SenForFire NEWS

FIRE FIGHTING TECHNOLOGY

Journal of the SenForFire project for the development of sensor networks for the prevention and early detection of forest fires.

This quarterly publication addresses environmental education in the face of fires, with news from the SenForFire project and stories about the science of fire. More than a journal, it is an invitation to care for the Earth.

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06

IN THIS ISSUE

THE THREE VOICES

This report brings together three researchers who, from different perspectives, are redefining how the risk of wildfires is measured and predicted.

Marcelino Núñez is a meteorologist specialising in wildfires at AEMET, the public agency responsible for weather forecasting in Spain, and has led the development of the IPIF.

Javier Madrigal is a senior scientist at the CSIC's Institute of Forest Sciences, a researcher with SenForFire — the sensor network project featured in this magazine — and coordinator of the CSIC group that provides advice on major wildfires.

Elia Quirós is a lecturer at the University of Extremadura and coordinates the UEx's participation in RAT_EOS_PC, a project that uses satellites and artificial intelligence to predict fires, floods and other risks arising from climate change.

Three scales — the regional scale of the meteorological index, the territorial scale of the satellite and the local scale of the sensor — which, as will be seen in the following pages, are increasingly interacting with one another.

KEY TERMS

IPIF: Forest Fire Hazard Index, a new system from AEMET (State Meteorological Agency).

FWI: Fire Weather Index, the classic meteorological index it replaces. NDVI: Normalised Difference Vegetation Index; measures, via satellite, whether vegetation is green (moist) or dry.

IPIF: A NEW WEATHER FORECAST ON FIRE RISK

In May 2026, the State Meteorological Agency (AEMET) launched the IPIF, the new Forest Fire Danger Index. Its purpose is the same as that of a clinical thermometer: to provide a simple figure that summarises, daily and for every point on the map, how easily a fire can start and spread. The IPIF replaces the FWI (Fire Weather Index), the traditional meteorological system that for decades has served as a 'traffic light' for fire risk in Spain and much of the world.

"The FWI system was by no means inaccurate; it was, and remains, a very good system," explains Marcelino Núñez, a meteorologist at AEMET and the person in charge of the new index. Its limitation lay not in its accuracy, but in its scope: the FWI only considers atmospheric conditions — temperature, wind, air humidity — but ignores the condition of the forest itself. The IPIF builds on this same meteorological basis and adds three new factors: forest land use (the type of terrain in each area), the condition of the vegetation (whether it is more or less dry) and soil moisture. Javier Madrigal, a CSIC researcher affiliated with SenForFire, agrees with this assessment: incorporating such variables was 'a long-standing demand from the sector'.

The result, according to AEMET data, is an index that detects virtually the same percentage of area burnt in major fires as the FWI, but which reduces false alarms: the proportion of days on which a danger warning is issued without a major fire actually occurring falls from 27 per cent to 18 per cent. "When the IPIF indicates high danger levels, there will be greater certainty that this danger is real," summarises Núñez. Added to this improvement is a leap in resolution — the level of detail on the map — from one calculation point every five kilometres to one every kilometre, which makes it possible to refine the risk assessment in valleys, islands and areas with complex terrain where the data was previously diluted.

The most innovative feature is soil moisture. AEMET uses this as a substitute for a variable that no meteorological service in the world currently measures on an operational basis: the moisture content of living fuel, that is, how much water the vegetation actually contains at the moment it could catch fire. The more water available in the soil, the wetter the vegetation is and the harder it is for it to burn. This moisture content is calculated daily based on rainfall and evapotranspiration. Added to this is the NDVI (Normalised Difference Vegetation Index), a satellite-based measure that compares how vegetation reflects infrared and red light to determine, without setting foot on the ground, whether a plant is greener — and more fire-resistant — or drier.

With these variables, the IPIF no longer provides five hazard levels, but six, calculated individually for each square kilometre based on the 40th, 65th, 85th, 90th and 98th percentiles of the historical data series covering more than ten years for that same area. A more refined system, designed to analyse the forest almost point by point.

PREDICTING FIRE WHEN THE PAST NO LONGER SERVES AS A GUIDE

Any model that predicts the future needs to learn from the past. The IPIF was calibrated — that is, adjusted and fine-tuned — using data on fires that occurred between 2015 and 2024. The problem is that 2025 and 2026 are breaking records for temperature and drought: the climate is moving beyond the range experienced in the recent past. How can an index trained on historical data remain valid when that history begins to fall short? This is the question that the three researchers share, without having discussed it beforehand.

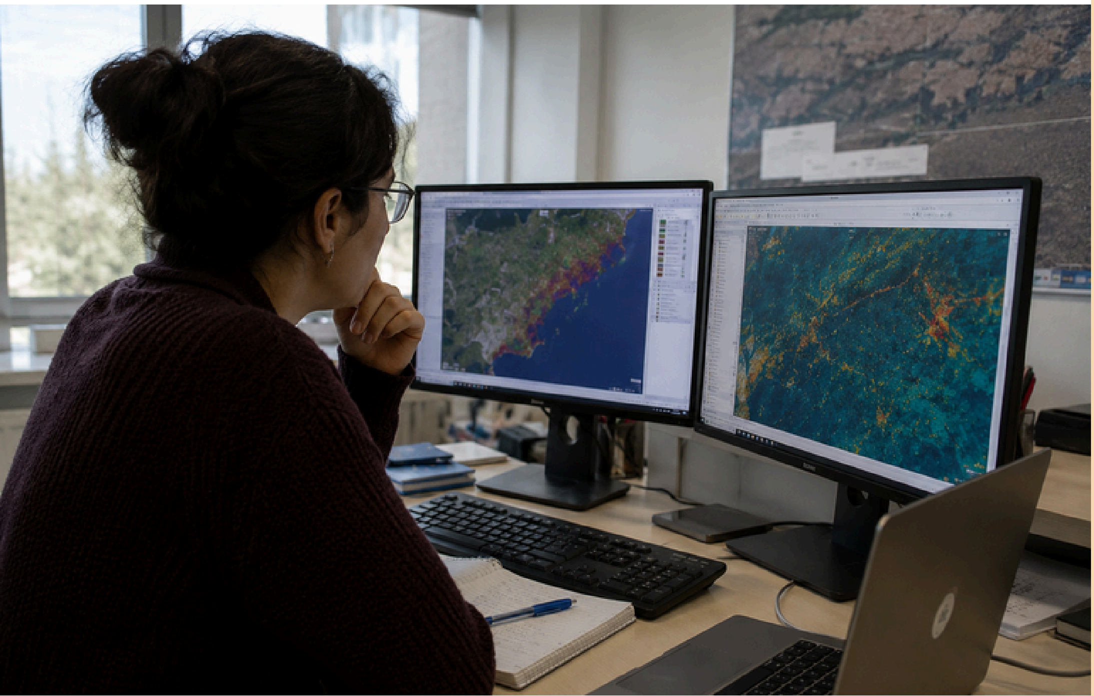
Núñez acknowledges that it is "an interesting question that is very difficult to answer". For the time being, at AEMET the calibration is reviewed every one or two years, a process which – as he explains – is neither automatic nor straightforward, and which serves to adapt the definition of 'very high' and 'extreme' danger to increasingly extreme conditions. Núñez himself also points to an underlying paradox: if, in five or ten years' time, a situation that today triggers the 'very high' hazard level becomes commonplace, should it still be classified as equally serious?

Javier Madrigal praises a specific feature of the IPIF — "I think it's a good move" —: the corrective function for the 2015–2024 period, which prevents the index from becoming oversaturated. Without it, he explains, Spain would appear "all red" on many days of the year, unable to distinguish between an exceptional day and a typical one — a common problem in indices that do not factor in the effects of recent climate change. As a complementary approach, he proposes generating 'what if' scenarios: simulating extreme situations that have never occurred to test how the index reacts to the unprecedented. If the system detects the anomaly, he points out, it will be time to consider changing the reference time series or turning to even more advanced meteorological tools.

Madrigal also adds an important caveat: the IPIF is, strictly speaking, a hazard index — based on meteorological conditions and vegetation — not a risk index, which would also need to consider the vulnerability of the area. With studies projecting a 30 per cent increase in large wildfires in Europe, he suggests that these climate projections could be integrated in the future to identify high-risk areas, although he acknowledges a fundamental difficulty: as these are regional projections, covering large geographical areas, it will always be challenging to translate them into operational, local-level data.

Elia Quirós, from RAT_EOS_PC, tackles the same problem using a different approach: artificial intelligence algorithms — XGBoost, Random Forest, neural networks — trained on a database of past fires that combines vegetation, meteorological data, topography and human activity. 'We do not validate the variables in isolation; what we validate is the behaviour of the model as a whole,' she explains. Faced with 'cloud cover'—the major limitation of satellites—his team does not discard any data: it analyses trends over the last 7, 14 and 30 days, so that a single cloudy day is offset by the rest of the period.

Different aspects of the same response: carefully reviewing the calibration, adjusting the index to prevent it from becoming saturated, envisaging scenarios that do not yet exist, distinguishing between meteorological hazards and the actual risk in each region, and training models capable of learning from trends rather than just from data for a single day.



RAT_EOS_PC: THE FOREST AS SEEN FROM SPACE

RAT_EOS_PC is a European project led by the Regional Government of Extremadura as the main beneficiary. It develops Earth observation–based early warning systems that use satellite imagery —images captured from space—to monitor wildfires, floods, and severe weather events.

Its added value compared to other indices is twofold. On the one hand, it is geographical: a uniform model covering the entire area of cooperation between Spain and Portugal. On the other hand, it incorporates variables not yet included in the IPIF: the slope, aspect and altitude of the terrain, and human factors such as proximity to roads, power lines, landfill sites or quarries.

Unlike the IPIF, which calculates its own estimate of soil moisture based on rainfall and evapotranspiration, RAT_EOS_PC uses soil moisture data directly from ERA5, the climate database of the European Centre for Medium-Range Weather Forecasts (ECMWF).

The project also links fires and floods: when fire destroys vegetation cover, runoff and sediment transport increase, which can silt up river channels and exacerbate future flash floods.

RAT_EOS_PC is due to conclude in 2026, but its work will continue through two new projects: BUR_PC, focusing on river basins in Extremadura and Portugal, and an initiative under the European HORIZON programme dedicated to civil protection.

MORE INFORMATION
https://rateospc.com

KEY TERMS

RAT_EOS_PC: Spanish-Portuguese satellite-based early warning project (EOS: Earth Observation System).

AI / machine learning: Programmes that learn to detect patterns by analysing thousands of past cases, rather than following fixed rules.

Runoff: Rainwater that flows over the surface of the ground without seeping in.

FROM THE INDEX TO THE SENSOR: THE ALERT THAT REACHES EVEN THE MOST REMOTE VILLAGE

A fire danger index, however accurate it may be, is still just a snapshot of the region: it gives an idea of the risk within a square kilometre, but it does not know what is happening at a specific point in the forest. The missing piece is on-the-ground sensors. Javier Madrigal has been working at this level for years through SenForFire, an Interreg Sudoe project that deploys networks of low-cost sensors capable of measuring, in real time, air and soil temperature and humidity, gases, volatile organic compounds (VOCs – substances emitted by plants that can signal a fire in its earliest stages) and airborne particles, such as smoke.

This information, explains Madrigal, could feed directly into the IPIF: soil moisture networks would improve predictions of the moisture content of living fuel, and the miniature sensor stations would refine the spatial resolution of the index — currently one square kilometre — in areas requiring special protection. Gas and particle sensors, meanwhile, detect smoke in the early stages of a fire and help assess air quality to advise on evacuations.

Madrigal also advocates a change in approach: measures targeting vegetation mitigate impacts and build resilience against mega-fires, but they do not reduce the area burnt or prevent new sources of ignition. He therefore proposes 'learning to live with more manageable fires' rather than aiming to prevent them all, which also involves 'good fire': prescribed, controlled and planned burns carried out by experts during periods of lower risk.

This approach only works if it is rolled out across all areas: small local authorities, with limited technical and financial resources, are the ones that suffer most from major fires and find it hardest to adopt these technologies. Madrigal calls for provincial councils to play a more coordinating role and points out that the law requires evacuation drills, which are rarely carried out today, with gas sensors serving as an additional aid.

Elia Quirós adds a complementary component from RAT_EOS_PC: a web viewer designed to enable any municipality or citizen, regardless of technical expertise, to check the risk level in their area. "The idea is to provide a simple and intuitive interface," she explains, with different user profiles for the general public and for organizations such as Civil Protection.

When asked about the common ground between her project and SenForFire, Elia Quirós sums it up as follows: "Satellites offer continuous monitoring and extensive territorial coverage, whilst sensors provide very specific, real-time measurements of local conditions." Núñez from AEMET agrees: he considers sensors for volatile organic compounds to be 'highly viable and extremely useful' for early warning – a different field from prevention, where the IPIF operates, but one that is complementary.

In technical terms, the three systems operate on complementary scales: the IPIF calculates the daily weather hazard with a resolution of 1 km²; RAT_EOS_PC adds continuous satellite observation, incorporating topographical and anthropogenic variables, at a regional scale; and

SenForFire provides direct field measurements — temperature, humidity, gases — at a local scale and in real time. Núñez, Quirós and Madrigal all agree on the same outstanding development: integrating these three data sources into a single data stream, so that satellite observations calibrate the field sensors and these, in turn, validate and refine the meteorological index.

The Interreg Sudoe programme logo, under the slogan 'Cooperation is in your hands', highlights news items directly related to the SenForFire project

THREE PROJECTS, ONE SAME ALERT CHAIN

IIPIF (AEMET): Regional weather hazard information, updated daily, with a resolution of 1 km².

RAT_EOS_PC (UEx / Regional Government of Extremadura): Satellite observation and artificial intelligence models for early warning within the Spain–Portugal cooperation area.

SenForFire (Interreg Sudoe): Low-cost ground-based sensors for real-time detection at a local scale.

Three layers — regional prevention, territorial monitoring and local detection — which, according to the three researchers, will cease to operate separately as the projects mature.

The shared challenge is no longer merely technological: it is to ensure that this warning chain also reaches municipalities with fewer resources.

KEY TERMS

VOCs: Volatile Organic Compounds, substances emitted by plants that can be detected before smoke or flames are visible.

Prescribed burning: A controlled fire, deliberately and systematically set by experts to reduce dry vegetation.

Spatial resolution: The level of geographical detail in a map or index; the higher the resolution, the smaller the area that can be distinguished.

Photo credits

- *Prescribed burn conducted as part of the SenForFire project.*
- *Researcher analyzing satellite imagery. Image generated with ChatGPT (OpenAI).*
- *SenForFire project sensors deployed during a prescribed burn.*

MORE INFORMATION

The report on the preceding pages summarises the discussions held with Marcelino Núñez (AEMET), Javier Madrigal (CSIC / SenForFire) and Elia Quirós (UEx / RAT_EOS_PC). Given their technical interest, we reproduce the three interviews below in their original form.

«THE IPIF NO LONGER SIMPLY DESCRIBES THE DANGER, BUT HOW REAL IT IS»

Marcelino Núñez has been monitoring the skies for years to predict wildfires. As a meteorologist specialising in wildfires at AEMET, he has led the development of the IPIF, the index that the agency launched in May 2026 and which features on the front page of this report. In this interview, he explains in more detail how an index capable of analysing the forest almost point by point is constructed.

Why did the old FWI system generate so many false alarms? What information was it lacking?

The FWI wasn't inaccurate: it's a very good system that has been thoroughly tested worldwide, and the IPIF is also based on it. But it only looks at meteorological variables – temperature, wind, air humidity – without considering the condition of the forest. That was the opportunity for improvement: the IPIF adds three new variables: forest land use, vegetation condition and soil moisture.

The IPIF reduces false alarms by 18 per cent. What does this mean in practice?

After comparing it with data on burnt area from the last nine summers, the IPIF detects almost the same percentage of burnt area in major fires as the FWI but generates false alarms on only 18 per cent of days without a major fire, compared with 27 per cent for the FWI. In practice, this means that when the IPIF gives high hazard values, there is greater certainty that the hazard is real.

What does it mean to move from a resolution of five kilometres to one kilometre?

Previously, fire danger was calculated at one point for every five kilometres. The new IPIF is calculated for the same area, but at one point for every kilometre: this provides much greater spatial detail in valleys, on islands and in areas with complex topography.

Why does fuel not burn in the same way when the ground is wet? How do you measure soil moisture?

The variable that really determines whether a plant will burn is the moisture content of the living fuel, but to date this is not operational in any meteorological service worldwide, so it must be estimated based on other variables. At AEMET, we realised that soil moisture is a good proxy: the more water available to the plant, the higher its moisture content will be. It is estimated daily based on precipitation and evapotranspiration.

How does a satellite determine whether a plant is flammable from space?

Using the NDVI, the Normalised Difference Vegetation Index, which estimates the amount and condition of vegetation based on how it reflects near-infrared and red light. It gives an indication of how green the plant is: if it is very green, it will be harder to set alight than if it is dry.

There are now six danger levels instead of five. What are the thresholds for each one?

The thresholds are not linked to fixed temperature or humidity values: they are calculated for each square kilometre based on the climatological series for that location, using the 40th, 65th, 85th, 90th and 98th percentiles from more than ten years' worth of data. They are, therefore, unique to each area. The measures to be taken by local councils and members of the public are set out in the Forestry Act and by the autonomous communities.

The IPIF was calibrated using data from 2015–2024. How does it remain valid in the face of a climate that is breaking records?

This is an interesting question that is very difficult to answer. At present, at AEMET, the calibration is reviewed every one or two years – a process that is neither automatic nor straightforward – and which adapts the definition of 'very high' and 'extreme' danger to increasingly extreme conditions. But one might well ask whether a situation that today triggers a 'very high' danger rating should continue to be classified in the same way a decade from now, if it becomes commonplace.

Do you consider sensors for volatile organic compounds to be a viable early warning system?

This takes us from the field of prevention – where AEMET's hazard index falls – to that of early warning. I consider these low-cost, interconnected sensors, which detect volatile organic compounds in the very early stages of a fire, to be highly viable and extremely useful: their widespread use would lead to better monitoring and an early response.

«SATELLITES PROVIDE A CONTINUOUS OVERVIEW; SENSORS PROVIDE SPECIFIC REAL-TIME MEASUREMENTS»

Elia Quirós looks down on the landscape from above. A lecturer at the University of Extremadura, she coordinates the UEx's involvement in RAT_EOS_PC, the project that converts satellite images into fire and flood risk maps. In this interview, she discusses aspects that were not included in the original report.

How does your index complement AEMET's IPIF? What is your added value?
It is complementary: we share the aim of improving traditional indices by incorporating land use, vegetation and satellite variables. Our added value is twofold: geographically, a standardised model for all cooperation between Spain and Portugal; and in terms of variables, as we incorporate those not covered by the IPIF — topographical and anthropogenic factors (roads, power lines, landfill sites) — which influence ignition and spread.

You use the NDVI to measure the greenness of vegetation. How does AI translate a satellite image into a flammability indicator?
It isn't transformed directly: it requires an extensive training phase. We extract the state of the vegetation from the images using indices such as the NDVI, combine this with meteorological data, topography and human activity, and use all of this to train algorithms such as XGBoost, Random Forest or neural networks, which learn which combinations of variables were present in actual fires in order to estimate the risk on a new day and in a new location.

How do you obtain soil moisture data, and how is it validated, as opposed to the IPIF?
We do not develop our own algorithm: we use data directly from ERA5, from the European Centre for Medium-Range Weather Forecasts. We do not validate the variables in isolation, but rather the behaviour of the model, and after training it, we analyse the weight each variable — including soil moisture — has had in the forecasts.

Satellites have a well-known limitation: clouds. How does your system maintain its predictive capability?
We use only images with less than 20 per cent cloud cover and filter out pixels containing clouds or shadows. Rather than relying on a single day's data, we analyse trends over the last 7, 14 and 30 days, so any occasional gaps in data are more than compensated for. If the day in question is still cloudy, we use the most recent valid observation.

You also model floods. How does a fire affect susceptibility to flooding afterwards?
There is a very clear link: when a fire destroys vegetation cover, surface runoff and the volume of water reaching rivers increase, and the water carries sediment more easily. This erosion can silt up riverbeds, reduce their drainage capacity and exacerbate the damage caused by a flood.

How do you guarantee that a small, resource-poor municipality can use this system?
We are developing a web viewer accessible to any user, without specialized knowledge, where any citizen or town council can quickly check the risk in their area. It will have different profiles: the public will see essential information, and Civil Protection will have more advanced tools for decision-making.

What stage is the project at?
Very advanced: for fires, the models are already working, and we are working on the viewer; for floods, it's in the validation phase. Adverse weather phenomena are further behind, partly because AEMET (the Spanish State Meteorological Agency) already has good tools for that. Although RAT_EOS_PC ends in 2026, it will be continued with BUR_PC for floods and a HORIZON project for fires.

Do you see any points of convergence with SenForFire?
Undoubtedly, they are very complementary. RAT_EOS_PC relies on satellites and predictive models, but it also incorporates IoT sensors. Satellites offer continuous monitoring and wide coverage; sensors provide specific measurements in real time. That combination is the direction in which current fire management is heading

«WE MUST LEARN TO LIVE WITH MORE MANAGEABLE FIRE»

Javier Madrigal observes wildfires from within the forest. A senior scientist at the Spanish National Research Council (CSIC) and a researcher at SenForFire, he also coordinates the CSIC group that advises on large wildfires. In this conversation, he elaborates on ideas that were only briefly touched upon in the report.

What do you think of the new IPIF (Fire Risk Index)? Does it represent a real advance from a research perspective? And in terms of improving the effectiveness of fire prevention by forestry operations?

Without knowing the details of the algorithms used to create this index, it is clear that it has been a long-standing demand of the forest fire sector to include variables such as the moisture content of live vegetation and the use of satellite data that indicate stress or physiological changes that imply a greater availability of live fuels in fire risk indices. All of this generates an index that not only describes the probability of a fire starting based on the weather, but also the probability of its spread based on the state of the vegetation.

The IPIF was calibrated using data from 2015-2024. How does research validate an index that uses the past to predict an unprecedented future?

I think the correction function for the 2015-2024 period is a good thing, as it prevents the index from becoming saturated—a common problem in series that don't incorporate recent climate change. Without it, Spain would appear "all red" many days a year. As a complementary approach, I propose generating "what if" scenarios: simulating a scenario that has never occurred and seeing how the index reacts.

At SenForFire, you develop low-cost sensors that measure temperature, humidity, gases, and particles. How does this help an index like the IPIF?

They could help validate or feed it in several ways: soil moisture networks would improve predictions of live fuel moisture, and these multisensors could refine the spatial resolution—currently 1 km²—in vulnerable areas. Gas and particle sensors detect smoke in the initial phase of a fire and help assess air quality. If the IPIF (Integrated Fire Prevention and Control System) were to consider these criteria, especially in its dynamic aspects, these networks would be fundamental for its calibration and operation.

In 2024, you warned the Spanish Congress about the increase in wildfires. Studies project a 30% increase in large wildfires in Europe. How should this projection be incorporated into current risk indices?

Indices like the IPIF are actually designed as early warning systems, and they act as hazard indicators. Incorporating risk involves assessing vulnerability, and in that case, projections of increased risk in certain geographical areas based on climate projections could indeed be included. However, these projections are usually regional for large geographical areas, so there will always be difficulties in incorporating it operationally.

You propose "living with more manageable fires" instead of preventing them altogether. What does this mean operationally?

Treatments to vegetation help mitigate impacts and increase resilience, but they won't reduce the affected area or the number of ignition points. It means designing a territory capable of coexisting with these fires, which also involves "prescribed burning": controlled burns during periods of lower risk, to give firefighters, the population, and the ecosystem a chance.

What role do small, under-resourced municipalities play in this new paradigm?

Local governments play an essential role, although limited by their scarce economic and human capacity to deal with increasingly intense fires. Provincial Councils must support municipalities with fewer resources, and the Autonomous Communities must oversee the implementation of self-protection plans. Furthermore, the resident population, seasonal workers, and tourists must be aware of the risk, just as we are aware of typhoons, hurricanes, or earthquakes when we travel to other countries. In Spain, fires and floods are the main natural risks, so training, drills and the use of gas sensors as technological support are essential.

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