrate the solution under real operating conditions. The performance indicators will be to improve the state-of-the-art 0,6% false alarms and 96% fire detection percentages by testing on 1500 smoke images and 1500 non-smoke images.²⁴

Real-time mapping and prediction of fire progression by unmanned aerial vehicles – FIREFRONT

The **FIREFRONT project** has as applicant institution the *Associação do Instituto Superior Técnico para a Investigação e o Desenvolvimento*. It aims to develop a support solution for fighting forest fires, through real-time detection and follow-up of the fire fronts and eventual reignitions. To achieve this goal, the information provided by Unmanned Aerial Vehicles (UAV) and Manned Aerial Vehicles (MAV), equipped with sensors and specialised communication systems, flying over the affected region, will be processed. This information will be made available to the coordination and combat forces, through a graphic interface with the location of the events in georeferenced coordinates. Predictions on the evolution of the fire front, images of the fire area, magnitude and direction of the wind, and other meteorological elements will also be provided.

²⁴ <https://www.inov.pt/project/resnetdetect/index.html>.

It is also intended, in this process, to produce a unique worldwide database of forest fires sequenced images in georeferenced coordinates that will be made publicly available and that will allow to mobilise future research in the field. The project considers several test stages and system validation, either in simulated fire, or in real fire.²⁵

Sensor network combined with fire propagation modelling integrated in a decision support system for fighting forest fire- foRESTER

The **foRESTER project** from the *Instituto de Desenvolvimento de Novas Tecnologias (FCT/UNL)*. It aims to develop a Decision Support System (DSS) by integrating several information sources on a simple and efficient platform. This system should provide the operational commanders with useful and solid informations to improve the strategy and the decisions about fire fighting. For this purpose, foRESTER proposes a quick DSS, trustworthy and informative, based on computational intelligence and advanced visualization techniques, integrating innovative technologies, based on multi-sensors, satellite image processing and near real-time (NRT) fire spread predictions (FSP). In order to obtain granular terrain information, a flexible, reconfigurable and low-cost multi-sensor system will be developed, which by combining stationary and portable sensors in a wireless network (WSNs), will combine atmospheric data with images for the classification of the fire front. This information will be processed using a signal-processing algorithm that will be locally executed at a dedicated hardware platform. DSS will provide tools to generate early warnings of extreme changes on the weather conditions, helping with the resource allocation planning.²⁶

25 <http://www.firefront.pt/>.

26 <https://forester.pt/web/inicio/>



**Prevention and Detection of fires
in Portugal – The opinion of the
Agency for Integrated Rural Fire
Management (AGIF, I.P.)**



The National Plan for the Integrated Management of Rural Fires (see RCM n. ° 45-A/2020) mentions that, after the tragic fires that ravaged the country in 2017, a consensus was reached about the systemic fragilities identified by the Technical Independent Commission. Some of them are chronic and long-standing, such as the lack of prevention or the non-integration of knowledge into the management of operations.

To assure a Portugal Protected from Severe Rural Fires (vision of 2030 Plan), it is necessary to have a functional system that instead of focusing its attention in suppression only, works on the entire chain of fire value (from the planning to the post-event), with special focus on prevention, i.e., educating and raising awareness for the proper use of fire and management of vegetation. On one hand, it is important to lower the probability of fires occurring, by reducing ignitions through awareness and education campaigns or through dissuasive monitoring actions and, on the other hand, it is important to reduce the susceptibility of the landscape to fire. Reducing susceptibility to fire is not only achieved by carrying out fuel management works, but it is also necessary to value rural space, whether through forestry production, agriculture or the natural capital of the territory.

In order to achieve this transformation, there are multiple challenges that must be faced, namely institutional, economic, social, cultural and behavioural, legal, environmental and politic. Innovation must happen at all these levels and not just at a technological level, and even though technological innovation is very important to achieve the goals that the country has set, it is many times presented as the only path to solve the problem, either in Portugal as in other parts of the world, frequently ravaged by rural fires.

Although there is quality scientific knowledge in Portugal, internationally recognized, there has been a lack of valorisation of the outputs through the incorporation of new products, services, processes and business models, which increase the income of rural landowners, either, for example, through the optimization of operations via automatization and digitalisation or through the trade of sustainable products and added value products (biomaterials, biological based chemicals or biofuels). Innovation and technologic development at this level are fundamental and directly contribute to accelerate the change that is intended to be achieved until 2030, countering the possible worsening of the risk of fire due to the weather conditions expected in the upcoming years.

With perfect awareness that the investment on prevention takes years to accomplish and to produce visible results and that fire risk will never be null, the work on other strands shall be carried on so that the country does not go through another tragic year such as 2017.

In fact, major fires are concentrated in a few days of the year and, during these days, activity highs are registered at the fight forces, who then cannot protect the entire population and forest. With climate change underway, more frequent occurrences of weather conditions leading to major fires, with extreme heat events and long droughts, is likely to occur.

A strong intervention at an early stage of a fire is crucial for containing rural fires on adverse meteorological conditions, and therefore early detection is a necessary condition for the success of operations. If all initial efforts are not enough, effective fire containment is limited to some strategic locations, since extreme events of rural fires are, generally, immune to fight efforts due to the high energy release. Typically, major fires concentrate in time and space

(in Portugal, 75% of annual exposure concentrates on a reduced parcel of less than 30% of territory) and a reduced number of forest fires (10%) is responsible for 90% of the total burnt area.

It is of interest, at the level of monitoring and detection, to maximize the effectiveness of the process, combining multiple technological solutions (drones, video monitoring, sensors, satellites, etc.) with monitoring carried out by the population and by operatives with the responsibility in the field of monitoring and detection, so as to achieve a full coverage of the territory and a rapid action, especially on higher-risk days.

The identification of critical fields through technological means is a critical success factor to pre-positioning fight teams, to guide human and technological resources to the monitoring and detection of fires and to prioritise prevention actions at the rural area. Therefore, the probabilistic analysis of fire risk, and using several weather scenarios as precursor for decision-making, is another field that requires new solutions, namely the development of decision support systems, capable of processing a major volume of data. In turn, these systems will only be effective if the information feeding them is of high quality, so the continuous incorporation of new technologies allowing the territory to be accurately characterised and as frequently as possible is another field where the System of Integrated Management of Rural Fires will continue to invest.

03

FIRE EXTINGUISHING





3.1. Fire extinguishing technologies

This section focuses on technologies that directly help to extinguish forest fires, and also on technologies that control and monitor fires that have already occurred.

Extinguishing tasks are performed by emergency operations, which cost about 600 million euros each year in Spain. This operation is variable throughout the year, reaching its peak during summer. The operation is responsible for monitoring and extinguishing. Once emergency services run to the spot, with most emergencies remaining as fire outbreaks. In other words, fires that affect less than 1 ha.

In Spain, the response time of most fires is between 15 to 30 minutes. However, despite this rapid response, some forest fires evolve to major fires due to adverse weather conditions in high-risk forest areas. High intensity propagation fires are sparked, lasting several days and jeopardising people, goods and ecosystems and demanding the use of countless terrestrial and aerial fire extinguishing means, coordinated in complex operations. These operations involve professionals from different fields (firefighters, forest checkpoints, police, forest agents, pilots, military, etc.) and a wide range of technologies (off-road machinery, heavy machinery, heavy road vehicles, 4x4 light vehicles, manual tools,

plains, drones, communication systems, geolocation systems, etc.). These major fires are the ones that demand and incorporate larger innovation.

In Portugal, also, the actions directed at controlling and extinguishing rural fires assume great relevance. First of all, the *Portuguese Recovery and Resilience Plan (RRP)*, approved by the Council of Economic and Finance Ministers of the European Union (Ecofin) on July 2021, foresees an endowment of 89 million euros for resources to fight and prevent rural fires²⁷. The creation of the *Special Device for Combating Rural Fires (DECIR 2021)*, by the *National Civil Protection Commission*, which made available to this Device the largest number ever of means involved in all phases of engagement, is also highlighted.

Within the field of fire extinguishing, the following innovative patents in eight types of different technologies have been detected, as shown below.

Over the last three years (2019-2021), the technologies with the highest number of patent applications in the field of fire extinguishing range from land technologies and aerial technologies to monitoring systems, which use IoT (Internet of Things) to fight a forest fire.



²⁷ <https://recuperarportugal.gov.pt/wp-content/uploads/2021/10/PRR.pdf>; <https://www.portugal.gov.pt/pt/gc22/comunicacao/noticia?i=primeiro-ministro-sauda-aprovacao-do-prr-portugues>

Aerial Technologies

Aerial technologies are the most innovative in forest fire extinguishing, with inventions that use aircraft, helicopters and, above all, drones. Mainly, the trend to innovate is drones that carry extinguishing agents to be released in the fire. Examples include patent application [KR20190037819](#) (SAFEUSDRONE CO LTD [KR]), with the title «A forest fire extinguishment system using an unmanned aerial vehicle for forest fire extinguishment» wherein a drone, which receives informations in real-time about a fire and that includes a buoyancy pocket and a water tank to be possible to directly collect water, is disclosed. On the other hand, application [JP3224081U](#) (CENTURY CORPORATION [JP]), with the title «The drone having a fire extinguishing bomb dropping module», discloses a drone with a fire extinguishing spherical bomb dropping module to slow down the forward speed of a forest fire.

Other inventions that use drones include hoses connected to these and, at the other extremity, connected to a large capacity water or foam tank on the ground. This allows to solve the problems of the low transportation capacity of drones. For example, patent application [WO2021085787](#) (KOREA FOREST SERVICE NAT INSTITUTE OF FOREST SCIENCE [KR]), with the title «Fire-fighting system using unmanned aerial vehicle», describes a drone that sprays water supplied through a tube connected to a water tank, located in a vehicle. Likewise, application [KR20200050081](#) (CHOI JAE HYUN [KR]), with the title «Forest fire extinguishment system using drone and method thereof», discloses a method and a system that includes a water tank connected by hoses to several drones that fly over the area of the fire.

Most inventions related to the use of drones in the direct extinguishing of fires

have the technological disadvantages of transporting major water volumes (between 1,500 - 5,000 kg) that are normally used to extinguish forest fires, besides the legal limitations on the use of drones when there are other aerial means in the area. While unmanned aerial technologies can solve this problem, the applicability of these inventions is considered limited.

On the other hand, there are still patent applications that use aircrafts as a mean for fire-fighting. For example, application [WO2021151000](#) (SUKAY LARRY [US]), with the title «Consolidated aerial high capacity foam firefighting system», discloses an aircraft with a foam production unit and a stream straightening that can be in a retracted or extended position for foam ejection. In other patent applications, such as [US2019084678](#) (HECK KENNETH [CA]), with the title «Airborne fire extinguishing system with infrared imaging and method», an aircraft is described, which includes a fire extinguishing agent reservoir and an infrared camera that regulates the flow of the fire extinguishing agent according to the thermographic image obtained by the fire camera.

Finally, improvements regarding the mechanisms of descend and rise of fire extinguishing loads in aircrafts, as well as in amphibious systems, continue to be put in place. A relevant example of such is application [WO2020214081](#) (PAJUS DAVID [SE]), with the title «Surfing arrangement for mounting to an aircraft, and an aircraft comprising such an arrangement», concerning an aircraft with a surfing device that improves the landing over masses of water.

Automotive Technologies

Most patent documents related to land technologies focus on manned vehicles or robot, tracked chassis for hilly terrain,

thermal protection cabins, and several devices assembled or coupled in chassis for the storage of water, dirt, fire extinguishing agents or water or high-pressured compressed air hoses. Some include sensors to detect the exact location of the fire and thus directing the fire extinguishing agent in a more efficient way.

Several patent applications can be quoted as example. Application [EP3520863](#) (EMMLER HEINZ [DE]), named «Method for putting out surface fires, venturi laval nozzle and fast closing valve for use in the method, and vehicle, with which the method is applicable», reveals a method that consists in providing compressed air through an air cannon in the direction of the seat of the fire to be extinguished. Application [RU194356U](#), (SCIENTIFIC AND PRODUCTION ENTERPRISE «TENSORSENSOR» [RU]) with the title «Fire-fighting robot» refers to a robot with a fireproof casing and antennas and that comprises a water tank and a video camera. [ES2844938](#) (LAHUERTA ROMEO MANUEL [ES]), with the title «Wind cannon against forest fire», collects a wind cannon that is attachable to local means, such as a farm tractor. Finally, application [AU2021100978](#) (NANJING FOREST POLICE COLLEGE [CN]), with the title «Forest fire-fighting soil spray gun based on crawler chassis», discloses a spray gun with a crawler chassis to operate at uneven forest roads.

There is a huge interest in robotization in fire-fighting, remotely mobilised machines and small size machines (brush cutters, chain saws, etc.).

Missile technologies

Long reach technologies use missile or rockets to remotely launch fire-extinguishing agents and avoid direct exposure to fire, for example, compressed air launchers to release bombs with fire extinguishing

agents; rockets with water bombs that include detonators to generate water steam when exploding; or other systems that use parachutes with devices that are dropped on the fire.

For example, patent application [WO2020257844](#) (BENHAM ZUHAIR ABDULAHAD MAJEED [AU]), with the title «Firefighting apparatus», describes an apparatus including a tank with a fire extinguishing substance and a rocket engine to propel the tank towards the burning site. Utility model [ES1252894U](#) (SANCHEZ DELGADO JAIME [ES]) with the title «Remote fire extinguishing equipment using rockets», uses a self-propelled bomb with a rocket engine for launching at a medium distance a fire extinguishing agent in the rocket bomb.

Another relevant application is [US2020018582](#) (BOEING CO [US]), with the title «Fire-retarding artillery shell», that claims a device connected to an artillery shell to trigger a fire extinguishing agent at a certain distance.

Operational and safety difficulties for the fire-fighting personnel or the affected population mean that these inventions based in long distance launching have low applicability, especially in inhabited landscapes such as the ones found in Europe.

Monitoring

In what concerns monitoring, innovation happens especially in drones that transmit images and informations in real-time about the state of a forest fire to the control centre, which allows decision making, knowing which temperatures are being registered or if the wind conditions can modify the fire spread. Other monitoring systems also use satellite images and weather informations to determine the probability of the evolution of the fire.

Patent applications in this field are [WO2020106720](#) (TOHIDI ALI [US])

et al.), with the title «Fire monitoring», that describes an access method to a database for accessing values associated with the fire, such as satellite images, vegetation information and weather data about the geographic region where the fire is occurring. Application [KR20210103598](#) (UNIV KOREA IND UNIV COOP FOUND [KR]), with the title «High-speed and accurate prediction of wildfire spread», concerning a wildfire simulation apparatus, with a machine learning unit that corrects the result of the fire simulation based on measurement data.

This type of technology will be strongly implemented due to the solid development of Big Data and complex analysis tools in recent times. The ease of use of remote sensors located in different platforms will create a strong information demand by the firefighting resources that should be processed for purposes of facilitating decision-making. Therefore, the inventions in this field are considered to have a high short-term applicability.

Retardant Products

In terms of chemical composition, water has been the most used compound in fire extinguishing due to its capacity to cool, suffocate and also interrupt the combustion reaction of the pyrolysate gases. To reinforce this action, inorganic compounds such as phosphorus and nitrogen salts are currently used as flame retardants, even though due to its non-biodegradable nature, they may cause an unwanted eutrophication if applied near watercourses. However, aerial fire extinguishing means are still the most used as long-term retardants, since its action does not depend on the presence of water, but on the action of salts on the surface of the fuel, which prevents or delays its combustion.

The other large retardant group are foams, which through its surfactant action

improve the water wetting capacity and are considered short-term retardants, since its action depends on the presence of water, so that when the latter evaporates, the product is no longer effective.

The current trend is to innovate as regards aqueous solutions that are more effective and efficient than water, for example, mixing surfactants (trisiloxine-polyether) and deliquescent anionic salts, and also in biodegradable solutions with low toxicity for the environment, such as non-polymeric organic components or solutions including nitrification inhibitors or gelling agents.

A representation of these compounds can be found in patent application [ES2780299](#) (GRACIA MARTINO JOAQUÍN [ES]), with the title «Extinguishing and protective composition for fires of great intensity and high temperatures as well as the procedure for its elaboration and use», which claims a long-term retardant compound whose effectiveness lies in the gelation of water, with high resistance to fire. Also, application [WO2021146782](#) (DO CARMO JOSE ROBERTO [BR]), with the title «Fire retardant and blocking composition for use in forest fires, and resulting preparation method», refers to a flame retardant consisting of a liquid compound with dissolved powders in suspension with nitrogen compounds.

These innovations were also partially approached in section «Retardant Products» in Detection and Prevention Technologies, and are also an important part of some inventions in hydraulic infrastructures or *in situ*.

In situ systems

Regarding in situ extinguishing systems, installed in forests before the fire, devices have been identified with a casing to hold a fire-extinguishing agent, that spreads the



compound in case a certain temperature is exceeded or smoke is detected. These devices can be poles distributed throughout the forest as referred in patent application [WO2021125314](#) (NIPPON BITAL CO LTD [JP]), with the title «Fire extinguishing device and fire extinguishing method».

There are also patent applications that disclose camera installations or other sensors in the forest, and the release of a fire extinguishing agent ready to use in the surroundings, as referred in application [RU198543U](#) (FAR EASTERN STATE TRANSPORT UNIVERSITY [RU]), with the title «Device for automatic extinguishing of forest fires».

Although inventors affirm its use in forests (landscape scale), it is not very realistic to apply this type of technology in larger areas. They can be useful only in forest-urban interface areas, either in forest environment closer to inhabited areas (technically known as mesoscale), or in closer gardened areas or mixed with buildings (technically known as microscale).

Portable Equipment

Portable devices range from backpacks with extinguishing agents or compressed air to devices that collect soil dirt and throw it to fire, avoiding the transport of firefighting material. It can also be dry ice devices that expel CO₂ to dislocate oxygen. Other portable devices are based on detachable barriers made of materials resistant to thermal radiation.

Application [AU2020217425](#) (EVANS KENNETH [AU]), with the title «Portable firefighting system», is enough to raise awareness to the importance of portable equipment in firefighting. It comprises a water tank unit, a hooper above the tank, that enables the tank to be filed on site from above by a helicopter, and a hose to eject

water. This set is assembled in a small off-road vehicle.

Also relevant is application [ES2686825](#) (BATISTA DE FRANCA GILSON [BR]), with the title «System for fire extinguishing», which claims a compact backpack-type device with an air compressor to compress the carbon dioxide obtained in the dry ice reaction. Another invention worth noting is described in patent application [KR101995264B](#) (HEO SEUNG HWAN [KR]), with the title «Portable soil collecting device for fire extinguishing equipment», which discloses a soil portable collector with an excavation screw to transport the collected soil to the above unit.

The mentioned inventions, although may be useful in specific cases, have limited use in forest fires due to low estimated operability in forest environment with steep slopes, mobility limitation and the need for fast operations.

Hydraulic Infrastructures

These technologies mainly use water as a means of fire extinguishing. These inventions range from a system which avoids the freezing of lakes in winter, methodologies that determine suitable locations to implement systems for collecting rain water, to cisterns buried in high mountain regions, with little visual impact, from which a network of pipelines with solenoid valves for spraying water is detected in case of forest fire.

Patent application [KR20190102891](#) (NAT UNIV KONGJU IND UNIV COOP FOUND [KR]), with the title «Freeze prevention device of lake as fire water supply source», consists of a plurality of stationary installations at the bottom of a lake that create nano-bubbles to activate the flux of water molecules, thus avoiding the freezing of the lake. However, it is of very limited use in the Iberian Peninsula, since fires do not occur in regions with frozen lakes.

Application **EP3839870** (UNIV DE TRAS OS MONTES E ALTO DOURO [PT]), with the title «Methodology to determine locations of systems for rainwater harvesting in hydrographic basins», regarding a methodology that determines the right sites for implementing systems for collecting rainwater to satisfy firefight needs, could broaden and improve the current methodologies for location of water refill spots.

In another group of innovations, several should be highlighted. They are essentially water tank fixed installations, pipes and sprinklers that automatically unload water or water and retardants. These innovations are closely connected to the developments in the in-situ systems section. These fixed installations have as main shortfall the efficiency in covering large areas vulnerable to wildfires, which can be insufficient on its own to stop a fire.

In the case of Spain, there are around 30 million ha likely to suffer a fire and less than 0,5% burn every year. In Portugal, between 2010 and 2020, the percentage of burnt area was 1,5%²⁸ Covering a significant part of forestland with these fixed installations would have a very high cost and the available public budget is assigned to human and technologic mobile teams, capable of effectively perform in any part of the land. However, as mentioned above, for interface areas of urban forest or very singular and specific sites, they may be useful.

In this group, one can list utility model **ES1237070U** (GARCIA DEL ROSARIO JOSE GREGORIO [ES]), with the title «Fire installation». It refers to a water tank from which a distribution network would start to arrive to water emission stations distributed throughout the mountain.

Also, patent application **KR102163752B1** (LEE KYUNG WOOK [KR]), with the title «Watering system for decreasing of fine dust and firefighting», which describes a system wherein the water, after being filtered, is stored in a tank, to which a pipe with sprinklers is connected, that are activated in case of a fire event. Likewise, patent application **KR20190092913A** (EOM GI HYUN [KR]) also discloses «The water storage tank to prevent the spread of forest fires» that would be activated when hit by flames and would release water and retardant.

Also noteworthy is patent application **KR102164234B1** (TERRA LANDSCAPE CO LTD [KR] *et al.*), with the title «Apparatus and method for preventing forest fire», wherein the water, provided by a supply unit, passes through a drain hose and is unloaded through holes, being subsequently absorbed by systems that enable fire extinguishing.

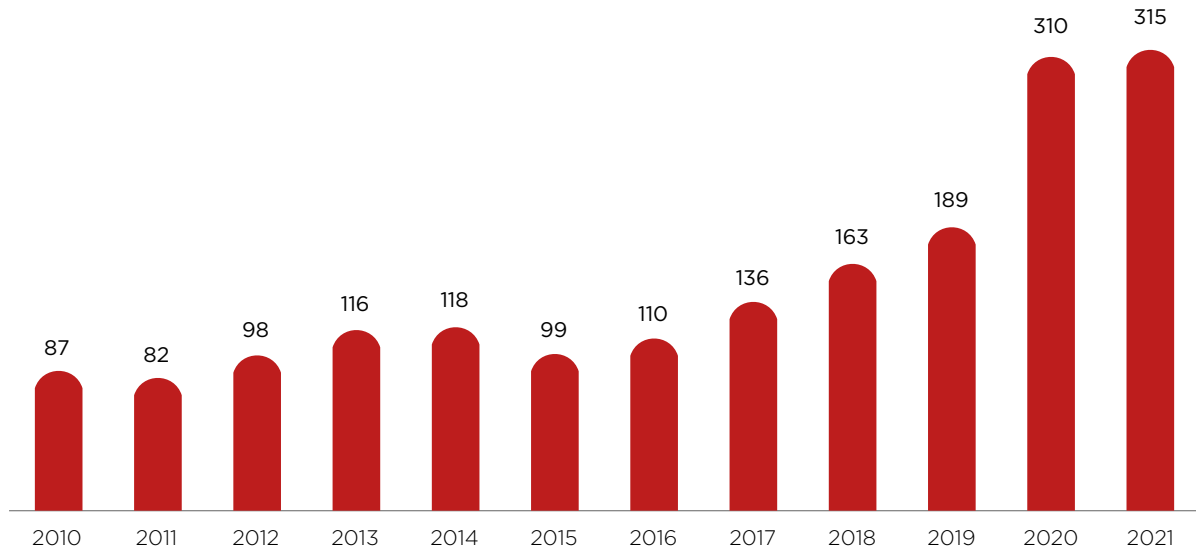
3.2. Sector development

Between 2010 and 2021, 1,828 patent applications on technologies focused in extinguishing forest fires have been published worldwide. From the four relevant technological fields defined for this study (detection and prevention; extinguishing; protection equipment; post-fire restoration), this is the one that presents the highest number of publications, slightly above detection and prevention of fire events.

Publications have risen 262% in the period taken into consideration (almost 24% on average per year), with another significant increase of publications from 2016 onwards, as shown in Figure 20. Of particular note is the 2020 increase in relation to 2019, which was 64%.

28 [https://www.pordata.pt/Portugal/Grau+de+%C3%A1rea+ardida+\(percentagem\)+%E2%80%93+Continente-3480](https://www.pordata.pt/Portugal/Grau+de+%C3%A1rea+ardida+(percentagem)+%E2%80%93+Continente-3480)

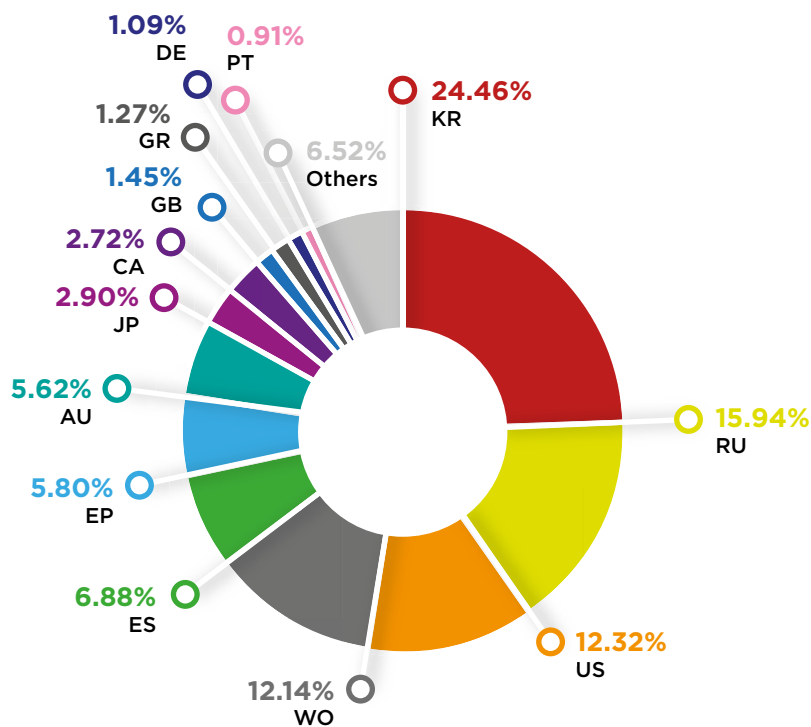
Figure 20. Patent documents on extinguishing, 2010-2021



Excluding China, on the fire extinguishing sector, South Korea is once again the country with the highest number of published patent applications, with 24.46%, followed by Russia with 15.94%, United

States of America with 12.32% and WIPO with 12.14%. Spain occupies the fifth position with 6.88% of publications. Portugal has 0.91% patent publications on the field of forest fire extinguishing (Figure 21).

Figure 21. Publications by Office. Fire extinguishing, excluding China



3.3. Relevant technologies

In the fire extinguishing sector, between 2010-2011, there are dozens of inventions whose protection was broadened to several countries, which may give an idea of the economic impact they hold. In particular, this section will comment on the inventions that were protected in, at least, three countries.

Patent application [WO2020247775](#) (FRS GROUP LLC [US] *et al.*) (AU, CA, US), with the title «Long-term fire retardant with corrosion inhibitors and methods for making and using same» refers to a retardant compound that is effective in suppressing, retarding and controlling forest fires, while inhibiting corrosion on aircraft tanks and exhibiting low toxicity.

This composition may be provided in several ways: as a dry concentrate, a liquid concentrate, or a final diluted product. The composition consists of a retardant compound, a corrosion inhibitor, a thickening agent and at least one dye or pigment. The retardant compound includes a magnesium salt or calcium halide salt, a carbonate salt, a phosphate salt, a metal oxide, a metal hydroxide, or combinations thereof. Furthermore, the composition of the forest fire retardant may include anhydrous salt and at least one hydrate salt.

Patent application [WO2012071577](#) (ZZAKEY TECHNOLOGIES LTD [IL] *et al.*), (AU, IL, US) with the title «Biodegradable fire-fighting formulation» is an aqueous formulation ambiently degradable for use in firefighting and a preparation method.

Figure 22. Scheme from patent application WO2020247775

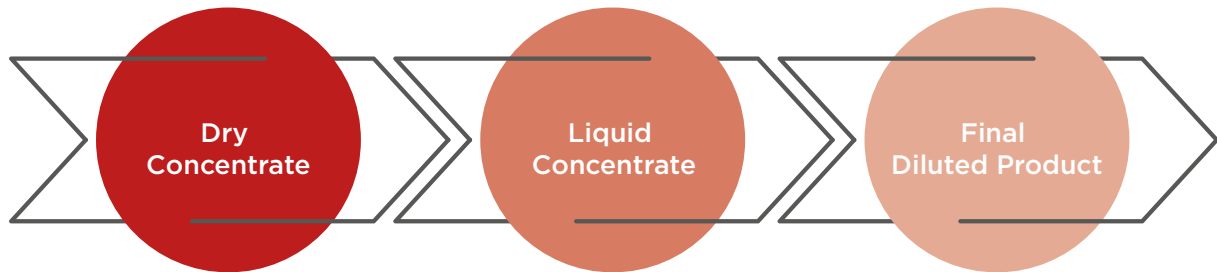


Figura 23. Figure from patent application WO2012071577

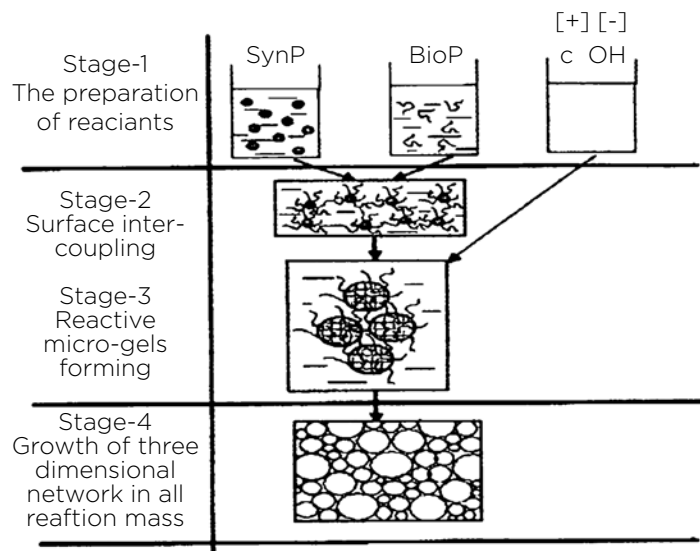
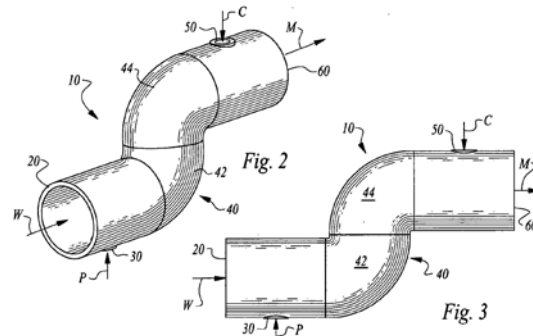
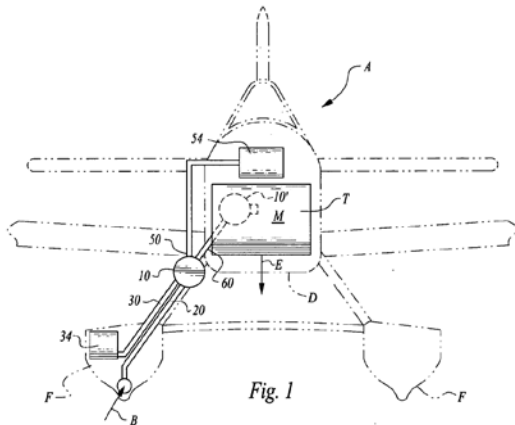




Figure 24. Figures from patent document WO2013070258



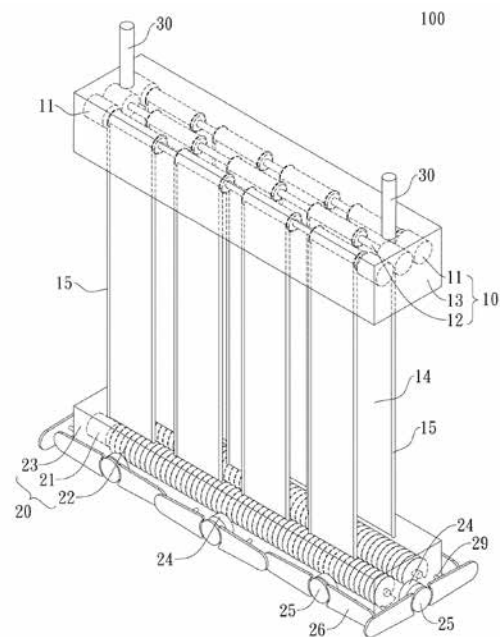
This formulation is composed of an anhydride copolymer whose functional group is an alkyl group (methyl, ethyl and propyl) and at least 0,1% by weight, of one cross-linking agent (a biopolymer and a tannin).

Patent [WO2013070258](#) (DOTEN LEONARD E [US]), (AU, CA, IL, MA, US) with the title «Polymer mixer powered by hydrodynamic forces» refers to a mixer that includes a high velocity water source, a water inlet deployed to that source, a chemical source, among which a polymer, an inlet of that polymer and elbows in the fluid pathway. The aim is to provide a mixer that does not require a separate power source to function, that is easily detachable from an aircraft and thus achieving a suitable mixture in firefight.

The high velocity water source has enough velocity to mix the polymer with the water at the elbow. Furthermore, the water source includes a gathering device on an aircraft float, so that when the plain touches the surface of the water, water is drawn into the opening.

Patent [US2018236277](#) (CHOU VICKI FEN [TW] *et al.*) (AU, CA, CN, DE, ES, FR, PT) with the title «Fire-stopping suspension

Figure 25. Figure from patent application US2018236277



apparatus and method for using the same to stop the spread of fire» relates to a suspension device to stop a fire and prevent a forest fire from spreading further. To do this, the invention comprises a top suspension device with transmission mechanisms of shafts to roll out or roll back the fire-retardant fabrics. These suspension devices can be suspended on helicopters and send to the fire scene, to delimit the burning areas.



Company in the sector:
Drone Hopper

DH
DRONE HOPPER

Established in 2016, Drone Hopper (DH) is an aeronautic engineering company 100% Spanish that manufactures high load capacity industrial drones with thermal engines. Specialised on the development of high load capacity and high-performance drones, firefighting was the first and main reason for starting the company.

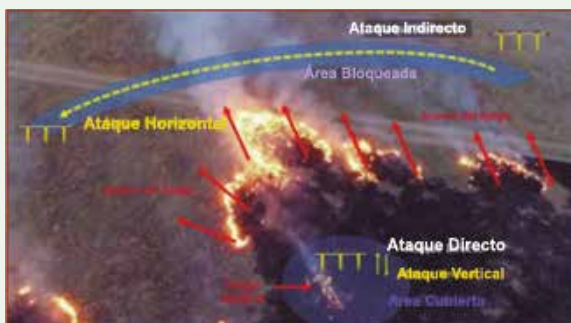
Drone Hopper has two lines of products: high load and autonomy capacity industrial drones and light drones with industrial features. The idea to build a drone for firefighting, the WILDOPPER project, comes from the observation of the conditions on which the conventional aerial resources operate and intends to be a complement to those, which do not cover all the operational scenarios that may occur in a fire. The clearest example is the nocturnal operation, when these piloted aircrafts cannot operate. Furthermore, the use of unmanned aircrafts in firefighting enables the elimination of the risk of loss of human life. The company's idea is to use these drones particularly in indirect attack (firebreaks, lines of defence...) and in direct attacks to small fires; also, as an element of quick intervention.

Figura 26. Drone Hopper (I)



WILD HOPPER has a detection system that uses different sensor systems and fire extinguishing cameras, with the capacity to move 600 kg of useful load, which can be water or any other suitable fire combat fluid, and covers up to 1.000 m², based on water nebulization, the same that is used on fire extinguishing in office buildings and that mixes «water and air».

Figura 27. Drone Hopper (II)



According to Pablo Flores Peña, Drone Hopper's CEO, «we use our own patented technology ([WO2019145584](#)), since transporting pressured air is expensive and may cause problems during flight. To bridge this gap, the drone **uses the air jets produced by the different petrol reactors** located around its body to throw the pressured water on the right spot. Besides, this

platform offers the possibility of acting in coordination with other equal platforms, known as swarm, creating a much larger effect and can refuel and fly back to the target within minutes. The sequential use of several units means that the time between the discharges is very short, especially if the refuel centre is located nearby the fire, so that the fire may be extinguished or at least controlled within a very short period of time».

«Our main goal is to add value to unmanned aircraft technologies and to improve decision-making with its different systems, it may be an important starting point in different industrial jobs, in critical situations such as firefighting, it can reduce a large number of material and human life costs».

Figura 28. Pablo Flores Peña. Drone Hopper CEO



DH, besides providing its high-performance aircrafts, also owns some patents on the firefighting method, for example, the «water nebulization system» ([WO2017037311](#)), given that nebulized water is the key element used by DH to extinguish fires. The key parameter that determines the water nebulization extinguishing capacity is the size of the drop, since the higher the air pressure, the smaller the drop size and the greater the efficiency in extinguishing the fire. Water can be nebulised with a pressure group, but Drone Hopper uses the energy from the air jet that comes out of the engines, based on several physical principles (Venturi effect, Coandă effect, aerodynamic forces on the discharge tube, etc.).

Pablo Flores highlights that in order to improve the efficiency of firefighting current methods, Drone Hopper is working to improve the cooling by evaporation, radiation blocking and oxygen displacement. The feature of applying nebulized water and high-speed air directly on the fire source makes Drone Hopper a competitive tool in firefighting.

Company in the sector: Nitrofirex



Figura 29. Nitrofirex Project

NITROFIREX
A BRIEF GLANCE AT THE CONCEPT AND ITS POSSIBLE USES

NITROFIREX is a new approach in the world of the Aerial Vehicles, which aims to develop the capacity of spraying or spreading a large payload in a hostile, difficult or impossible to access for manned aircraft environment.

The main elements to be used by NITROFIREX are:

1. The LAUNCHER AIRCRAFT or LA
2. The AUTONOMOUS GLIDING CONTAINERS or AGCs

This is the innovative vehicle proposed by NITROFIREX able to carry the payload from the LA to the programmed release point. It then autonomously returns to base to be reused again.

POSSIBLE USES OF THE CONCEPT

- THE MAIN USE IS **NIGHTTIME AERIAL FOREST FIRE FIGHTING**
- OTHER USES INCLUDE:
 - OTHER FIRES - Toxic fumes, Big Buildings... among others
 - NUCLEAR, CHEMICAL or BIOLOGICAL EMERGENCIES
 - METEOROLOGICAL PHENOMENA
 - DRUG PLANTATION SPRAYING at NIGHT
 - PEST- SPRAYING or SEEDING (Remote and / or inaccessible areas)

THE NITROFIREX AGC
AUTONOMOUS GLIDER CONTAINER
TECHNICAL SPECIFICATIONS

NITROFIREX, is an innovative project that integrates two Defense Industry technologies: Guided Bombs and RPAS. Nitrofirex has developed a greatly unique solution offering the ability to fight forest fires from the air at night.

To overcome the limitations of the current airborne assets, which do not allow night operations, NITROFIREX introduces a novel new concept: AGC's, Unmanned Glider Containers, containing an extinguishing agent are launched from the rear ramp of a heavy transport aircraft, the LA or Launcher Aircraft.

Depending on the type, Launcher Aircraft can carry between 8 and 24 AGCs carrying 2500-2500 litres of extinguishing agent each. This depends on the LA used, which have non exclusive roles.

The AGCs direct themselves autonomously to the source of fire in order to drop their content with great precision and then return to base.

LENGTH:	5.0 m
SPAN:	4.4 m
WIDTH (WINGS FOLDED):	0.70 m
EMPTY WEIGHT:	500 Kg
WEIGHT AT LAUNCH:	3000±250 Kg
EXTINGUISHING AGENT:	2500±250 L
RETURN WEIGHT:	700 Kg

CURRENTLY UNDER DEVELOPMENT

NITROFIREX

Nitrofirex represents an innovative and worldwide unique solution that enables aerial firefighting during the night, through the combination of manned and unmanned aircrafts, integrating the latest drone technologies.

To overcome the limitations of current aircraft resources, which do not allow night operations, Nitrofirex has patented an innovative concept ([US2008202775](#)): Autonomous Gliders Deposits (AGD). These are capable of transporting large quantities of an extinguishing agent inside its integrated tanks, which are then dropped, one at a time, from a helicopter with a hanging bucket, or several in sequence, from the back ramp of heavy transport aircrafts.

These run autonomously (GNSS-Infrared-Inertial) towards the fire source to release its content with the same precision as a guided glider bomb. Immediately after the discharge, the empty AGD fly like a drone back to the operations base of the helicopter or plain, to be reused as quickly as possible.

The integration of already available and mature technologies enables the reduction of the risk during the R&D stage and assures low production and exploitation costs.



**UNE Standard 23530:2021
on long term Retardants**



New UNE standard 23530:2021 «**Long-term retardants for Wildfire application. Requirements, qualification and quality control**» was developed by the technical Committee CTN23 «Fire safety» whose secretariat is provided by the association TECNIFUEGO.²⁹ It is a pioneering document in Europe, since it's the first time that this sector was regulated, even though some countries like France are currently in the process of standardization. Due to the high number of patents and innovations in the last years in the field of firefighting products, the technical committee considered appropriate to promote the elaboration of this standard. The main goal is to establish the definitions of what a long-term fire-retardant product used in wildfires should be, as well as the conditions that should be fulfilled for its correct use, effectiveness and security, both when handling the product and in the environment, once applied.

In the new standard UNE 23530:2021 document, the different types of retardants are defined in the following way³⁰:

- **Short-term retardants:** active compounds that optimize the use of water in fire extinguishing. Its effect is limited to the water content applied to fire. Gels, class A foams and hydrating are part of this group. These products are not subject of the standard 23530:2021.
- **Long-term retardants:** active compounds which base their retardant effect on the chemical reaction of phosphates and polyphosphates in the pyrolysis and combustion process of cellulose.
- **Concentrated product:** long-term liquid or powder retardant. Defines the concentrated product as marketed.
- **Diluted product:** long-term retardant, once diluted to the prescribed dosage by the manufacturer of the concentrated product for its use.

Long-term retardants are conceived to improve the extinguishing capacity of water, enable a delay or interruption of the flaming stage through a carbonization process (Figure 30)³¹. This must be achieved without risk to people or the environment and without corrosive capacity of the application equipment. The way the long-term flame retardants are applied on vegetation influences their effectiveness. The user must assure that the retardants are used in the recommended dosage of the manufacturer and with the usual means used by firefight services. It also warns against mixing brands or formulations from different manufacturers. This standard specifies the requirements of the physical and chemical proprieties, minimum performance requirements (effectiveness) and other proprieties of long-term retardants based on phosphate and polyphosphate, suitable for application in wildfires.

The standard includes the methodologies developed for the evaluation of the characteristics of the long-term retardants: viscosity, pH, density, phosphate determination and concentration (p_2O_5), phase separation, miscibility, corrosion (of the concentrated as well as of the diluted product), effectiveness against fire, toxicity and environmental impact, colour and storage. Of all these characteristics, special attention is paid to the effectiveness of retardants

²⁹ <https://www.tecnifuego.org/>

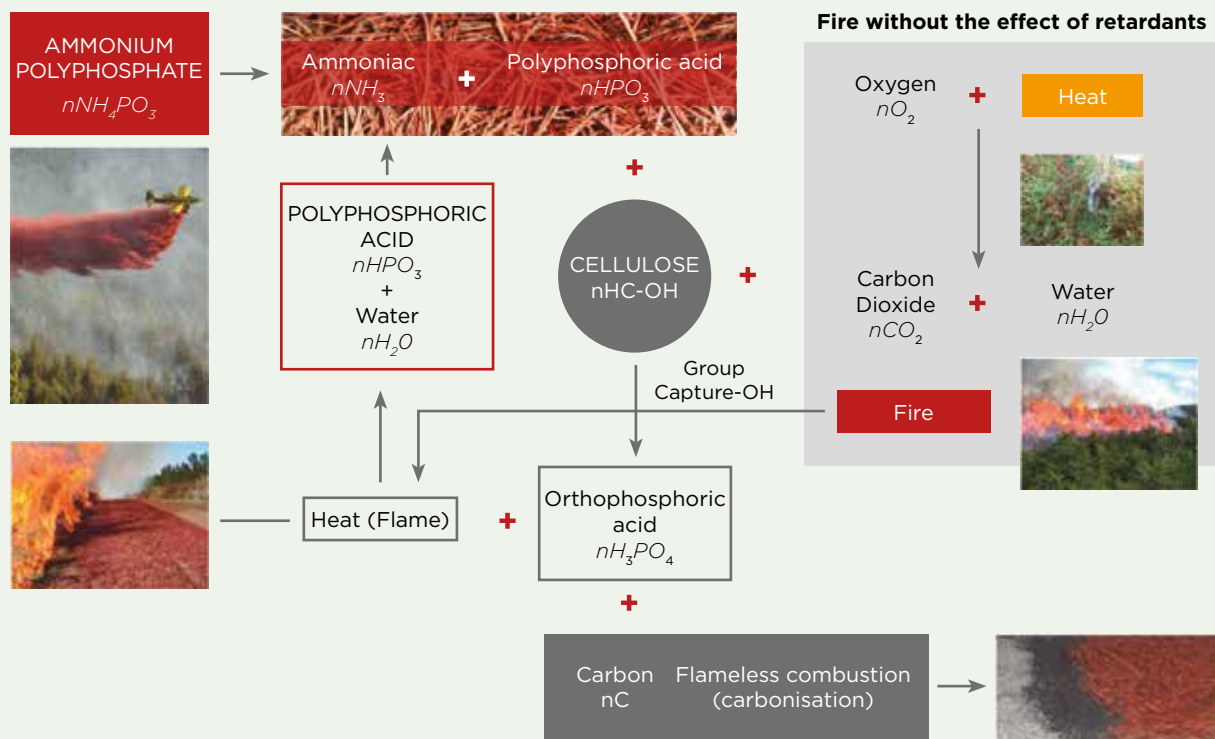
³⁰ UNE2350:2021. «Retardantes de largo plazo para incendios forestales: procedimientos para la clasificación y control de calidad de los materiales».Asociación Española de Normalización. Madrid. [available online <https://en.tienda.aenor.com/norma-une-23530-2021-n0067487>]

³¹ OSBO digital <https://osbodigital.es/2021/11/24/une-235302021-nueva-norma-de-retardantes-para-incendios-forestales/>

in fire extinguishing and to toxicity and environmental impact. Hence, any product or innovation that has to meet this standard must be adapted to the proposed methodologies for evaluation of these parameters.³²

Standard 23530:2021 is, therefore, a milestone of great importance in the regulation of retardant products used in firefighting and, in particular, in the so-called long-term retardants, which are largely used worldwide by the fire extinguishing services.

Figure 30. Diagram of operation of the long-term retardant³³. Elaborated by the author



32 Seguritecnia https://www.seguritecnia.es/actualidad/proteccion-contra-incendios-actualidad/une-235302021-nueva-norma-de-retardantes-para-incendios-forestales_20211213.html#:~:text=UNE%2023530%3A2021%2C%20nueva%20norma%20de%20retardantes%20para%20incendios%20forestales&text=La%20nueva%20Norma%20UNE%2023530%3A2021%20de%20retardantes%20de%20largo,los%20retardantes%20de%20largo%20plazo.

33 Carmen Hernando, Mercedes Guijarro y Javier Madrigal. 2009. Metodología para la determinación en laboratorio de la eficacia de los retardantes utilizados en la extinción de incendios forestales. Revista Montes N° 96 Año 2009 [disponible online <http://www.revistamontes.net/Buscador.aspx?id=13377>]

04

PROTECTION EQUIPMENT





4.1. Protection equipment technologies

This section includes personal protection equipment as well as equipment for the protection of structural elements in forests, e.g. tension towers.

thermal protection, which is achieved through a combination of fastening systems and use of fireproof fabrics; and must provide a barrier to the intrusion of fine or very fine particles, especially in the case of hoods or helmets.

PROTECTION EQUIPMENT

Personal protection

Personal protection

Personal Protection Equipment (PPE) is essential for those who work at extremely high intensity in fire extinguishing. It is necessary to constantly seek for new fabrics and lighter materials that may be ventilated in a suitable way, resistant and fireproofed for boots, helmets, gloves and overalls. The research in other PPE, such as more effective facial masks and glasses or visors that do not fog up, is also important.

The innovation in protection equipment is still mainly focused on the configuration of the protection garments, in the development of breathing systems and in the composition and manufacturing methods of fireproof fabrics. In the past years, sensor and communication systems integrated in these garments have started to be developed, with the aim of helping to locate and guide the firefight teams and monitoring their biometric constants as well as environmental data (for example, air quality).

As general features, protection equipment such as jackets, sweaters, overalls, hoods, helmets and other similar garments must be comfortable, so that the operator is not unduly prevented from executing fire extinguishing tasks. They must offer:

Protection of structural elements

Patent applications [WO2019070650](#) (LION GROUP INC [US]), with the title «Garment fastener and method for assembling a garment portion» and [EP3470117](#) (VIKING LIFE SAVING EQUIPMENT AS [DK]), with the title «Firefighter protective garment having a detachable wristlets», have the particularity of being composed of several parts that can be coupled by different adjustment systems. This type of garments is designed so that it can be put on and taken off quickly. Furthermore, as it is composed of several parts, it is easier to wash. On the other hand, the jacket described in patent [EP3701822](#) (HEINEMANN NICOLE [AT]), with the title «Protective jacket» discloses a zip that improves watertight and thermal insulation. The t-shirt described in [DE102019123124](#) (WEBER ENRICO [DE]), with the title «Protective clothing» discloses an integrated quick fastening system. And patent [WO2019023083](#) (BURNETT STEVE [US] *et al*), with the title «Protective clothing for firefighters» describes a T-shirt consisting of four items (non-separable) which improve the adaptation of the garment to the wearer's body, the comfort and thermal insulation against fire.

Other type of accessories, such as vests and backpacks, must provide easy

access to compartments, necessary for lodging fire extinguishing equipment. It is also important to provide some protection against sharp or pointed objects that may be carried. Examples of achieved innovations in this respect can be found in documents [KR20210001652U](#) (HUISOLUTECH CO.LTD. [KR]), with the title «Rescuer vest with waist belt», [KR20210001653U](#) (HUISOLUTECH CO.LTD. [KR]), with the title «Rescuer vest with leg pocket» or [KR102255795B](#) (CNS KOREA CO LTD [KR]), with the title «Military and firefighting bags».

Besides the already mentioned characteristics (comfort, easy to put on and take off, etc.), hoods, helmets and other head protections should have certain specific features: optimized visibility (in terms of vision field as well as in terms of fogging of the transparent element), hearing and respiratory conditions. Developments in this field may be observed in patent applications [WO2021047789](#) (BLUECHER GMBH [DE]), with the title «Head covering, in particular a hood or balaclava, for use as protective clothing», and [US2020069980](#) (PGI INC [US]), with the title «Firefighter hood». In turn, document [DE202020106130U](#) (BUSCH PROTECTIVE GERMANY GMBH & CO KG [DE]), with the title «Holding device for fastening a face mask to a helmet and helmet with holding device» discloses a comfortable and safe fixation system of a mask to a fire or police helmet, in such way that the mask is easily put on and taken off. Document [RU195259U](#) (SANKT-PETERBURGSKIY UNIVERSITET GPS MCHS ROSSII [RU]), with the title «Forest firefighter's protective hood» discloses a hood that does not muffle the operator's voice, improves visibility through three windows and enhances ventilation. In what concerns the problem of providing a good ventilation, simultaneously protecting the head against particles and excessive heat,

patent [EP3827683](#) (DRAEGER SAFETY AG & CO KGAA [DE]), with the title «Head protection system» offers a solution through an air channel.

Geolocation and communication equipment are essential to the parties involved in firefighting and in monitoring the variables. In what concerns the integration of monitoring or communication devices in protection equipment, the following solutions proposed in patent documents are highlighted: [EP3431146](#) (EUROTECH S P A [IT]), with the title «Garment for use in operations of fire extinguishing», which enables to send and receive signals concerning environmental conditions, even in very adverse situations and with poor visibility. [WO2021025492](#) (LEESTECH SYSTEM CO LTD [KR]), with the title «Headgear-type device for hazardous air quality warning and air quality improvement», which monitors the biometric variables of the user as well as its surroundings, sending out warning signals if necessary. Or [WO2020033733](#) (DYKES JEFFREY L [US]), with the title «Directional indicator for protective face masks», which enables to determine quickly and efficiently the direction and the direction of travel in an unknown environment or with low visibility.

The development of suitable fabrics for use in protection equipment is focused on achieving fabrics that are flexible, light, breathable and not easily disintegrated. The fabric described in patent application [WO2021009502](#) (AW HAINSWORTH AND SONS LTD [GB]), with the title «Fire resistant textile material» consists of a single net of meta-aramid, para-aramid, polyamide-imide, polybenzimidazole, polybenzoxazole and other mixtures, thus achieving a good thermal protection and great flexibility. Other materials include resins and expandable graphite, as described in



document [WO2019212549](#) (GORE & ASS [US]), with the title «Flame retardant composite articles and methods for reducing exposure to flames», concerning a fabric with great resistance to size reduction. Application [WO2019147164](#) (OBSHCHESTVO S OGRANICHENNOJ OTVETSTSTVENNOSTYU FABRIKA NETKANYH MAT WES MIR [RU]), with the title «Non-woven insulating fire-resistant material for clothing», describes bicomponent fibres, while in application [WO2019023293](#) [(INVISTA TEXTILES UK LTD [GB]), with the title «Flame resistant, breathable protective garments for fire fighters and first responders», layers of laminate and non-woven material are described.

Some respirators, besides fulfilling the general features of being light, cheap and preventing gas leaks, have specific characteristics that can help in fire extinguishing operations. Patent application [WO2019050844](#) (BOULAN CHRISTIAN [US]), with the title «Mechanisms of breathing apparatus user identification», for example, introduces a system for effectively identifying the user of the breathing equipment. A breathing unit with improved cooling is disclosed in document [JP2021079063](#) (KOKEN KK [JP]), with the title «Air respirator and fireproof garment used with air respirator».

Accidents at work lead to the need for immediate adoption of preventive measures, many of which involve the development or improvement of PPE. In this context, several patents and utility models have been developed in this field, which will be applied in short and medium term. Testing these patents and utility models to understand its efficiency is another way of technological development that shall be taken into consideration in the future evaluation of these ideas.

Protection of structural elements

There are other protection elements that do not involve garments, but that are based on the quick use of a blanket or protection coverage to cover the intervening party in case of need. Thus, patent [US2021038931](#) (HUTTON LEONARD [US]), with the title «Fire protection enclosure» consists of a stable, light, cheap and with easy implementation protection system. A similar protection methodology, but applied to housing and other building types is proposed in patent [US2020147423](#) (PAULL LEE D [US] *et al.*), with the title «Special Fire Protection System for Runaway Grass and Forest Fires and Method for Use».

Other building protection systems against the action of fire include the application of layers of retardant products, for example, as described in patent [WO2020142857](#) (COMERCIAL E IND CHILE CHEMICALS SPA [CL]), with the title «Fire-resistant composition that provides active and passive protection against fires», to several types of fixed structures or buildings and work tools. Patents [US2020316421](#) (PATZELT THORSTEN [DE]), with the title «Preventive protection against fire, in particular forest fire, including a flame-retardant substance, flame-retardant fabric and fire protection device comprising the same» and [ES1265974U](#) (SEGUI ROMA ALVAR [ES]), with the title «Fire resistant protector for forest fire extinguishing hand tools» are also emphasised.

4.2. Sector development

In the framework of this study, the sector in which less documents were published —and with a large difference compared to the others— was the one relating to protection equipment. Over the last 11 years, only 67 documents specifically related to protection equipment for firefighting and

Figure 31. Patent documents 2010-2021. Protection equipment

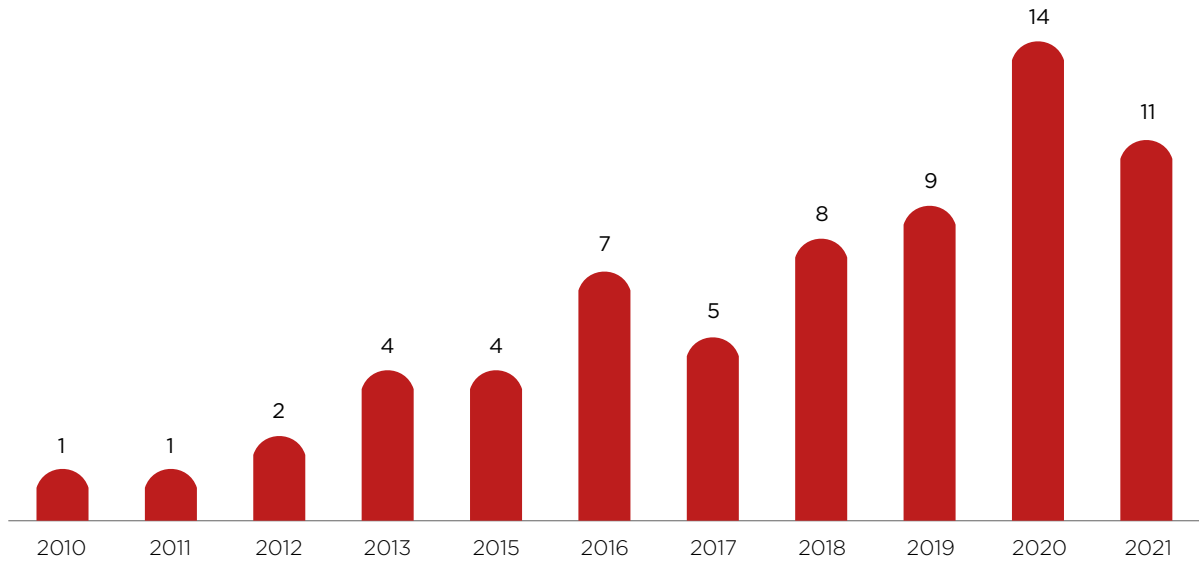
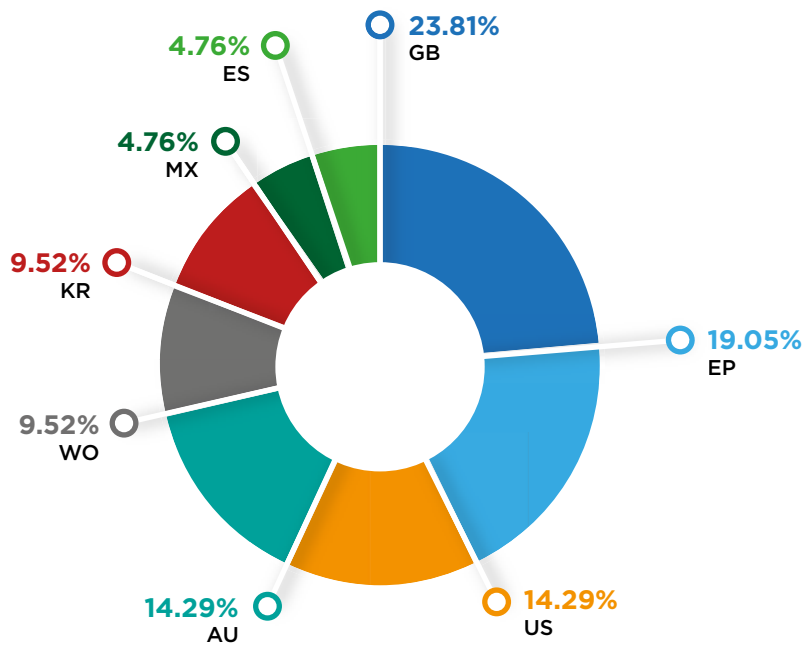


Figure 32. Publications by Institute. Protection equipment, excluding China



control of forest fires were found. However, it is noted that there is a trend for the rise on the number of publications (Figure 31).

Not considering Chinese applications, it is noted that within this sector, the

proportion of inventions from the United Kingdom is remarkable, reaching 23.81%, followed by the EPO with 19.05%. In third and fourth places are the United States of America and Australia with 14.29%, as shown in Figure 32.



4.3. Relevant technologies

This section analyses relevant inventions between 2010-2021. Together with the publication number of the document and its applicant, the country codes where the patent was filed are indicated. This analysis is performed for a larger period (2010-2021) than the corresponding to the applications discussed in section 4.1. This is because a longer period is needed to ascertain to which countries the inventions have been internationally extended.

Patent [WO2018150165](#) (ARVILLE TEXTILES LTD [GB]), (AU, EP, ES, GB) discloses a textile material resistant to fire comprising two layers, an outer woven layer and an inner woven layer, and another intermediate woven layer. The outer woven layer comprises polyparaphenylene isophthalamide (meta-aramid) fibres or a blend of meta-aramid with polyparaphenylene terephthalamide (para-aramid) fibres. The inner woven layer comprises polyparaphenylene terephthalamide (para-aramid) fibres and

the intermediate woven layer comprises a blend of wool fibres and cellulose fibres. The fireproof garment that embodies this material is lighter, more comfortable and breathable. Furthermore, this textile material effectively draws moisture away from the skin to reduce the risk of burns.

Patent [KR20180013354](#) (IUCF SUNMOON UNIV [KR]), shows an intelligent device (wearable) suitable for being used during firefighting, that embodies a sensor to detect close obstacles and a visualisation unit capable of exhibiting information about a safe escape route based on the user's current position.

Document [WO2017212225](#) (STS DEFENCE LTD [GB]), (CN, EP, GB, US) describes a method for predicting a flashover event caused by a fire, that involves temperature data processing, collected by a sensor, and sending of a warning sign. Temperature data collected by the sensor is processed by a machine learning model in order to determine the risk of occurring a temperature rise event in the environment in a future window of time.

Figure 33. Figure from application WO2018150165

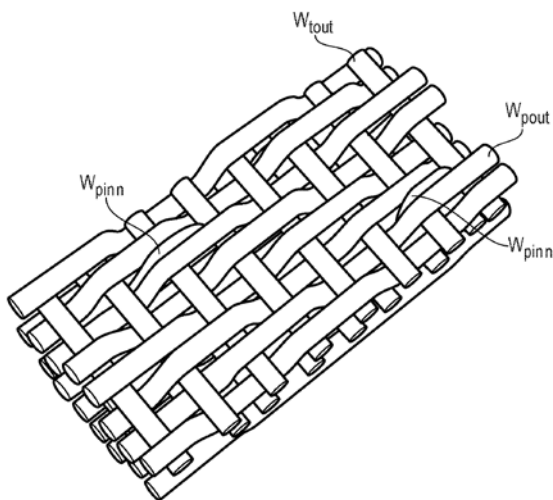
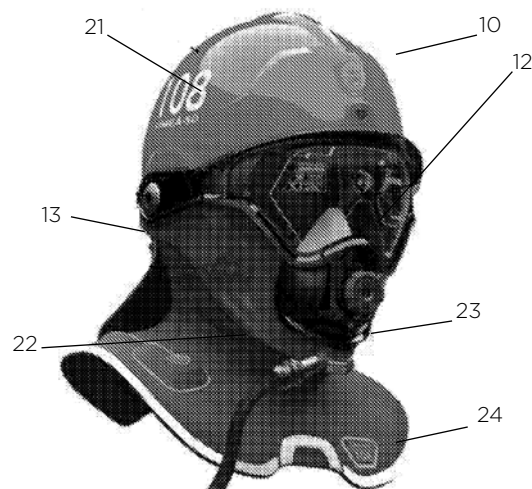


Figure 34. Figure from application KR20180013354



Patent [WO2021260539](#) (SEYNTEX NV [BE]), (WO, BE) describes a piece of protection garment suitable to be used in firefighting. The piece of garment has a zip system with a fixating element, and comprises a base element with a central zip,

and a multilayer garment piece, insulated and waterproof. The two parts of the garment piece can be cleaned separately. Furthermore, perspiration is easily removed, as it is absorbed and pushed to the outside by them.

Figure 35. Figure from application WO2017212225

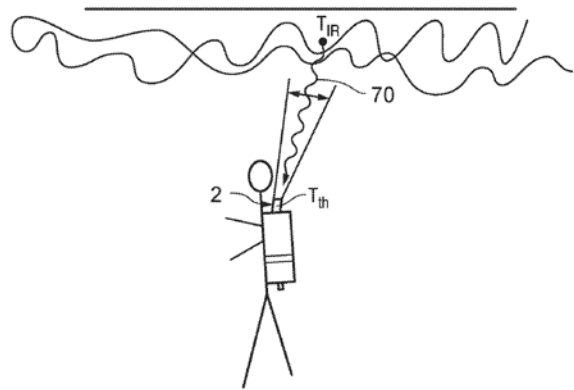
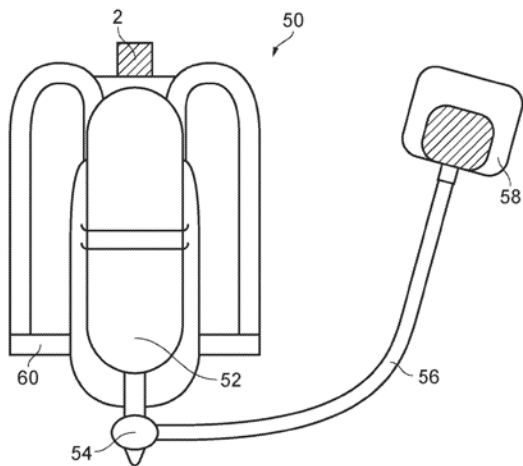
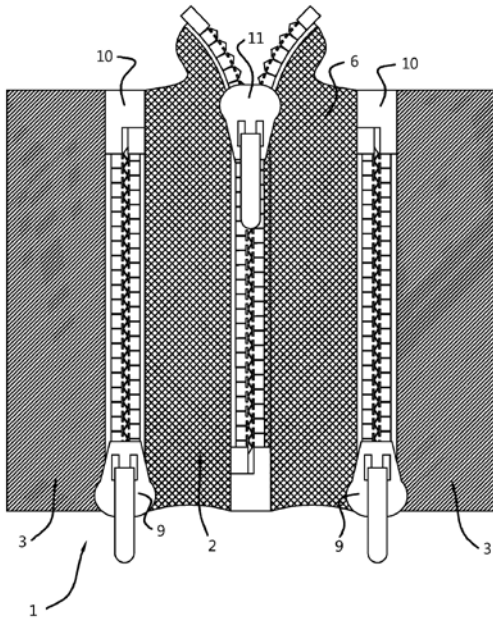


Figure 36. Figure from application WO2021260539





Company in the sector: Vallfirest

vft vallfirest
the wildfire company

Vallfirest stands for innovation and greater efficiency in forest firefight, offering innovative solutions adapted to new needs.³⁴

Over the last 20 years, forest fires have evolved in terms of intensity, speed and magnitude, creating more and more problems and difficulties in current fire extinguishing systems. These major fires require new strategies, new tactics and new tools and equipment.

The aim of this company is to improve the world of forest fires, by providing professionals with tools, equipment and services, based on technological innovation and on the analysis of the lessons learned to manage and fight 21th century fires efficiently and safely.

Figure 37. Image of Vallfirest (I)



The company, a Spanish and international reference in the efficient management of forest fires, was established in 2007, after years of study of the fires that had occurred in Spain and the United States of America.

Vallfirest has a big team and, in particular, a team of R&D projects, to conceive and improve the resources and equipment that are commercialized, paying special attention to client's demands.

Figure 38. Image of Vallfirest (II)



34 www.vallfirest.com

Gorqui (multiuse tool) is the first Vallfirest's patented and developed product and is currently an equipment used all over the world ([USD 774854S](#), VALLFIREST [ES]).

Figure 39. Gorqui from Vallfirest



The company has been focusing on innovation, efficiency, technology and quality. From 2008 until today, 15% of the company's revenue has been reinvested in R&D&I. It is currently present in more than 60 countries and the tools and solutions that it provides are being used in forest fires in great part of the world.

New equipment has been developed for aerial means (Leo System creates a continuous jet of firefighting foam), remote control brushcutters (Dronster) or water portable spots (Heliskid), that help in current fire extinguishing.

05

POST-FIRE RESTORATION





5.1. Post-fire restoration technology

Wildfires have an important influence in the advance of the desertification throughout the east and southeast of the Iberian Peninsula, as well as in some areas of the Canary Islands. They represent an important element of soil loss, since the passage of fire is usually accompanied by torrential rain in Autumn and summery stress prevents the regeneration of vegetation. Erosion is also present in the most humid areas of the west of the Iberian Peninsula (centre and north of Portugal, Galicia and Spanish Cantabrian Arc) as a result of the short-term disappearance of mulch, after the fire, and from the emergence of abundant rainfalls in Autumn that last all year round, leading to severe erosion and soil loss, partially offset by the rapid recovery of vegetation.

In these cases, the risk of desertification is low, but the degradation of the system on the medium and long term is not, especially if the frequency and severity of fires increases, as the forecasts tell us about the interaction between fires and climate change in Europe.³⁵ Since the geomorphic modifications generated by hydraulic works (cross-cutting for purposes of reducing runoff) in the drainage network, to the alteration of the vegetation dynamics or edaphogenesis processes, many criticisms have been made to traditional protocols of action based on forest engineering, which have led, in recent years, to the proposal of new alternatives. These resort to less striking methods, such as the use of biodegradable materials that act as transversal barriers to soil loss or even to the possible application of tecnosoils, that is, the addition of technological products of biologic nature that accelerate the recovery process of soil recovery. These technologies are commonly used in other fields

such as agriculture, mining or public works, and the possibility of using them in forest areas affected by fires is still being explored.

In the context of current global change (rural abandonment and climate change), it is predictable that the number of fires as well as the area burnt in Portugal and Spain will tend to rise. Urgent action for soil stabilization after fires and hydrological-forestry restoration are one of the instruments for achieving the goals of UE strategy on soil conservation and biodiversity. Several protocols have been established for the restoration of burnt areas.³⁶ Techniques such as mulching (leftovers of plants and other materials that pile up over the soil and don't create a compacted layer) have shown to be highly effective in reduction of soil loss after fire.³⁷ However, research groups are exploring the use of selected microorganisms that can be used to improve the negative effects of more severe fires, thus contributing to the improvement of soil proprieties and boosting the growth of vegetation, although specific commercial products are not yet available.

Hence, the research on the efficiency and effectiveness of forestry-hydrology restoration measures is necessary, in order to establish the most suitable tools to correct the disturbances and changes created by wildfires on forest ecosystems. This will improve the resilience and reduce the vulnerability of forest ecosystems affected by fires. In many cases, the management of the wooded burnt must be compatible with post-fire restoration activities, and it is necessary to increase information on this issue and the necessity of technologies and patents that may support the forest engineering measures adopted in each case.

³⁵ Dupuy JL, Fargeon H, Martin-StPaul N, Pimont F, Ruffault J, Guijarro M, Hernando C, Madrigal J, Fernandes P. 2020. Climate change impact on future wildfire danger and activity in southern Europe: a review. *Annals of Forest Science* 77: 35.

³⁶ Alloza JA, García S, Gimeno T, Baeza J, Vallejo VR, Rojo L, Martínez A. 2014. Guía técnica para la gestión de monte quemados con riesgo de desertificación. Ministerio de Agricultura, Alimentación y Medio Ambiente. Madrid

³⁷ Fernández C, Vega JA. 2016. Effects of mulching and post-fire salvage logging on soil erosion and vegetative regrowth in NW Spain *For Ecol Manage* 375: 46-64

Microorganism products from forest areas, obtained through molecular techniques, can be used to improve the soil properties and accelerate the restoration of vegetation. These products could be added in combination, or not, with rehabilitation treatments, and are a future line of great interest that could be explored by businesses and investigation centres in search of patents and specific commercial products for forest fires. On the other hand, it seems to be necessary to explore in the field the use of new materials to support hydro technologies with low environmental impact and high efficiency in post-fire stabilisation tasks.³⁸ The use of new methods and tools to improve the effectiveness of seeding and planting—in case natural regeneration is not achieved—is another line of interest. Innovations are being made in work tools, such as the hollow bucket that is normally fitted to backhoe loaders or a brushcutter head developed by the Asturian company Valledor, which can perform specific cleaning and prepare the soil at the same time.³⁹

Although the post-fire restoration sector is wide, covering subjects that range from soil stabilization and recovery to the evaluation of vegetation damage and forest recovery measures, including the different techniques

used in seeding and planting, there are not many patent document publications related to this subject.

Therefore, it is a technologic field that presents many opportunities for innovation. For example, patent [RU2745117](#) (FEDERALNOE GOSUDARSTVENNOE BYUDZHETNOE OBRAZOVATELNOE UCHREZHENIE VYSSHEGO OBRAZOVANIYA IRKUTSKIY G [RU]), with the title «Method of reforestation of mountainous and hilly relief of the earth's surface with bedrocks», simply describes a reforestation method by stages. More innovative is utility model [ES1224321U](#) (INSTITUTO NAC DE INVESTIGACION Y TECNOLOGIA AGRARIA Y ALIMENTARIA INIA [ES] *et al.*), with the title «Electronic device for the determination of the survival of live tissues under the bark of the trees», which comprises two electrodes that are inserted in the tree trunk and measure the displacement and the electrical resistance as they penetrate it. According to the obtained readings, the presence of live or dead tissues is determined depending on the existence of variations in the recorded electrical resistance, improving the evaluations of tree mortality after fires and, simultaneously, the effectiveness and ecologic compatibility of the recovery treatments proposed.

38 Lucas-Borja ME, Plaza-Álvarez PA, González-Romero J, Miralles I, Sagra J, Molina-Peña E, Moya D, de las Heras J., Fernández C. 2020. Post-wildfire straw mulching and salvage logging affects initial pine seedling density and growth in two Mediterranean contrasting climatic areas in Spain. *For Ecol Manage* 474: 11863.

39 Pemán, Navarro, Prada y Serrada, 2022. Bases técnicas y ecológicas del proyecto de repoblación forestal. Tomo 1. Publicación del Ministerio para la Transición Ecológica y Reto Demográfico.

06

TECHNOLOGY AGAINST FIRES IN THE IBERIAN PENINSULA



In the Iberian Peninsula, between 2010-2021, a total of 47 patent documents were published, which can be grouped in 28 families of inventions related to firefight and control of forest fires.

The protection on several of these inventions was extended outside Portugal and Spain, mainly through the request of PCT international applications and European patent applications. The publishing number, the applicants or holders and a brief description of these patent application can be found in Table 3.

Table 3. Examples of Patent Applications in the Iberian Peninsula 2010-2021

Document	Applicant	Description
<u>ES2414304</u>	MEDI XXI GSA SL [ES]	System of self-protection against forest fires which comprises a protection area around the urban core in which a hydraulic system is assembled.
<u>PT109921</u>	JOÃO FILIPE BRANDÃO AZEREDO LOUREIRO [PT]	Device consisting of a support engine that pumps water through a hose connected to a remote-control platform.
<u>ES2397586</u>	GARCIA GARCIA, FCO JAVIER [ES]	Automatic system for detection of forest fires based on the detection of electromagnetic radiation dispersed by smoke.
<u>WO2019150272</u>	UNIVERSIDAD DE COIMBRA [PT] <i>et al.</i>	Anti-fire barrier and associated housing for control of forest fires which is only activated when necessary.
<u>ES2644966</u>	NUEVAS TECNOLOGIAS FORESTALES SL [ES]	System and method for detecting and predicting the evolution of forest fires, comprising a series of detection nodes, climatic nodes and a database.
<u>WO2021130531</u>	INSTITUTO DE SIST E ROBOTICA [PT] <i>et al.</i>	Device for forest fire detection, which is based on the flame condition data obtained from a sensor.
<u>ES2569533</u>	FERNANDEZ GARCIA, MANUEL [ES] <i>et al.</i>	Fireproof collective shelter for self-protection of people and goods in case of fire, consisting of elements of anchoring and gas detection.

**Table 3.** Examples of Patent Applications in the Iberian Peninsula 2010-2021 (cont.)

Document	Applicant	Description
<u>ES2662982</u>	SAINZ ARAPILEZ, Jesús Pedro [ES]	Aircrafts for forest firefight capable of unfold vertically, hovering and quickly carry large quantities of water.
<u>PT115025</u>	VICTOR CARLOS MOREIRA VIEGAS [PT]	Aerial vehicle for direct attack on forest fires with a liquid tank and a hose to release the liquid under high-pressure.
<u>WO2020030830</u>	SUCCESS WORLD, SL [ES]	Fireproof composition applicable to products to be protected from fire, consisting of an aqueous solution containing sugar and magnesium chloride.

As it can be seen, most patent applications were filed by private individuals. Only a few of those have a company or public body as the holder.

One should highlight Patent ES2414304, from the Spanish company MediXXI GSA

(Table 3), whose implementation was performed in the Guardian project. The original idea, which gave way to protection, was recognized by the UN with the «best practice» certificate in terms of sustainability.

07

CONCLUSIONS





Public administrations have in recent years furnished themselves with monitoring, communication, fire extinguishing and detection technologies and protection equipment for wildfires that are not always protected by a patent. Therefore, the field of forest fire fighting is very dynamic and offers business opportunities for its final users, but not necessarily through a patent. In fact, many initiatives of public funding through the several European funding programs (Horizon 2020, LIFE Program, INTERREG Programs) fund ideas and best practices in the field of forest fires which not always have in its goals the filing of patent applications or the use of innovations subject to industrial propriety protection.

Nonetheless, **the number of patent applications concerning forest fires has progressively increased in the last decade worldwide:** in 2021, 357.66% more patent documents were published than in 2011.

In particular, in **the last 5 years, the number of applications increased in an accelerated pace, with Spain as the European Union country with the highest number of filed patent applications** in the field of forest fires.

Overall, in the field of forest fires, China is the country with the highest number of patent applications, followed by South Korea. Nonetheless, **Russia, Australia and Spain, despite their lower number of applications, stand out ahead of other important countries and regions,** such as Japan, or the European Patent Office (EPO).

More specifically, **Russia, Australia, Spain and the United States of America, countries which have suffered the severe consequences of forest fires, jointly originate over 43% of the patent applications** in this field, if publications from China are not considered. This may point towards a relation between countries with most patent applications and those registering a higher number of forest fires, **which**

reflects that patents are good indicators of technologic development created by social needs and, in that case, connected to a certain geographic and climatic region.

The Portuguese 2017 fires had an unprecedented severity, never recorded in Western Europe or in the Mediterranean. In response to this unique situation, the Integrated Management System of Rural Fires (SGIFR) was developed. Among other actions and activities, awareness **campaigns such as «Portugal Chama» aim against alert to risk behaviour and raise public** awareness in order to help and protect the country from severe rural fires.

Although in Portugal there is no predominance of patent applications in the field under analysis, it is important to highlight all these actions that have been developed in the fight against forest fires, in which prevention assumes a key role. A strong commitment to public funding for various scientific and technological research initiatives has also been present. Currently, Portugal counts with research groups in the field of rural and forest fires and its multiple strands, holding important knowledge and skills for its prevention, namely regarding forest management and action plans thereof.

Among the four technological fields analysed in this study, **fire extinguishing is the one where most patent applications** were filed, ahead of detection, prevention and protection equipment sectors. Post-fire restoration is the sector where less patents were filed, and therefore it holds many opportunities for innovation.

However, and despite the initiatives previously mentioned, the statistics show that, in Portugal, there is still a large scope for evolution and a need for investment in the valorisation of technologies associated with prevention, control and fight against forest fires, through patent protection.

The increase of the fire problem worldwide, the strong investments made by public administrations over the last years, particularly in terms of firefighting, and the advance of new Information and Communication Technologies (ICT), the management of great volumes of information (LargeData, BigData) and the easier access to different sensors with potential uses in the field of forest fires, may be some of the reasons for the increase in the number of patent applications. There is also a trend over time towards **the use of artificial intelligence and drones** in firefighting and control of forest fires.

On the other hand, **the majority of patent applications filed on forest fires are not**

extended internationally and only a small percentage files for protection in other countries. This may indicate that there is a lack of companies with a strong international presence behind the inventions and that, in many cases, these could remain unlicensed.

Collaboration between Portugal and Spain in firefighting and prevention of forest fires is essential to solve this problem. The Common Strategy for Cross-border Development, which includes different measures for a joint approach of the situations that affect both countries, favoured the development of different collaborative projects in this field, such as the *Iberian Center for the Investigation and Fighting of Forest Fires* (CILIFO).

**ANNEX I. Glossary.
Country codes**



Table 4. Glossary

Classification	Category in which several inventions are indexed.
Patent Applications	Document that describes the scope of an invention for which protection is sought.
Patent Family	Patent group which refers to the same invention, but that were filed in different patent offices.
Number of families	Number of patents included in the same family.
Priority	First patent application filed in each family.
PCT Application	Patent application filed under the Patent Cooperation Treaty (PCT) which allows the protection of an invention in a large number of countries simultaneously (155 countries on February 2022), by filing an «international» patent application.
EPO	European Patent Office (EPO) is the entity responsible for the application of the European Patent Convention.
GPI	The Global Patent Index (GPI) is a tool from the European Patent Office (EPO) which allows patent searches in the worldwide EPO database.

Table 5. Country codes

AT	Austria	GB	Great Britain
AU	Australia	GR	Greece
BE	Belgium	IL	Israel
BR	Brazil	IT	Italy
CA	Canada	JP	Japan
CH	Switzerland	KR	Republic of Korea
CL	Chile	MA	Morocco
CN	People's Republic of China	NL	Netherlands
DE	Germany	PT	Portugal
DK	Denmark	RU	Russian Federation
EA	Eurasian Patent Organization	SA	Saudi Arabia
EE	Estonia	SE	Sweden
EP	European Patent Office (EPO)	TR	Turkey
ES	Spain	TW	Taiwan
FI	Finland	US	United States
FR	France	WO	World Intellectual Property Organization (OMPI)

ANNEX II. Search Strategy



In firefighting and forest fire control, unlike other sectors, there is no specific patent classification that embraces every technology.

Fires, in general, are classified in A62C IPC (International Patent Classification) which refers to «Firefighting». Inside this class, forest fires are only mentioned specifically in subgroup A62C3/02 «Prevention, limitation or fire extinguishing [...] for fire areas, for example, forest fires, underground fires». However, the reality is that not all patent documents, whose main subject is forest fires, are classified in this subgroup.

Therefore, it became necessary, to broaden the classification to other less specific groups/ subgroups and limit them through keywords related to forest fires. For example, the search was limited by the use of forest_fire, bush_fire or combinations of fire synonyms (fire, flame, smoke...) and forest (forest, mountain, hill...). The results obtained were verified manually, and the new detected classifications or keywords were used to power the search.

Table 6, without being too exhaustive, shows some of the classifications that have been used in combination with keywords to search specialized worldwide databases.

Table 6. Classifications for forest fires

IPC Symbol	Description
A62C 3/02	Fire prevention, containment or extinguishing for forest fires and subterranean fires.
A41D 13/00	Professional, industrial or sporting protective garments.
A62B 17/00	Protective clothing affording protection against heat or harmful chemical agents or for use at high altitudes.
A62C 27/00	Fire-fighting land vehicles.
A62C 31/00	Delivery of fire-extinguishing material.
A62D 1/00	Fire-extinguishing compositions; Use of chemical substances in extinguishing fires.
B64C 1/00	Fuselages; Constructional features common to fuselages, wings, stabilising surfaces, or the like.
B64C 39/00	Aircraft not otherwise provided for.
C09K 21/00	Fireproofing materials.
G01W 1/02	Instruments for indicating weather conditions by measuring two or more variables.
G01W 1/10	Devices for predicting weather conditions.
G08B 17/00	Fire alarms; Alarms responsive to explosion.

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