HUMANIDADES E CIÊNCIAS SOCIAIS:

Perspectivas Teóricas, Metodológicas e de Investigação

Luis Fernando González-Beltrán
(organizador)

EDITORA ARTEMIS
2024

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PRÓLOGO

Como la obra "Humanidades e Ciências Sociais: Perspectivas Teóricas, Metodológicas e de Investigação", ha tenido gran éxito, nos complace presentar el Volumen 6. Si, ya son 6, y aquí tenemos 18 capítulos en tres secciones, donde agrupamos las investigaciones sobre Humanidades y Ciencias Sociales que abarcan la Educación, las problemáticas Sociales, y las empresas.

En el apartado que llamamos "Educación: Investigación y Nuevas tecnologías" incluimos 8 capítulos que abarcan desde la Educación Básica hasta la Universitaria, desde nuevas tecnologías, como las redes sociales, pasando por la enseñanza híbrida, hasta la Inteligencia Artificial. Como el nombre lo indica, son tecnologías nuevas, por lo que no se han establecido aún parámetros de normalidad con fines de comparación. Cuales tecnologías son más efectivas que otras, cuando se deben aplicar solas, y cuando en combinación. De esta forma, cada estudio que se realiza agrega un granito de arena al vasto océano del conocimiento. Iniciamos revisando la primaria rural, donde se propone que la Interculturalidad puede romper la desigualdad, la exclusión y la dominancia, resolver los conflictos y las tensiones en las perspectivas de vida, sus cosmovisiones y sus saberes. En el segundo capítulo se estudian las redes sociales y su posible efecto sobre las habilidades sociales. A continuación se ensaya la modalidad híbrida en la formación técnica y tecnológica, con mayor éxito, logrando un perfil óptimo. En cuarto lugar se utiliza un sistema digital de Enseñanza Aprendizaje, con Inteligencia Artificial, para traducir texto a lenguaje de señas y realizar la traducción en sentido inverso, mejorando la comunicación bidireccional. Esto representó un proceso de retroalimentación personalizada, y de forma inclusiva y equitativa. Seguimos con la medición del perfil agentivo en universitarios, midiendo el logro de metas y el aprendizaje colaborativo. Conforme los alumnos avanzan en los semestres, aumenta su percepción de agencia colectiva. Continuamos con la revisión de la técnica de observación de las prácticas educativas, como procedimiento metodológico de investigación, su interconexión, triangulación y procesamiento de datos. Incluimos a continuación un trabajo sobre Inteligencia Artificial donde se tratan cuestiones éticas como su uso responsable. Se detalla su aplicabilidad, sus límites, sus impactos tanto positivos como negativos y sus verdaderos alcances. El apartado finaliza con un capítulo sobre la práctica en el trabajo social. Proporciona ejemplos prácticos de estrategias y habilidades duras (técnicas) y blandas (comunicación, empatía).

En la segunda sección "Problemáticas Sociales y Ambientales" se ilustra un tema de actualidad, que incluye la posibilidad de desastre, de un camino sin retorno, como consecuencia del abuso de recursos que han provocado cambios climáticos, escases de agua y alimentos, incendios, inundaciones, pérdida de bosques y selvas, etcétera. Con 4 capítulos, esta sección trata de problemáticas analizadas para el caso de México, Colombia, Camerún, e Italia. Problemas comunes a una infinidad de países. Iniciamos con la certificación de Playas en Acapulco. Las playas son un recurso común, y aunque los grandes hoteles se han apropiado de algunas, es un recurso de difícil exclusión, y la certificación, aunque necesaria, no es suficiente para la búsqueda de un turismo sustentable. Seguimos con la construcción de obras que responden a necesidades nacionales, pero que provocan problemas locales. Este caso corresponde a una repesa para generar energía, con fines de modernización y desarrollo, pero con consecuencias socioculturales en la comunidad donde se construyó. Como tercer trabajo tenemos el conflicto del uso del suelo, en específico, la minería contra la degradación del bosque. Oro y demás metales que pesan más en la balanza económica que el oxígeno y los alimentos. El cuarto y último capítulo de la sección trata de la estimación de eventos meteorológicos extremos, que son ahora más frecuentes por las malas decisiones que hemos tomado contra nuestro planeta. Como si tuviéramos recursos infinitos para depredar, las consecuencias de nuestros abusos se reflejan en un porcentaje de mayor peligro de incendios cada verano, pronosticados especialmente para Italia, pero que hemos sufrido en muchas otras partes del mundo.

El tercer apartado “Economía, Empresa y Gestión”, con 6 capítulos, trata sobre la economía desde el caso de los particulares, a las pequeñas tiendas, a la relación entre Universidades y Empresas, pasando por las PYMES, las decisiones de inversión en empresas de mayor envergadura, y finalizando con el papel de la mujer en la economía. Iniciamos con una de las consecuencias económicas del COVID, el repunte de los pagos electrónicos, el cierre de las tiendas físicas, la educación digital, y la persistencia de la digitalización. Seguimos con las tiendas y su competencia y los desafíos que enfrentan contra las multinacionales. Se sugiere, entre otras estrategias, la cooperación entre las tiendas, mejorar el marketing, ajustar los precios, etcétera. El tercer capítulo presenta a las pequeñas y medianas empresas, con un débil vínculo con las Universidades, que no poya de manera clara la transformación empresarial, ni la gestión del conocimiento. La baja inversión en infraestructuras que impulsen la inteligencia empresarial impide ajustarse al orden global. Continuamos con un tema con íntima relación: la Cultura Organizacional, que debería impulsar en este sector, la gestión del conocimiento, las estrategias corporativas, estabilidad y armonía. El quinto capítulo habla del presupuesto de capital y las decisiones de inversión. Antes de la toma de decisiones tan crucial, las oportunidades de inversión deben clasificarse según los rendimientos esperados, y aquí se revisan diversas técnicas con dicho objetivo. La obra finaliza analizando el rol que la mujer juega no digamos en la economía, sino en toda la sociedad. Se revisa la obra de Soledad Acosta, prolífica escritora, periodista, historiadora, que reivindica la educación de las mujeres para construir una mejor sociedad.

Esperamos que este Volumen, además de muy completo, y muy variado, resulte también muy placentero en su lectura.

Dr. Luis Fernando González Beltrán
Universidad Nacional Autónoma de México (UNAM)

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ESTIMATING FIRE DANGER OVER ITALY IN THE NEXT DECADES[1]

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ABSTRACT: Extreme meteorological events pose serious risks for human activities and infrastructures, above all in this last decade in which severe climatic events are increasing in frequency and intensity with significant impacts on human and natural systems. In particular, wildfires represent severe threats for environmental and economic sectors, as they can degrade air quality, damage forests, exacerbate natural hazards with also serious implications for the security of electric system and its governance. In order to identify the most likely vulnerable regions in the next decades, the effects of climate changes on fire danger over Italy have been investigated by comparing the current climate (1971-2000) with medium-term future scenarios (2021-2050) inferred from several high-resolution regional climate simulations provided by two EU-funded Projects: ENSEMBLES models (with an horizontal resolution of 25 km under the SRES A1B emission scenario) and MedCORDEX models (with 12 km spatial resolution under the two radiative forcing configurations RCP 4.5 and RCP 8.5). The wildfire danger has been characterized by computing the Canadian Forest Fire Weather Index (FWI) using a single Med-CORDEX model (ICTP-RegCM4). Moreover, to achieve more robust results, the likely occurrence of meteorological conditions favourable to trigger wildfires has been analysed on the basis of a sub-set of ENSEMBLES models. The results inferred from Med-CORDEX model and the multi-model ensemble projections highlight an alarming model agreement on increasing fire probabilities: in line with previous experiments, fire danger is expected to increase of at least 20% by 2050 in most of Italy in summer, projected drier and warmer for the next decades.

KEYWORDS: Regional Climate Models. Fire Danger. Climate Projections. Fire Weather Index.

ESTIMATIVA DO PERIGO DE INCÊNDIO EM ITÁLIA NAS PRÓXIMAS DÉCADAS

RESUMO: Eventos meteorológicos extremos representam sérios riscos para atividades humanas e infraestruturas, especialmente nesta última década em que eventos climáticos severos estão aumentando em frequência e intensidade, com impactos significativos nos sistemas humanos e naturais. Em particular, os incêndios florestais representam ameaças severas para os setores ambientais e

[1] Euro-Mediterranean Journal for Environmental Integration (2018) 3:15. https://doi.org/10.1007/s41207-018-0053-1

econômicos, pois podem degradar a qualidade do ar, danificar florestas, exacerbando os riscos naturais e implicando sérias consequências para a segurança do sistema elétrico e sua governança. Para identificar as regiões mais vulneráveis nas próximas décadas, os efeitos das mudanças climáticas no perigo de incêndios na Itália foram investigados comparando o clima atual (1971-2000) com cenários futuros de médio prazo (2021-2050) inferidos a partir de várias simulações climáticas regionais de alta resolução fornecidas por dois Projetos financiados pela UE: modelos ENSEMBLES (com resolução horizontal de 25 km sob o cenário de emissão SRES A1B) e modelos Med-CORDEX (com resolução espacial de 12 km sob as configurações de forçamento radiativo RCP 4.5 e RCP 8.5). O perigo de incêndio florestal foi caracterizado calculando o Índice de Perigo de Incêndio Florestal do Canadá (FWI) usando um único modelo Med-CORDEX (ICTP-RegCM4). Além disso, para obter resultados mais robustos, a provável ocorrência de condições meteorológicas favoráveis para desencadear incêndios florestais foi analisada com base em um subconjunto de modelos ENSEMBLES. Os resultados inferidos do modelo Med-CORDEX e as projeções do conjunto de modelos destacam um alarmante acordo do modelo sobre o aumento das probabilidades de incêndio: em linha com experimentos anteriores, espera-se que o perigo de incêndios aumente pelo menos 20% até 2050 na maior parte da Itália no verão, projetado para ser mais seco e mais quente nas próximas décadas.
PALAVRAS-CHAVE: Modelos Climáticos Regionais. Perigo de Incêndio. Projeções Climáticas. Índice Meteorológico de Perigo de Incêndio.

1 INTRODUCTION

There is a general awareness that climate is changing and extreme weather events (like storms, flood, heat wave and droughts) are steadily growing. Changes in mean climate variables may have important environmental, economic, and societal impacts, but the changes of extreme events pose the most serious risks. Indeed, their impacts on human activities and infrastructures are becoming more and more severe entailing loss of lives, in addition to serious environmental disasters and high economic costs (IPCC-AR5 2013). European Environment Agency highlights that the last decade (2007–2016), characterized by an average annual temperature for the European land area of about 1.6°C above the pre-industrial level, is the warmest decade on record and annual average land temperature over Europe is projected to increase by more than global average temperature by the end of this century in the range 1 to 4.5 °C under the forcing scenario RCP4.5, and 2.5 to 5.5 °C under RCP 8.5 (EEA 2017a). Consequently, Europe is expected to face major impacts from a changing climate. Indeed, Europe is currently experiencing an increasing number of natural hazards: notably extended periods of high temperatures, droughts, and extreme rainfalls are occurring with serious losses in terms of human lives and environmental damages (EEA 2017b). According to recent assessments (Forzieri et al., 2016a), Europe will likely face an exacerbation in overall climate hazards particularly over south-western regions as heat waves, droughts, and forest fires. In the framework of EU Adaptation Strategy, a JRC Report (Forzieri et al., 2016b) predicts an upsurge in climate hazard damages to critical infrastructures in Europe: at present costs from climate extremes in the energy, transport, industrial and social sector, amount to €3.4 billion/year, but they could triple by the 2020s, multiply six-fold by 2050, and increase to more than 10 times by the end of the century with the highest economic losses for industry, transport and energy sectors. Southern and South-Eastern European countries, subjected also to strong human pressures and land use change, will be mainly affected by them (EEA 2017c).

Among extreme events, wildfires are of great interest. They play an important role for ecosystems leading to changes in vegetation structure and species composition (DeFries et al. 2009; Scott and Glasspool 2006). Regular occurrence of fire is an important natural process that affects biogeochemical cycles, biogeophysical properties, the carbon cycle, and climate (Bowman et al. 2009). However, they represent considerable threats to humans, ecosystems, and economic sectors as the destructive force of uncontrolled fire events can rapidly consume large amount of biomass and become frequently responsible for catastrophic damages in terms of human casualties, economic losses, or both. Besides, they degrade air quality and exacerbate natural hazards, such as enhancement of debris flows, erosion, and avalanche danger. Wildfires pose also serious risks for electric power management as they could damage or destroy infrastructures (i.e., transmission lines or substations) with consequently serious energy supply interruptions (Kenward and Raja 2014).

In the United States, hundreds of thousands of fires burned almost two-million ha of forest and other ecosystems during 1992-2001 (USFA 2005). The year 2015, with more than 11 million acres burned in US, is recorded as America's most devastating fire year since at least 1960. In Europe, despite a lot of money spent on prevention work, on average 70.000 fires take place every year burning more than half a million hectares of the forest areas (Camia et al. 2010; EEA 2010) with a high number of fatalities: 307 in the years 1998–2009, most of which (85% of the total) occurred in Mediterranean Europe (Schmuck et al. 2011). Even more the summer 2017 will likely be remember as one of the most devastating wildfire seasons in Europe since records began, as by early September 2017 wildfire have burnt nearly 700.000 ha of land (JRC 2017).

Knowing the main driving factors of ignition is a fundamental step towards effective fire prevention policies (Ganteaume et al. 2013). As wildfires are events highly dependent on meteorological conditions (Pechony and Shindell 2010), Moritz et al. (2012) investigated the interaction between climate change and fire across the planet by considering vegetation characteristics, weather conditions (dry, hot and/or windy periods) and ignitions as the three dominant factors influencing fire activity. They derived a globally consistent analysis of future fire activity from a broad range of global circulation models (GCMs) and found, in the complex patterns of fire probability changes across the planet (both spatially and temporally), a relative agreement among models for increased fire probability over the Mediterranean region. Further recent studies support such results (Turco et al. 2014; Wu et al. 2015): future fire activity in Europe is expected to increase due to projected enhance of weather conditions like warm and dry days. But not all regions will be affected in the same way. In some places these challenges could have little impacts, in other places (Southern European regions and, specifically, Mediterranean) they could reinforce each other and provide a serious challenge for future (European Commission 2010).

Indeed, although the strong linkage between fire and climate (Aldersley et al. 2011), the predictability of fires is a complex issue, as the relative importance of environmental and human factors on fire activity varies regionally and may be difficult to disentangle (Bowman et al. 2009; Wu et al. 2015). Actually, more than 90% of the fires in Europe are human-caused (Ganteaume et al. 2013).

Many attempts have been made to quantify the potential impact of climate change on fire risks (Wotton and Flannigan 1993; Mouillot et al. 2002; Brown et al. 2004). One of the most widely used fire danger indices in the world is the Fire Weather Index (FWI) (Van Wagner 1987; Wotton et al. 2009) designed to estimate fire danger in a generalized fuel type on the basis of daily meteorological data to describe moisture content of forest fuels (determined by temperature, precipitation, relative humidity) plus the effect of wind behaviour. FWI, part of the Canadian Forest Fire Danger Rating System (CFFDRS), was established in Canada in 1979 and found a wide application in a number of countries: south-east Asia (deGroot et al. 2006), New Zealand (Briggs et al. 2005), Mexico, Florida and Argentina (as mentioned by Moriondo et al. 2006), as well as the Mediterranean region (Dimitrakopoulos et al. 2011). A comparative study of various methods of fire danger evaluation in Mediterranean basin (Viegas et al. 1999) found that the FWI system components were well correlated with fire activity in southern Portugal, Spain, France, and Italy, even though the Mediterranean vegetation and climate are markedly different from that in Canada. FWI System has been even adopted by European Fire Information System (EFFIS) as the reference method to assess the fire danger level in a harmonized way throughout Europe (Camia et al. 2007).

GCMs are inadequate for local impact studies, especially in areas like the Mediterranean with a complex morphology because of their low spatial resolution. Instead, Regional Climate Models (RCMs) can reproduce well enough the fine-scale features (Christensen et al. 2007) and become suitable tools for climate change impact studies in general, and fire risk assessments in particular.

In order to provide useful information in decision making processes to plan effective adaptation and mitigation strategies at the national level, this study aimed to investigate fire danger over Italy in the future on the basis of several high-resolution simulations under different combinations of global-regional climate models provided by two EU-funded projects: ENSEBLES models, under the emission scenario SRES A1B (Nakicenovic et al. 2000), and Med-CORDEX runs, under two Representative Concentration Pathways RCP 4-5 and RCP 8.5 (Detlef et al. 2011). In particular, the changes of FWI over Italy have been analysed.

The paper is structured as follows: datasets and methods are presented in Section 2. The models' performances in the current climate reconstruction and the future climate scenarios are described in Section 3. Some projections about the change of fire danger are discussed in Section 4. Summary and Conclusions are reported in Section 5.

2 DATA SETS AND METHODS

2.1 DATASETS

The analysis of climate change and associated fire danger over Italy has been done by considering a domain extending between 36N ÷ 47N and 6E÷19E, and two time slices: the reference period 1971-2000 (REF) and the future scenario 2021-2050 (FUT).

The study was based on meteorological daily data provided by three reference datasets (§2.2.1) and two models archives (§2.2.2). Moreover, EFFIS data, dealing with fire episodes occurred over Italy, have been considered (§2.2.3).

2.1.1 Reference data

Reference data of mean, minimum and maximum surface temperature (T, TN, TX) [°C] and total precipitation (P) [mm/day] have been provided by gridded observation dataset E-OBS - Version 11.0 (Haylock et al. 2008) with a horizontal resolution of 0.25° (~25km) from 1961 to 2013. Further information about precipitation have been acquired from EURO4M-APGD (EURO4M) (Isotta et al. 2014), whose precipitation fields have 5x5 km grid spacing, based on measurements at high-resolution rain-gauge stations (more than 8500 in total) from 1971 to 2008.

E-OBS archive does not provide wind data. Then daily wind speed (W) [m/s] has been computed by considering horizontal wind components every six hours (00:00, 06:00, 12:00, 18:00 GMT) for the period 1981-2010 from ERA-Interim (Simmons et al. 2002), a reanalysis dataset at 1.5 × 1.5° resolution provided by the European Centre for Medium-Range Weather Forecast.

All the reference data are listed in Table 1.

Table 1 List of reference data used to assess models' performances.

Project	**Variables**		**Spatial res**
E-OBS (1)	mean surface temperature minimum surf. temperature maximum surf. temperature total precipitation	T [°C] TN [°C] TX [°C] P [mm/d]	0.25 deg (~25km)
EURO4M-APGD (2)	total precipitation	P [mm/d]	5 km
ERA-Interim (3)	wind speed	W [m/s]	1.5 deg (~120km)
Institute			**Spatial res**
EFFIS (4)	Fire events	**Data, x, area burned**	0.11° (~120km)

(1) *http://eca.knmi.nl/download/ensembles/ensembles.php*
(2) *http://www.euro4m.eu/*
(3) *http://apps.ecwf.int*
(4) *http://effis.jrc.ec.europa.eu/*

2.1.2 Model data

Among the ENSEMBLES models (Van Der Linden et al, 2009), seven simulations at 25 km spatial resolution under A1B emission scenarios have been selected and used here as their outputs matched satisfactory the current climatology (not shown for sake of brevity).

In the framework of World Climate Research Program Coordinated Regional Downscaling Experiment (CORDEX http://wcrp-cordex.ipsl.jussieu.fr/), Med-CORDEX database has been developed. At the moment three simulations are available at the high resolution of 0.11° (~12km): CNRM-ALADIN52 (hereinafter ALADIN) driven by the RCP4.5 and RCP8.5 forcings; ICTP-RegCM4 (RegCM4) in RCP8.5 configuration. All of them have been analysed here.

In order to compare the results from the two datasets it is worthwhile considering that in A1B scenario the greenhouse gases emission values are roughly equal to the mean between the emission values of RCP4.5 and RCP8.5 configurations at the end of the 21st century, whereas in the mid of the century A1B emissions are nearer to RCP8.5 values.

The simulations used in this study are listed in Table 2. Indeed, ALDIN is omitted because, after a validation process (discussed below), the model showed some deficiencies in representing adequately summer dry season and wind regime over Italy. As both of them are climate aspects strongly affecting fire regime, ALADIN has been discarded in estimating the fire danger.

2.1.3 Fire data

EFFIS (http://effis.jrc.ec.europa.eu) is the most up to date information on the current fire season in Europe and in the Mediterranean area. EFFIS data available for Italy include the period from 2000 to 2015 and characterize fire events by specifying the time of occurrence, fire location and the burned area. They were used to test performances of the models in describing the fire danger.

Table 2 List of regional climate simulations used to elaborate future fire danger projections.

<table>
<tr><td colspan="5">ENSEBLBES data http://ensembles-eu.metoffice.com/</td></tr>
<tr><td>Institute</td><td>Simulations</td><td>Spatial res</td><td>SRES - scenarios</td><td>Ensemble mean</td></tr>
<tr><td>CNRM (1)</td><td>CNRM-RM5.1_ARPEGE</td><td>25 km</td><td>A1B</td><td rowspan="7">ENS</td></tr>
<tr><td>ETHZ (2)</td><td>ETHZ-CLM_HadCM3Q0</td><td>25 km</td><td>A1B</td></tr>
<tr><td>ICTP (3)</td><td>ICTP-REGCM3_ECHAM5</td><td>25 km</td><td>A1B</td></tr>
<tr><td>KNMI (4)</td><td>KNMI-RACMO2_ECHAM5</td><td>25 km</td><td>A1B</td></tr>
<tr><td>HC (5)</td><td>METO-HC_HadCM3Q0</td><td>25 km</td><td>A1B</td></tr>
<tr><td>SMHI (6)</td><td>SMHIRCA_ECHAM5</td><td>25 km</td><td>A1B</td></tr>
<tr><td>SMHI (6)</td><td>SMHIRCA_BCM</td><td>25 km</td><td>A1B</td></tr>
<tr><td colspan="5">Med-CORDEX data https://www.medcordex.eu/</td></tr>
<tr><td>Institute</td><td>Simulations</td><td>Spatial res</td><td colspan="2">Representative Concentration Pathways</td></tr>
<tr><td>ICTP (3)</td><td>ICTP-RegCM4</td><td>0.11deg</td><td colspan="2">RCP 8.5</td></tr>
</table>

(1) Météo-France - Centre National de Recherches Météorologiques
(2) Swiss Institute of Technology
(3) The Abdus- Salam International Centre for Theoretical Physics
(4) The Royal Netherlands Meteorological Institute
(5) UK Met Office, Hadley Centre for Climate Prediction and Research
(6) Swedish Meteorological and Hydrological Institute

2.2 THE FIRE WEATHER INDEX - ANALYSIS METHOD

In the original equations (vanWagner and Pickett 1985), FWI is described by six components each measuring different aspects of fire danger: the first three components are fuel moisture codes that simulate daily changes in the moisture contents; the others three are related to the fire behaviour representing the rate of spread, fuel weight consumed and fire intensity. According to its original definition, FWI is built upon instantaneous values of temperature, relative humidity, and wind speed at noon, together with 24 hourly daily precipitation. However, to relate fire danger to future climate scenarios, in this study daily values of maximum temperature, precipitation, relative humidity and wind speed have been used as done in other works (among others Moriondo et al. 2006). From FWI the Daily Severity Rating (DSR) is estimated through an exponential function. Then the

Seasonal Severity Rating (SSR), an index specifically designed for impact studies has been gathered by aggregating DSR seasonally.

Hanson and Palutikof (2005) found a non-linear relationship between the frequency of forest fires and FWI on local scale (Greece and Italy). Then Moriondo et al. (2006) worked to classify the FWI values into fire danger classes appropriate for the Mediterranean environments and found that FWI = 15 as appropriate threshold value indicative of fire danger over Mediterranean region. Therefore, the occurrences of FWI ≥15 have been investigated here.

As Herrera et al (2013) warn against the use of daily mean data for computing FWI because the use of daily mean could underestimate fire danger conditions, a simple heuristic approach has also been adopted as further investigation. Climate models are not expected to represent extreme weather events because of their relatively coarse spatial-temporal resolution. Nevertheless, they can identify likely vulnerable areas characterized by high frequencies of moderate weather phenomena. Considering that weather or climate events, even if not extreme in a statistical sense, can still lead to extreme conditions or impacts by occurring simultaneously with other events (IPCC 2012), an investigation about weather conditions such as hot, dry, and windy days has been done considering they key role in extreme fire situations (Amatulli et al. 2013). These "critical days" have been selected through three threshold values (P < 0.5 mm/d, TX > 30°C, and W > 2m/s) considering them reasonable in defining weather conditions favourable to fire ignition.

So on the basis of RegCM4, the effects of climate change on the fire danger have been characterized by analysing, at seasonal scale, the variation in:

a) the number of days with the Fire Weather Index FWI ≥15 (FWI15)
b) the SSR values
c) the days selected through the threshold values: TX > 30°C, P < 0.5 mm/d and W > 2m/s.

Bedia et al (2014) highlight the importance of adopting a multi-model ensemble approach to generate future fire danger scenarios in order to account for the variability of different model projections and, therefore, to increase the confidence in the results. Thus, the third criterion has also been applied to the seven ENSEMBLES models and the agreement among them have been analysed. According to the terminology defined by Mastrandrea et al. (2010), *medium* and *high* confidence have been stated if models agree in the sign of the mean change at least 50% and 90% respectively (i.e., in our case of 7 models by requiring a minimum agreement of 4 and 6 simulations respectively).

Before computing fire indexes, the Med-CORDEX simulations have been validated in describing the current climate, as was done for some ENSEMBLES models in a previous study (not shown) by which a sub-set of seven ENSEMBLES models has been selected (Table 2) to represent satisfactory the observed seasonal patterns both in amplitude and phase. This multi-model ensemble (ENS) and the Med-CORDEX simulations have been analysed at seasonal scale to describe the trends of the single drivers directly related to forest fire risk. While considering that dry summers and strong windy periods characterize the Mediterranean fire hazards (McCutchna, 1977), the analysis covered all the seasons (not only summer) to investigate if some critical conditions are projected to extend over the years.

3 ANALYSIS OF CLIMATE CHANGE PROJECTIONS IN THE STUDY AREA

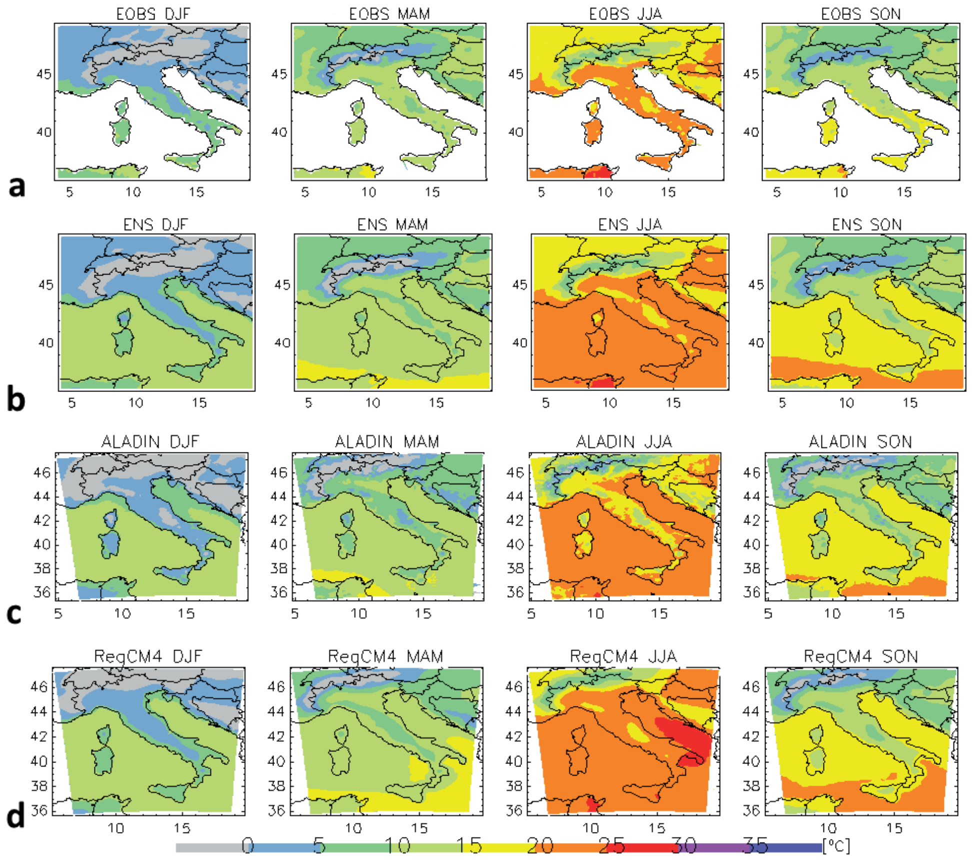
At first model reconstructions of temperatures, precipitations and wind speed have been verified against reference data (E-OBS, EURO4M and ERA-Interim) in REF period (3.1). Then the "anomalies", namely the differences between FUT and REF periods for each meteorological variable, have been analysed to extract some signal of the climate change (§ 3.2).

3.1 SEASONAL VALUES IN THE REF PERIOD: 1971-2000

The typical T seasonal spatial patterns, described by E-OBS (Figure 1a), is well reproduced by the multi-model ensemble ENS with a good land/sea interface and an appropriate orographic gradient (Figure 1b): the lowest temperatures are in correspondence with the mountain peaks, the highest ones characterize the surrounding valley areas. ALADIN represents better the dependence of T with elevation in comparison with ENS results, thanks to its higher spatial resolution (Figure 1c); the RegCM4 fields are more smoothed (Figure 1d), even if they are of the same spatial resolution as ALADIN. Analogous results are obtained for TN and TX (not shown for sake of conciseness), whose patterns have a seasonally dependent fine scale structure in response to the topographic forcing.

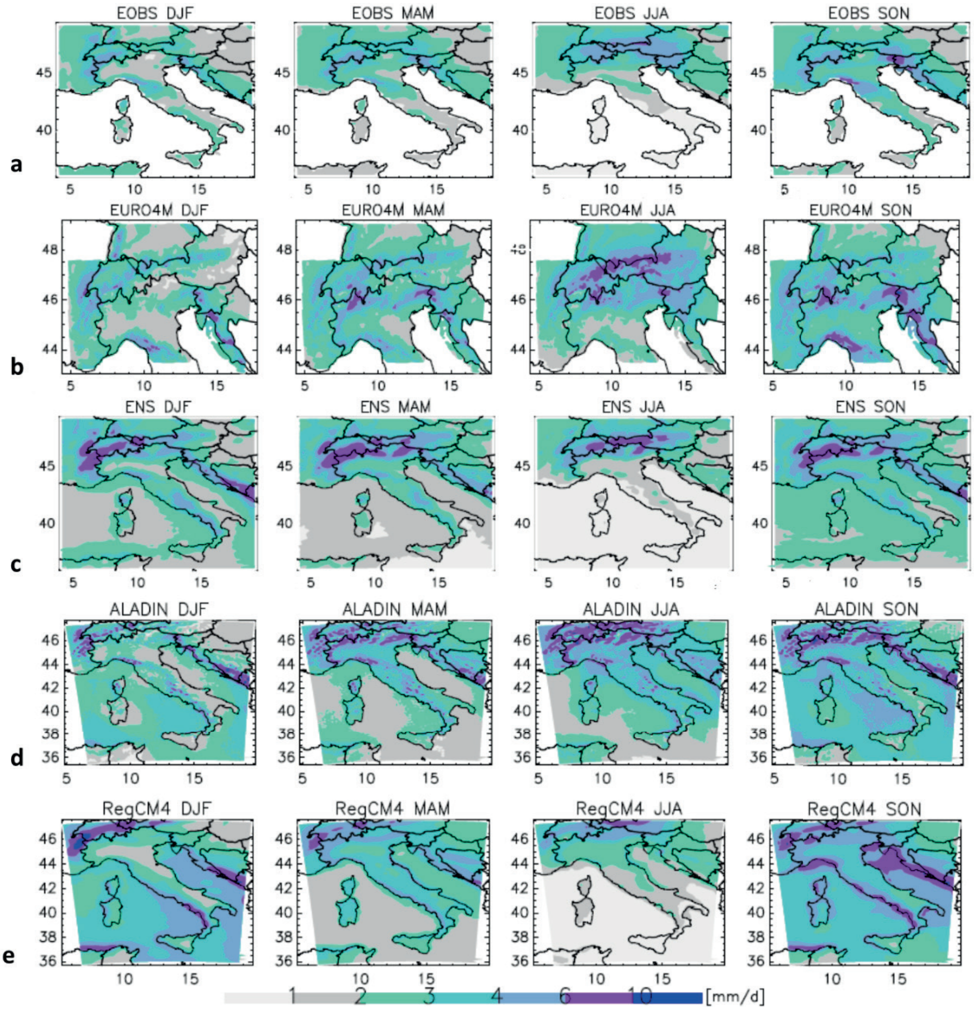
P regime has been analysed by considering both daily mean and cumulative precipitation values. In addition to E-OBS data, EURO4M archive has also been used as reference to strengthen model performance evaluations: as expected E-OBS and EURO4M fields are totally coherent (Figure 2 a-b). Obviously EUOR4M can describe better the actual precipitation patterns over complex terrain, thanks to its very high spatial resolution (5km), with local values over mountain regions higher than those from E-OBS.

Figure 1. Mean seasonal surface temperature T provided by EOBS (a) and reconstructed by ENS (b), ALADIN (c) and RegCM4 (d) in REF period (1971-2000); in winter (DJF), spring (MAM), summer (JJA) and autumn (SON).



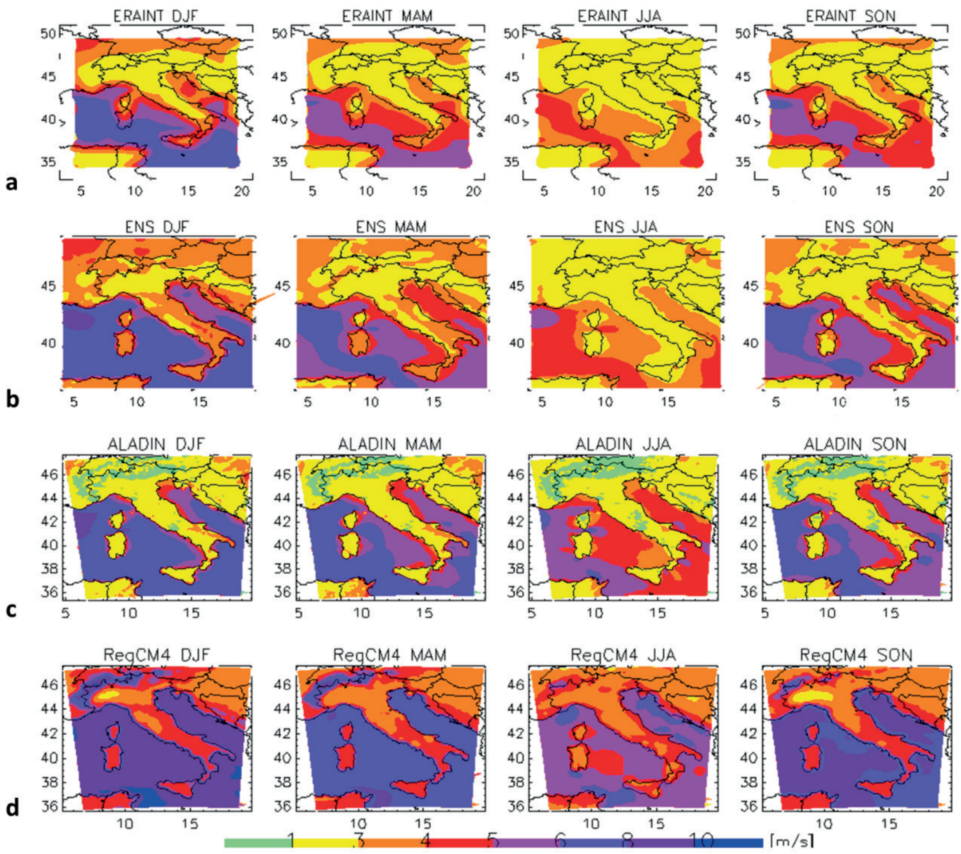
ENS gives a reasonable representation of rainfalls and reproduces fairly the typical Mediterranean climate characterized by wet winters and dry summers, with the highest precipitations over the Alps, and the lowest values over the Po valley and the southern areas (Figure 2c). Instead, ALADIN returns too high P values in summer (Figure 2d). This shortcoming cannot be neglected as the rainfall is an important factor for determining the severity of a forest fire and the amount of the burned area (Pausas, 2008). RegCM4 reproduces pretty well the seasonal precipitation regime despite some overestimations over coastal areas and underestimations over high altitudes (Figure 2e). This is more evident again if the cumulative precipitations are considered (not shown).

Figure 2. Mean seasonal daily precipitation in the REF period for EOBS (a), EURO4M (b), ENS (c), ALADIN (d) and RegCM4 (e).



Generally, hill crest are windier than valleys (Raupach and Finnigan 1997); in particular Po Valley is characterized by very low wind speed. This characteristic is barely described from ERA-Interim data, depicting low winds of Po Valley widespread over Alpine Region. Actually ERA-Interim presents obvious shortcomings in characterizing local winds over high terrain because of its very coarse spatial resolution. In spite of such limitations, ERA-Interim points out correctly strong wind speed over Northern Alpine Region (Figure 3a). ENS describes fairly the seasonal wind fields by identifying the windiest regions in the southern Italy in the cold months and characterizing mountain areas as windier than flat ones (Figure 3b). Instead ALADIN estimates very low winds over Alpine Region with values even lower than the speeds characterizing the Po valley (Figure 3c). RegCM4 wind fields have spatial patterns coherent with orography, although they have a strong discontinuity in sea-land interface and too strong wind speeds compared to the typical ones (Figure 3d).

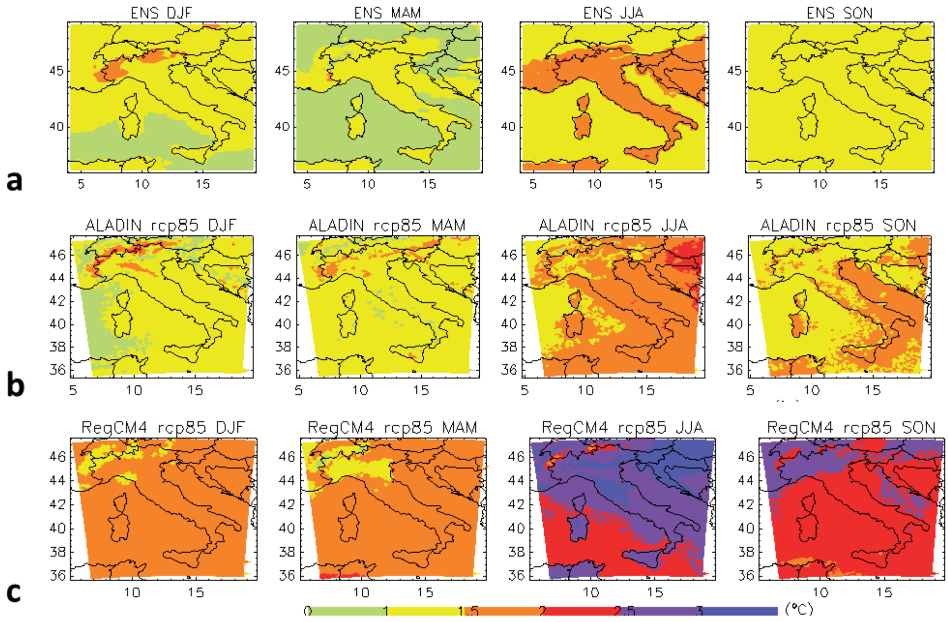
Figure 3. Mean seasonal daily wind speed in the REF period for ERA-Interim (a), ENS (b), ALADIN (c) and RegCM4 (d).



3.2 FUTURE PROJECTIONS FOR THE SCENARIO 2021-2050

Concerning T changes [°C], Figure 4 represents the results in a-b-c maps respectively for: ENS in A1B, ALADIN and RegCM4 in RCP8.5 forcing. All the models project a warming with a marked seasonality, in accordance with previous analyses (among others, Giorgi and Lionello 2008; Faggian and Giorgi 2009): ENS indicates an increase of T ranging from a minimum of 1–1.5 °C (in spring and autumn) to a maximum of 1.5 – 2.0° (in summer) (Figure 4a); analogous results are inferred from ALADIN (Figure 4b), with anomalies in RCP8.5 configuration higher than ones in RCP4.5 (not shown) as expected because of the stronger radiative forcing; RegCM4 projections are much more emphasized with positive anomalies at least 1° higher than the other scenarios (Figure 4c), above all in summer with values of about 3°C.

Figure 4. T seasonal anomalies projected by 2021-2050 relative to 1971-2000 for: ENS (a), ALADIN (b) and RegCM4 in RCP8.5 (c).

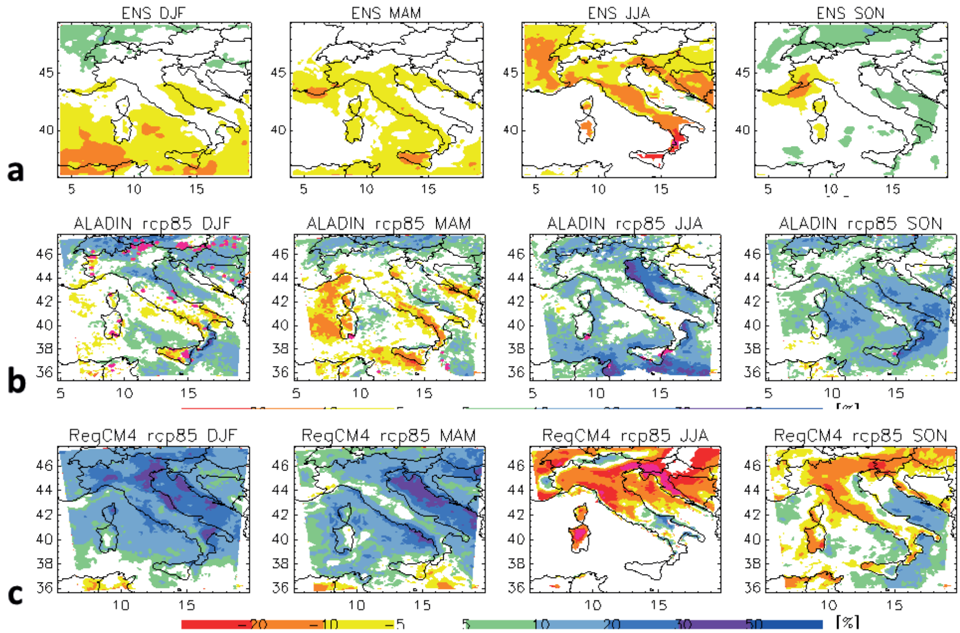


Analogous results have been obtained for TN and TX (not shown).

P changes are expressed in percentage values between FUT and REF periods. Different spatial patters are obtained from the models (Figure 5): ENS highlights a remarkable reduction of precipitation during summer (~ 20%) and some spatial variability in the other seasons (Figure 5a), confirming relevant studies (IPCC 2013); ALADIN describes a quite different P changes scenario, in particular it projects a light increase of precipitations in some area in summer season (Figure 5b), in contrast to most climate scenarios (among other Christensen et al. 2007). There are also some remarkable differences between RgCM4 with ENS results: according to RegCM4, P is expected to reduce in summer (~ 20%) and autumn (~ 10%), over most of Northern and Central Italy, and to increase in the other two seasons with values reaching 10-20%, up to 30-40% over some spot locations in winter (Figure 5c). Instead ENS projections point out some precipitation increasing over North of Alps during the cold months.

No significant signals of wind changes have been detected by model simulations (not shown).

Figure 5. As for Figure 4 but for total precipitation in % values.



To summarize the results, models' projections reveal warming in all seasons for the whole Italy, while changes in precipitations, more variable across sub-regions and seasons, are affected by different degree of uncertainties. ALDIN showed some deficiencies in representing adequately the seasonal precipitation cycle (in particular the summer dry season) and wind structure over Italy. As fire regime is strongly affected by both these meteorological variables, ALADIN simulations were discarded to investigate the fire danger.

4 FIRE DANGER ANALYSIS

FWI and SSR values have been computed in FUT and REF periods on the basis of RegCM4 outputs only.

Unfortunately, the representativeness of FWI15 and SSR in REF period has been verified only in part because EFFIS archive resulted incomplete (not shown). Anyway, the fire danger conditions inferred from models' estimations resulted coherent with actual fire occurrences (in time and location, when available).

According to the three above mentioned criteria the following signals have been inferred:

a) FWI15 events are depicted to increase widespread over Italy, lightly in spring, more strongly in summer (about 20%) and in autumn (beyond 50%) (Figure 6), highlighting a longer fire season. Although there might be some overestimation about this projection because RegCM4 describes a very strong warming in comparison with other models (Figure 4), this result is compatible with other studies (Lozano et al. 2016; Carvalho et al. 2011; Moriondo et al. 2006).

b) SSR values are projected to rise especially in summer, but also in autumn (Figure 7), indicating an intensification of fire hazard during these two seasons.

c) The "critical days", selected from RegCM4 outputs with threshold values, are expected to increase considerably in summer (above 20%) over most of Italy (Figure 8) coherent with the signals described by FWI15 (Figure 6) and SSR (Figure 7). The same criterion applied to the 7 ENSEMBLES models strongly confirms such results: likely changes of fire danger conditions are projected to enhance in the hot season (20% at least) over most of Italy with high confidence as visualized in Figure 9 by the stippled grid cells over the spatial patterns.

Figure 6. Seasonal changes of events (%) with SWI ≥ 15 projected by 2021-2050, relative to 1971-2000, according RegCM4 in RCP 8.5 configuration.

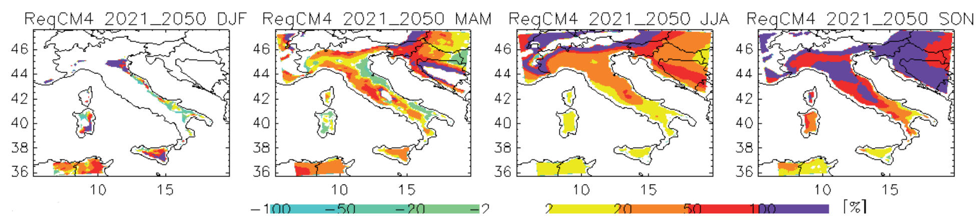


Figure 7. Seasonal changes of SSR projected by 2021-2050, relative to 1971-2000 according RegCM4 in RCP 8.5.

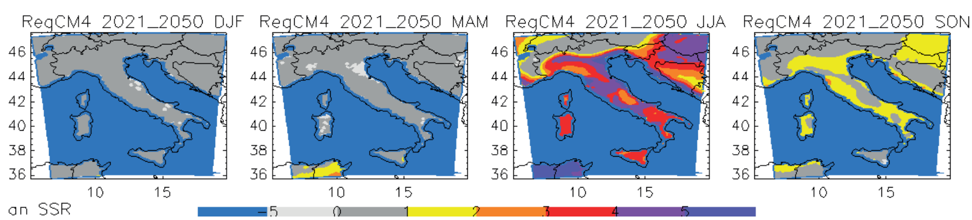


Figure 8. Seasonal change of potential fire danger conditions in FUT scenario relative to REF period on the basis of RegCM4 simulation.

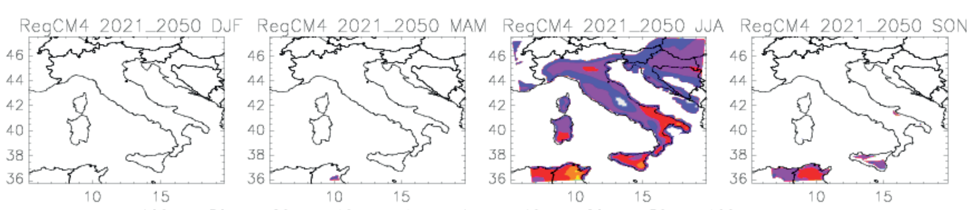
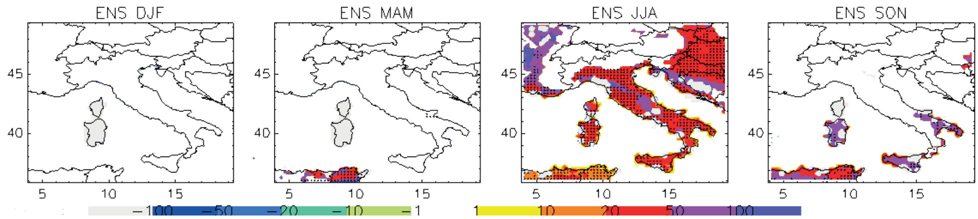


Figure 9. Likely seasonal change of fire danger according to some ENSEMBLES models. The grid cells stippled indicate very likely changes (at least 6 simulations over 7 considered).



5 SUMMARY AND CONCLUSIONS

In order to provide useful information in planning adaptation and mitigation strategies, this study aimed to evaluate the fire danger over Italy expected in the next decades by analysing a range of future climate projections, focusing the study on the weather conditions favourable to easy fire ignition.

Meteorological data used in this study come from different datasets which provide observationally based reference data (E-OBS, EURO4M-APGD and ERA-Interim), and climate regional simulations, consisting of two Med-CORDEX models (CNRM-ALADIN52, ICTP-RegCM4 at 0.11° spatial resolution) and seven ENSEMBLES models (at 25 km horizontal resolution).

Two time-slices have been considered (REF=1971–2000 and FUT=2021–2050) to represent present and future climate conditions. At first the performances of climate simulations in describing the current climate over Italy have been analysed at seasonal scale by comparing models' outputs directly related to fire danger (temperature, precipitation and wind speed) with reference data: the multi-model ENS (inferred from the ENSEMBLES models) proved to be able to describe the observed patterns satisfactorily both in amplitude and phase, instead Med-CORDEX models showed some shortcomings in reproducing the reference climate.

Then some investigations about climate change signals have been done, with some interest concerning temperature and precipitation. The projected temperature increase (1÷2 °C) appears robust and relatively certain because detectable by all models. It is worth noting that the widespread future warming is particularly stressed by ICTP-RegCM4 whose scenarios highlight a temperature increase of 2.5-3 °C by 2050. About precipitation, ENS projections are coherent with CMIP5 results and point out a significant precipitation decrease in summer season, variable across sub-regions between 10 and 20 % (over 20% in Southern Italy), whereas some controversial findings are deduced from Med-CORDEX projections. Despite some uncertainties (because of discrepancies among the models), the results reveal a trend toward increasing impacts from weather-related hazards in the coming decades, considering that “consecutive dry days” and “mean summer temperature” are the main drivers to enhance fire occurrences in the medium-term scenario over Europe (Lung et al. 2013).

The effects of climate change on the fire danger have been study by computing the Fire Weather Index (FWI) from ICTP-RegCM4 simulations (CNRM-ALADIN52 has been discarded because its poor performances in describing both seasonal precipitations and wind structure). The events with FWI ≥15 and the Seasonal Severity Rating (SSR) have been analysed at seasonal scale by considering their changes between FUT and REF. In addition, a simple statistical approach has been used by computing the percentage changes of the days selected through three threshold values (TX > 30°C, P < 0.5 mm/d and W > 2m/s). This last criterion has also been applied to seven ENSEMBLES models, investigating the degree of agreement among them in order to achieve more confidence results.

All the three criteria indicate the fire danger is projected to increase in the coming decades, above all in summer (at least 20% in most of Italy) with high confidence, confirming previous results (among others, Lung et al. 2103; Turco et al 2014; Lonzano et al. 2016). Indeed, if temperature rises without accompanying increase in rainfall amount, the meteorological conditions lead to a much drier forest and make fire ignition easier (and fire control more difficult).

The complexity of the problem was reduced by neglecting numerous societal components, land use and vegetation change. In particular, land use-land cover change is an important driving factor of global change and can affect a number of earth processes, including fires (Foley et al. 2005). Despite these simplifications and some uncertainties about the results, the presented set of indicators could be useful to achieve a more robust assessment of future fire danger over Italy thanks to the high spatial resolution of the models considered in this study.

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ERA-INTERIM data have been provided by ECMWF data server.

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7 CONFLICTS OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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