SERV_FORFIRE

INTEGRATED SERVICES AND APPROACHES FOR ASSESSING EFFECTS OF CLIMATE CHANGE AND EXTREME EVENTS FOR FIRE AND POST FIRE RISK PREVENTION

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SERV_FORFIRE – INTEGRATED SERVICES AND APPROACHES FOR FIRE MONITORING

1. EO based Operational applications for the fire management within the SERV_FORFIRE project

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In the framework of SERV_FORFIRE project, the use of satellite data has been adopted as operational tool. An example of best practice is provided by the Basilicata pilot area, where CNR-IMAA has further improved the operational tools already devised for the various phases of the fire management with specific attention to the estimation of: (i) fire danger and (ii) post fire monitoring, in terms of burnt areas and burn severity mapping using satellite sentinel 1 and 2 data.

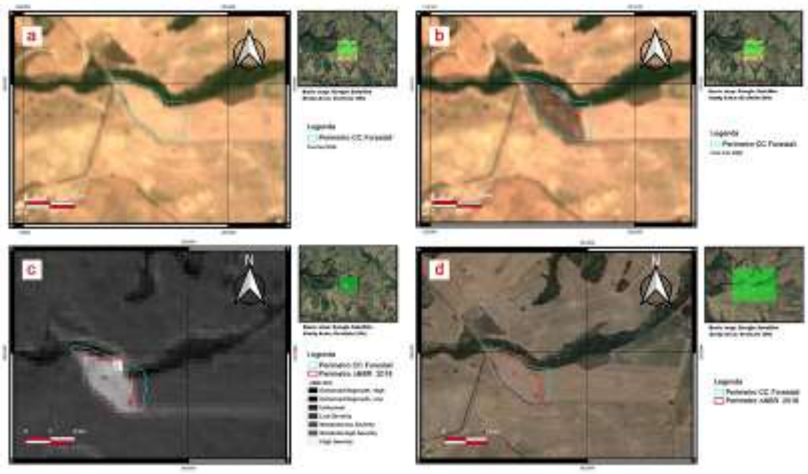

Figure 1. Fire occurred on the 25 July 2018 in the Grottole municipality (MT) affecting an area of about 4,04 ha mostly agricultural activities. A) Sentinel-2 pre-fire; and in b) post-fire; c) spectral index adopted to highlight the fire-affected area; d) comparison of fire mapping as obtained from satellite (in red line) and from the Carabinieri Forestali (in cyano line) in Italy in charge to perform the operational mapping of burnt area in situ

All the sentinel platforms provide satellite big data which require expensive hardware infrastructures and pose challenges linked with the processing, interpretation and validation issues, for transforming data into useful information. To face the need of suitable infrastructure today there are several cloud facilities as Google Earth Engine (GEE), available as open and free tools for research purposes or at low cost for other applications. Within SERV_FORFIRE, with the joint efforts of all the partners and several end –users, several tools have been developed which have been firstly adopted and tested in the pilot areas and later also applied and validated in other EU e non-EU countries as shown from the figures.

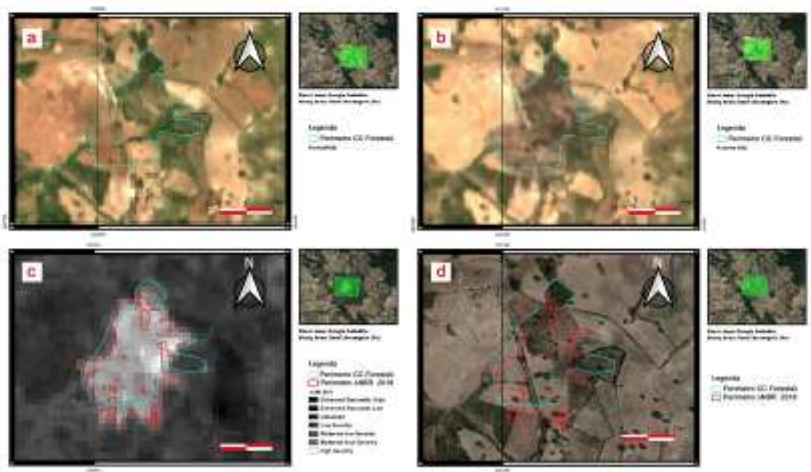

Figure 2. Fire occurred on the 16 July 2018 in the Sant'Arcangelo (PZ), affecting an area of about 9,56 ha mostly agricultural activities. A) Sentinel-2 pre-fire; and in b) post-fire; c) spectral index adopted to highlight the fire-affected area; d) comparison of fire mapping as obtained from satellite (in red line) and from the Carabinieri Forestali (cyano) in Italy in charge to perform the operational mapping of burnt area in situ

In particular, Figure 1 and Figure 2 show the small fire detected in Basilicata, along with the bigger events detected in France through the use of USGS (United States Geological Survey) thresholds for the characterization of Fire Severity as it can be seen in Figure 3. While, Sentinel-5 (S5) were used for the analysis of pollutants emissions due to the combustion of fires occurred in August 2019 in the south of Brazil, in the area of Mato Grosso do Sul (fig. 4).

As in example, the methodologies developed and applied in Basilicata have been continuously improved and joint tested by the Argon laboratory research team of the CNR-IMAA and the decision-makers of the Civil Protection Office of Basilicata Region. In particular,

- fire danger system is fully operational and daily updated during the fire season and *(http://www.protezionecivilebasilicata.it/protcivbas/css/themes/01/images/mappa.jpg)* developed by CNR-has been further improved using Copernicus products and satellite Sentinel data.
- Google Earth Engine tools have been developed to identify and map burnt area and burn severity
- Artificial Intelligence has been applied to improve the automatic categorization of several fire danger degrees as well as the different fire severity levels

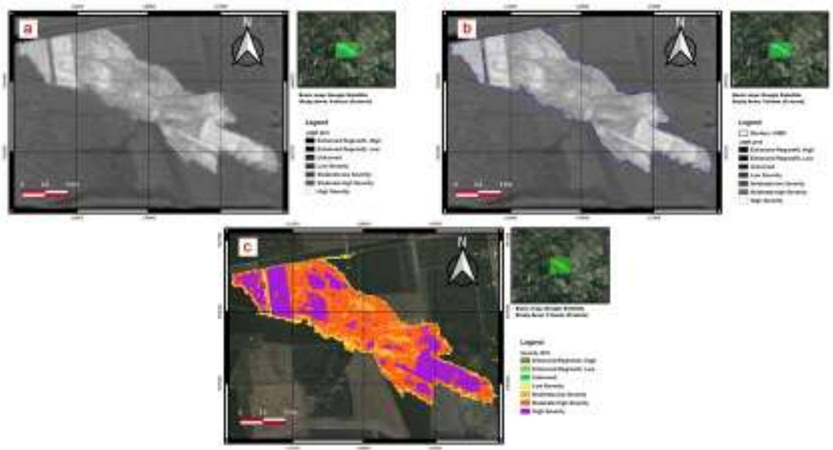

Figure 3. *Fire occurred on the 12 July 2019 in the Ychoux (France), affecting an area of about 153 ha mostly agricultural activities and forest of coniferous. A) Sentinel-2 ∆NBR; b) Perimeter (blue) of Sentinel-2 ∆NBR; c) Fire Severity threshold classification by USGS.*

- Assessment of cascading effects on soil erosions and landslides

Among the other tools, the joint use of Sentinel-2 satellite data and Google Earth Engine (GEE) has been set up to promptly map burnt areas and burn severity. The outputs from these tools are currently under validation in the diverse pilot areas of SERV_FORFIRE. The case study herein highlighted is the Basilicata Region (Southern Italy) selected as it is characterized by heterogeneous and fragmented ecosystems generally affected by very small fires (often ranging from less than 10 to 1 hectares). Today, it is widely recognized as a pressing issue because these fires, though small, are generally quite frequent and therefore strongly impacting the ecosystems and they were not captured by the medium space resolution satellite data as MODIS or Landsat TM, but they can be now captured using sentinel 1 and 2 data.

In Italy, as common for the whole Europe, the operational mapping of burned areas is performed on the basis of in situ analyses conducted at the end of the fire season in the locations where fire occurred. This is of course time consuming and moreover, no information / records are collected about burn severity, that is a critical information needed to support reliable mitigations strategies at diverse spatial and temporal scale, and in particular those that must be activated immediately after the fire occurrence.

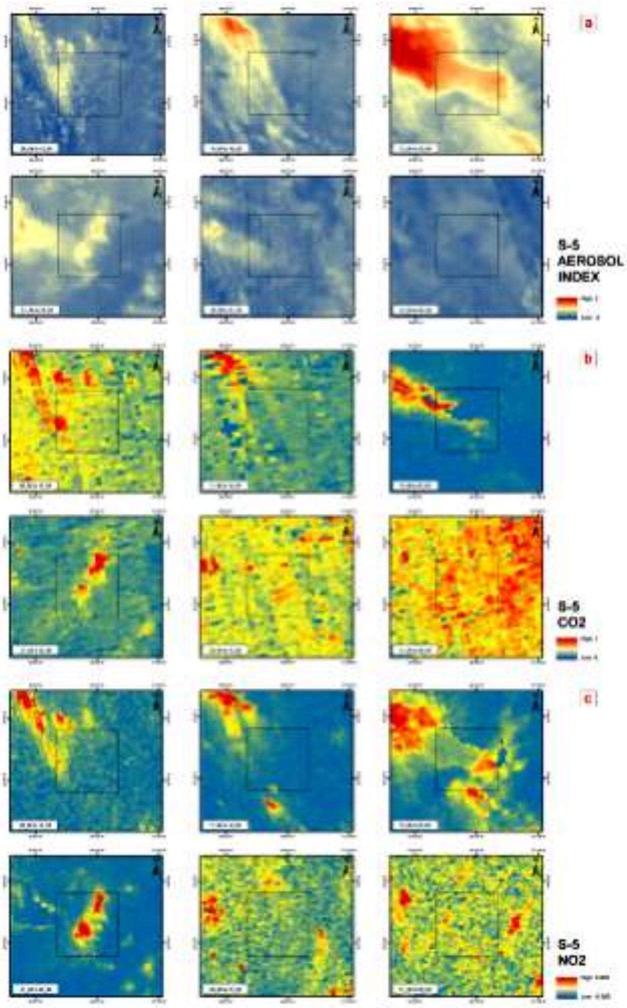

Figure 4. *Sentinel-5 imagery of pollutant emissions in the Mato Grosso do Sul, (Brazil). A) Aerosol index; b) CO2 (carbon dioxide); c) NO2 (nitrogen dioxide).*

2. What comes out from forest fire? An in-depth analysis of gaseous and particulate emissions from biomass burning on "Metaponto Natural Reserve".

Contribution by Enrica Nestola, *Consiglio Nazionale delle Ricerche (CNR) - Istituto di Ricerca sugli Ecosistemi Terrestri (IRET)*

Combustion tests have been performed on the biomass sampled in Metaponto National Reserve (Basilicata Region, South of Italy). The aim was the characterization of gaseous and particulate emissions from the combustion of different plant species.

Biomass was burned into a combustion chamber, which continuously quantifies emissions throughout the different phases of a fire. Controlled conditions allowed the characterization of the emission factors for different biomass types and properties.

As largely known, particulate matter (PM) is highly detrimental to human health, also depending on its chemical composition, and is one of the most significant emissions from forest fire. Furthermore, the finer is the PM the more dangerous is for health. For these reasons, PM was characterized both for the dimensional (PM1, PM2.5, PM10) and chemical composition, related to different tree species. Through this approach a PM emission profile of important forest species, such as Pinus sp. and Eucalyptus sp., has been created.

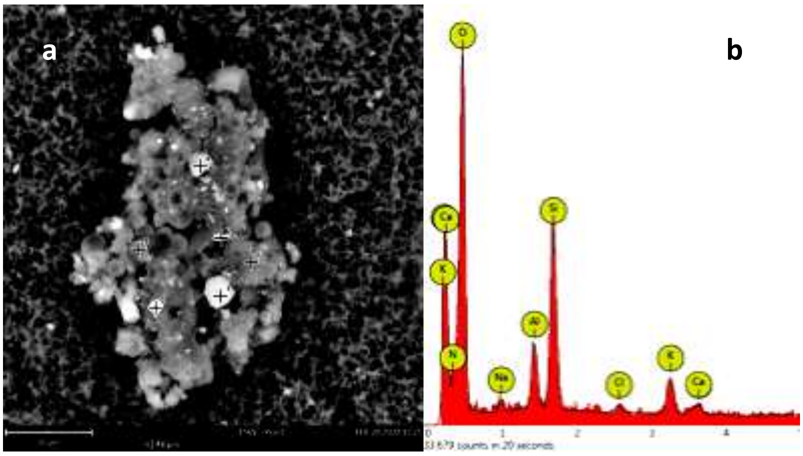

Figure 5. *(a) Representative SEM image showing PM on nitrocellulose filter; the laser beam position during the acquisition of the EDX spectra from the selected particles is indicated by the black cross; (b) representative EDX spectrum of particle Pinus halepensis sampling.*

Parametrization of the emissions coming from different plant type provides important information relevant to modelers and for the improvement of fire management.

3. The sub-seasonal forest fire risk outlook successfully piloted during the fire season 2020 in Finland.

Contribution by Andrea Vajda, *Finnish Meteorological Institute (FMI)*

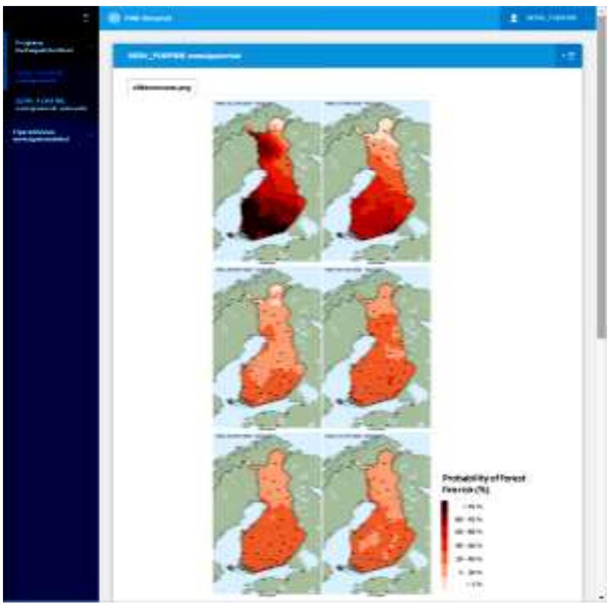

Figure 6. *Sub-seasonal forest fire risk climate outlooks issued to the end-users for testing through the web-based delivery platform Ilmanet (example from June 19, 2020).*

The sub-seasonal forest fire risk outlook prototype developed by the Finnish Meteorological Institute within the framework of SERV_FORFIRE project was piloted for the second time during the fire season 2020 with Finnish end-users. The end-users involved were the Regional State Administrative Agency (AVI) from Northern Finland and the Finnish Rescue Services from North Karelia. The newly developed sub-seasonal fire risk forecast product complements the already existing forest fire risk monitoring system and the short-range forest fire warnings. Predicting forest fire weather conditions a few weeks in advance allows fire authorities and rescue services to prepare and take sufficient provision of resources for potential forest fires earlier in advance.

The probability of fire danger was predicted using a statistical model originating from the Finnish Forest Fire Index (FFI) and the post-processed sub-seasonal system data from the European Centre for Medium-Range Weather Forecasts (ECMWF). The six-week forest fire risk outlooks were produced in an automated operational system and disseminated to the users during April-September through a web-based delivery platform (Fig. 6). The forecasts were updated twice a week.

Following the pilot season, a feedback survey was conducted among the users to gather their opinion about the usability of the sub-seasonal forest fire risk outlook prototype. 85% of the respondents found the sub-seasonal fire risk forecast product very useful or useful when planning the fire survey flights and 90% indicated their willingness to use the forecasts in the future.

4. On limits of short-term wildfire prediction.

Contribution by Tero Partanen, *Finnish Meteorological Institute (FMI)*

As a continuation of the fire prediction method developed within the ERA4CS SERV_FORFIRE project and presented at the 12th EARSeL Forest Fires SIG Workshop in Rome, Italy, October 2019, an extension of its results are briefly reported here. The predicted quantity of interest is the time-dependence of the fire radiative power (FRP) emitted by the fires of an area, which depends on the time of day, day of the year, area, and weather. Based on the prediction method developed and high temporal resolution SEVIRI FRP data, it was found that in areas with large numbers of wildfires on a daily basis during the dry seasons from year to year, the temporal FRP is quite predictable. On the other hand, in areas in which these conditions are not met, the temporal FRP is not predictable. To demonstrate, founded on parameterization to 2010 data, the map of Fig. 7 illustrates the correlations between the observed and predicted fire radiative energies (FREs, i.e., the temporal integrals of FRPs) on cloudless days over the dry season in 2018 for each 1.5° x 1.5° grid area in the savanna region of south-central Africa, whose observed fire seasonal FRE exceeds 1 PJ amount of energy to ensure adequate predictability. In most cases the r value exceeds 0.6, which indicates a moderate to very strong correlation between observations and predictions and that the method possesses some true predictive power. The ratio of the sums of observed and predicted fire seasonal FREs over all the 106 areas depicted in the right panel of Fig. 1 is 1.39. The method was also tested in Europe using nearly the entire Iberian Peninsula as a fire area of size 6.5° x 6.5°. Similarly to the unpredicted areas, with low FRE, in Fig. 7, it turned out that wildfires, which occur only in scarce numbers even within the vast Iberian area, on sporadic days are either randomly ignited or not. To predict such fires at a daily level is a game of pure luck, and thus cannot be done sensibly. The results make evident that with the exception of some specific areas of the world, predicting wildfires in general with a reasonable spatiotemporal resolution is practically impossible.

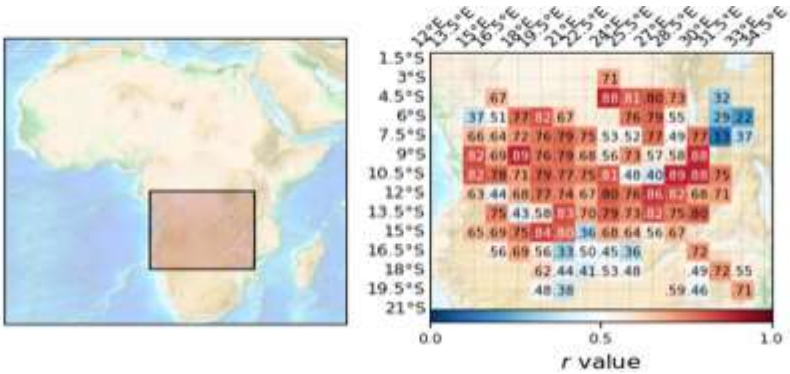

Figure 7. Correlation map between observed and predicted FREs of areas whose dry season is between April and November In the r values the zero before the decimal point is omitted. The shaded rectangle on the map of Africa on the left panel of the figure encloses the geographic test region spanned by the geographic coordinates [13.5, 33.0]° E and [1.5, 19.5]° S. The right panel of the figure illustrates a magnification of the test region, which contains all the 1.5° x 1.5° sized and evenly distributed areas whose the sum of the observed FRE values of the days that are unmasked by clouds over the fire season exceeds 1 PJ.

5. Merge historical documents digitalization with LiDAR: a method for the assessing, mitigation and dissemination of POST FIRE rockfall.

Contribution by: Lasaponara R.[1], Notti D.[2], Giordan D.[2], Guenzi D.[2]

[1] *Consiglio Nazionale delle Ricerche (CNR) - Istituto di Metodologie per l'Analisi Ambientale (IMAA)*
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We have created a methodological approach (that helps to create a database of previous knowledge and data for future study and dissemination for the population. The methodology is made of four steps: i) data collection; ii) organised geo-database setup; iii) OM reduction; iv) result dissemination (Fig. 8).

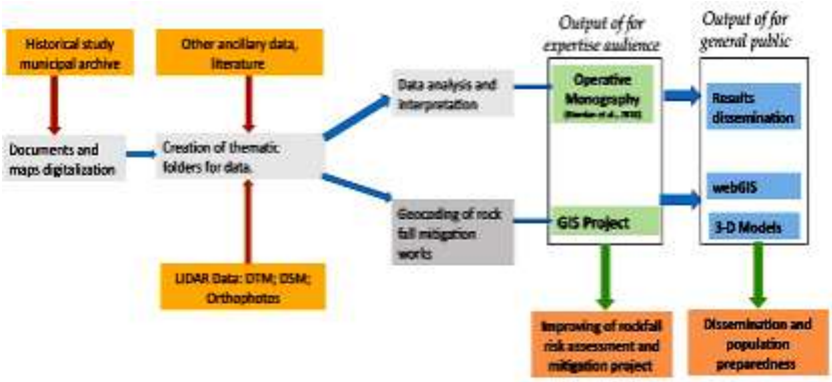

__Figure 8.__ The methodology flow-chart

In the first step, the data collection, we have two main inputs data:
The digitalisation of old studies from the archive of Lauria municipality and the geocoding of project maps on a GIS.
Very high-resolution LIDAR data (DTM and Orthophotos) of the study area. The LIDAR survey was made by an external enterprise.
The second step is creating an organised database, in which the studies and project materials were allocated in different folders on the base of the year of production, works certification and typology.
At the same on GIS software, we create a geo-database of the main rockfall mitigation works, geomechanical data, and other ancillary data. The mitigation structure was geolocated also using the high-resolution LiDAR orthophoto. We also did a ground survey to take photos of the most representative mitigation structures. In a third step, we create the OM that represents a practical (and standardised) organisation of what we already know about the studied phenomenon is the first fundamental step for better management of a possible emergency related to an increase of the activity of the slope instability.
The setup of the geo-database of mitigation works combined with high-resolution LIDAR and RPAS surveys could be the base for future and detailed rockfall modelling. (e.g. precise impact energy estimation for new structures).
The last step is dissemination. This phase is aimed to increase the population preparedness and knowledge about the rockfall risk. The main products are creating WebGIS with free-cost software and 3-D models for interactive visualisation of the affected areas.
To create the WebGIS of Lauria rockfall mitigation works, we used GeoServer and MapStore services.
The GeoServer (http://geoserver.org/) is a web mapping server for the dissemination of GD. GeoServer is a FOSS server written entirely in Java that allows users to store, view and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards (Cignetti et al., 2019).
MapStore (https://www.geosolutionsgroup.com/technologies/mapstore/) is a professional open-source cartography and geographical information platform based on the topological map model that allows creating WebGIS service using the WMS obtained from GeoServer.
To create a 3-D interactive view of the mitigation works (that can be used with any browser without installing GIS or other software), we used the Qgis2threejs plugin for QGIS and LIDAR DTM as elevation layer to create the 3-D view model.

A digital archive of past mitigation works

We digitalised about 70 documents and maps from the Lauria town hall archive, and we organised them in structured folders (Table 1). The maps of the ubication of the rockfall mitigation structures were digitalized in geo-database (Fig. 9), containing more detailed information than the paper map. For instance, for each installation, it is possible to know the type and the number of anchors, eyebolt anchor or the mesh used (e.g. double-twisted hexagonal wire mesh). When it was possible, we also classified the barrier using the photos taken on the ground (Fig. 10).

Folder	Name	Description	Format
01 1997 projects	Barrier specification	Design specification required for barriers	PDF document
	Impact test	Impact test to evaluate the energy load on barriers	PDF document
02 1998 studies	Geomechanical stations	Resume of the main geomechanical parameters for each station	PDF document/ Table
	Maps of geomechanical stations	Approximative ubication of geomechanical stations	Geo-database on GIS
03 2000 final projects	Spread instability mitigation	Ubication of the mitigation works for widespread rockfall instability	Geo-database on GIS
	Spot instability mitigation	Ubication of the mitigation works for local rockfall instability	Geo-database on GIS
04 2002 Restoration work	Geological settings reports	Geological and survey report on 2002 rockfall event	PDF document
	1-D Rockfall modelling	Results of 1-D Rockfall modelling on collapsed areas	PDF document
	Restoration of barrier	Maps of the design of the restoration of barriers, nets damaged by the 2002 event	Geo-database on GIS

Table 1. *An Example of the organisation of the digitalised materials*

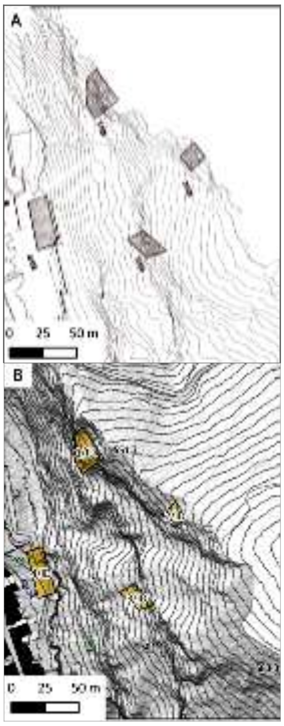

Figure 9 *. A) Original document showing the location of some mitigation structure for widespread rockfall. B) the digital version overlapped to hillshade derived from LIDAR DTM.*

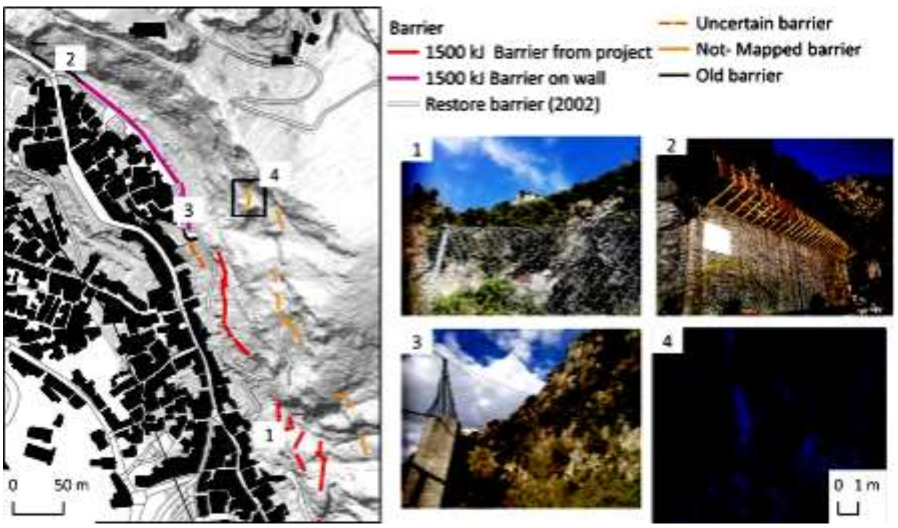

Figure 10. *Map of barriers classified on the base of available documents. 1) An example of a certified barrier (1500 kJ energy); 2) An old type of barrier not reported in any documents; 3) A certified barrier installed over an older concrete wall; 4) A Detailed view of a barrier partially masked by vegetation in LiDAR orthophoto*

6. High Resolution Seasonal Forest Fire Danger mapping for South Italy

Contribution by Vassiliki Varela, Diamando Vlachgiannis, Athanasios Sfetsos, Stelios Karozis

National Center of Scientific Research "Demokritos" - NCSRD)

This work shows the use of the the Canadian FWI system indices of the Canadian System CFFDRS (Van Wagner et al 1985) combined with a state-of-the-art seasonal meteorological forecasting model, for predictive high resolution fire danger mapping for the fire period of the year 2020 and 2021, for South Italy, as a tool to design medium-term prevention planning.

The resulting maps for 2020 are presented below:

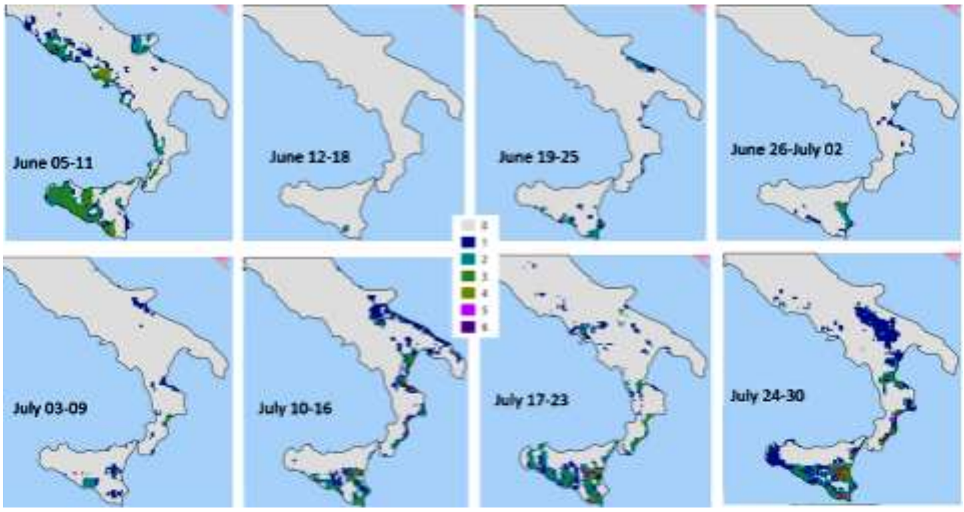

Figure 11. *Weekly maps of the number of days with very high and extreme FWI class (FWI>50) for June – July 2020, for South Italy*

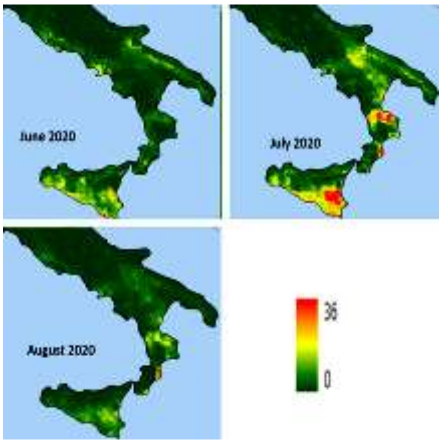

Figure 12. *Monthly Severity Rating Maps for June, July and August 2020 for South Italy*

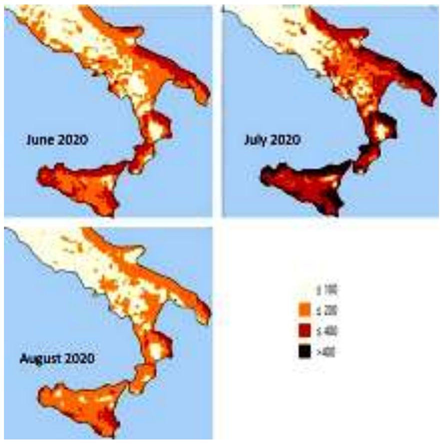

Figure 13 - Monthly Mean Drought Code Maps for June, July and August 2020 for South Italy

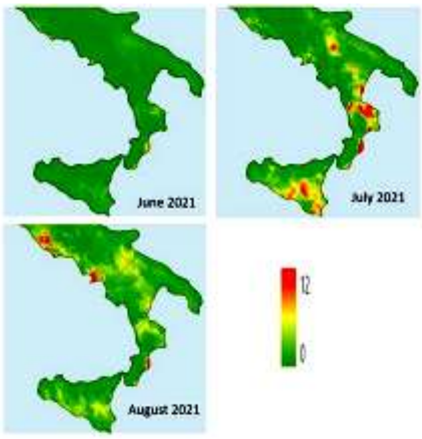

Figure 14. *Monthly Severity Rating Maps for June, July and August 2021 for South Italy*

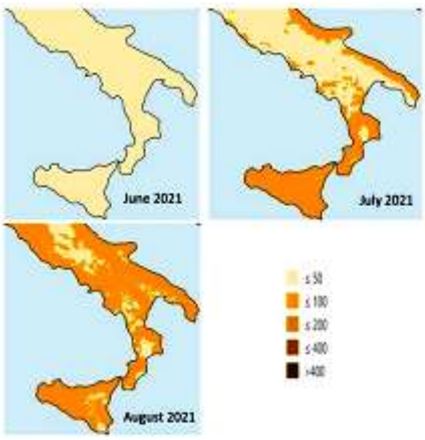

Figure 15 - Monthly Mean Drought Code Maps for June, July and August 2021 for South Italy

7. Empirical statistical forecasting system of fire risk using the monthly drought code

Contribution by *Krikken F., van Oldenborgh G.J., Kew S., van Velthoven P.F.J.*
Royal Netherlands Meteorological Institute (KNMI)

In WP3 KNMI has developed an empirical statistical forecasting system of the fire weather monthly drought code (MDC) which is an established indicator for seasonal fire activity. The MDC is constructed from monthly maximum temperature and monthly precipitation. We use the dataset from Berkely Earth Database, for monthly precipitation (the Global Precipitation Analysis Products of the Global Precipitation Climatology Centre, GPCC). The main predictors are climate indices (NINO34, PDO, AMO, etc) which are available in the KNMI climate explorer.

The model is based on multiple linear regression for producing probabilistic forecasts of monthly drought code across for the northern hemisphere based on Eden et al. (2015). The global CO2-equivalent concentration is taken as the primary predictor; subsequent predictors, including large-scale modes of variability in the climate system and local-scale information, are selected on the basis of their physical

Figure 17. *Screenshot of the Climate Explorer app for dissemination of the MDC seasonal forecasts.*

relationship with the predictand. The forecasts are made in the beginning of the fire season, and then updated monthly. Verification of the forecast is done through cross-validation.

The forecasts are disseminated through the KNMI climate explorer, using an interactive online Python application (figure 17), in order to convey forecast information in a simple and digestible manner. The website is accessible at http://climexp.knmi.nl/kprep_mdc. A forecasting page allows for end-users to assess local seasonal fire weather risk, associated forecast skill, and the relation between historical MDC and observed fires. The forecasts are updated monthly throughout the fire season. A research page allows for local and global analysis of the sources of predictability, and characterization of the patterns of spatial and temporal variability of fire weather risk.

KNMI has also performed climate attribution studies of recent extreme forest fires in Sweden, Portugal and Australia:

The forest fires in Sweden in 2018

For climate change attribution of extreme forest fires a methodology was developed that is similar to those in other climate attribution studies. First, we study the specific case using observations and reanalysis products. Then we define the event in a spatial and temporal coherent way to reflect its impact. Next, we assess the return times of the event using extreme value statistics. Using climate model simulations of previous, current and future climate we can assess whether the likelihood of such an event has / will increase or decrease relative to pre-industrial climate. For the forest fires in Sweden we used the ERA-Interim reanalysis (Dee et al., 2011) and climate model simulations from EC-Earth (Hazeleger et al. 2010) and from CESM1-LENS (Kay et al. 2015). The results were reported in (Krikken et al., 2019) and the results were also presented at the EGU in 2019. Here we list the general conclusions. We find that the maximum forest fire risk in July 2018 had return times of ~15 years in Svealand, ~20 years in Gotaland and ~40 years in Norrland. Further, we find a negative trend of the Canadian Fire Weather Index (FWI) for Svealand and Gotaland for the 1979 to 2017 time period, yielding a decreased risk of such an event solely based on reanalysis data. Note however that the uncertainty herein is large, owing to a relative short observational record and large natural variability of the FWI. The 2 large-ensemble climate models (EC-Earth and CESM1-LE) point to 2 to 3 times increased risk for such an event in all three regions for a 2OC warmer climate, relative to pre-industrial climate (figure 18). For the current climate relative to pre-industrial climate we find no clear response, where CESM1-LE points to a slight decreased risk of such an event but EC-Earth to a slight increased risk of such an event.

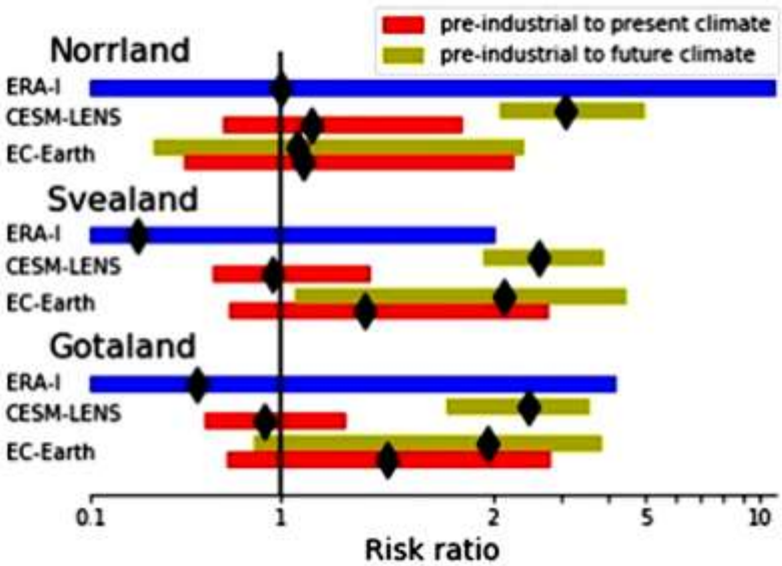

Figure 18. Risk Ratio for Norrland, Svealand and Gotaland

The forest fires in Portugal 2017

The forest fires in Portugal 2017 were selected as a case study because of the severity of the fires and the impact it had on society, specifically the large number of casualties.

We follow the same method previously applied to the climate attribution of the forest fires in Sweden 2018 (see above). We used again the FWI to quantify the fire weather risk, this time using the ERA5 instead of the ERA-interim reanalysis, and again simulations with the two climate models EC-Earth and CESM. The reanalysis is used to get an observational estimate, while the climate models are used to get an estimate of past, present and future fire weather risk.

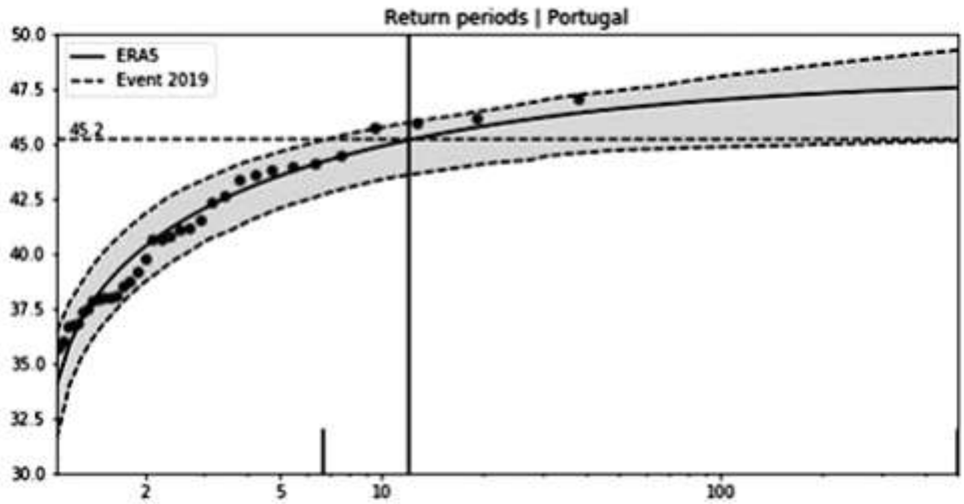

Figure 19. *Return times of the 2017 forest fire event, based on ERA5 reanalysis data*

Figure 19 shows the return time of the 2017 forest fire event, defined as the maximum FWI during the fire season, averaged over Portugal, with a 7-day rolling mean applied. The return time of ~11 years indicate that based on only the fire weather, it was indeed a rare event but not unprecedented over the last 40 years.

Figure 20 again illustrates the risk ratios, i.e. how much more or less likely such an event has become relative to pre-industrial climate. We can see that based on ERA5; the event has become ~10 times more likely. Both climate models show distinct different responses, where CESM gives a large increased risk for such event both for current and future climate. EC-Earth however shows decreased risk for such an event for the present climate and the same risk for future climate.

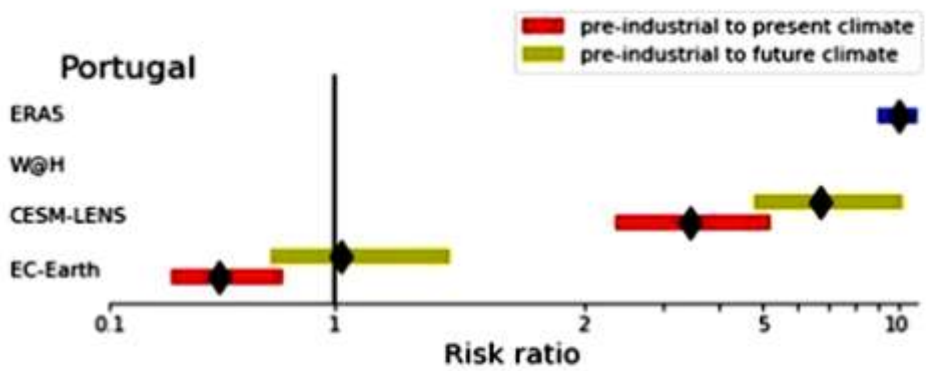

Figure 20. *Risk ratios of the Portugal 2017 forest fires, for ERA5 (reanalysis) and CESM and EC-Earth (climate models). The risk ratios are given relative to pre-industrial climate.*

The forest fires in Australia in 2019/2020

Disastrous bushfires during the last months of 2019 and January 2020 affected Australia, raising the question to what extent the risk of these fires was exacerbated by anthropogenic climate change. To answer the question for southeastern Australia, where fires were particularly severe, affecting people and ecosystems, Van Oldenborgh et al. (2021) used again the Fire Weather Index (FWI); the ERA5 ranalysis; and in this case 11 large ensembles of state-of-the-art climate models. They found large trends in the FWI in ERA5 since 1979 and a smaller but significant increase by at least 30 % in the climate models. Hence, climate change has induced a higher weather-induced risk of such an extreme fire season. This trend is mainly driven by the increase of temperature extremes. In agreement with previous analyses we find that heat extremes have become more likely by at least a factor of 2 due to the long-term warming trend. However, current climate models overestimate variability and tend to underestimate the long-term trend in these extremes, so the true change in the likelihood of extreme heat could be larger, suggesting that the attribution of the increased fire weather risk is a conservative estimate. We do not find an attributable trend in either extreme annual drought or the driest month of the fire season, September–February. The observations, however, show a weak drying trend in the annual mean. For the 2019/20 season more than half of the July–December drought was driven by record excursions of the Indian Ocean Dipole and Southern Annular Mode, factors which are included in the analysis here. The study revealed the complexity of the 2019/20 bushfire event, with some but not all drivers showing an imprint of anthropogenic climate change.

8. Modeling potential impact of wildfire on hydrology and soil erosion

Contribution by De Girolamo A.M.[1], Cerdan O.[2], Grangeon T.[2], Vandromme R.[2], Lo Porto A.[1]

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Wildfire is a disturbance for ecosystems, it may alter the soil properties (i.e. reducing infiltration capacity, increasing water repellency) increase soil erosion, and it may have a severe impact on water quality. Fire-related contaminants, which are delivered to the river with suspended sediment, may lead to a depletion of water quality with consequences for aquatic ecosystems that could preclude the achievement of the Water Framework Directive objectives.

After wildfires, to reduce soil erosion, post-fire mitigation or rehabilitation measures are generally adopted. The choice of the most appropriate mitigation measure is not an easy task. Hydrological and soil erosion models may be useful tools to predict the hydro-sedimentary response and to select the appropriate rehabilitation measures.

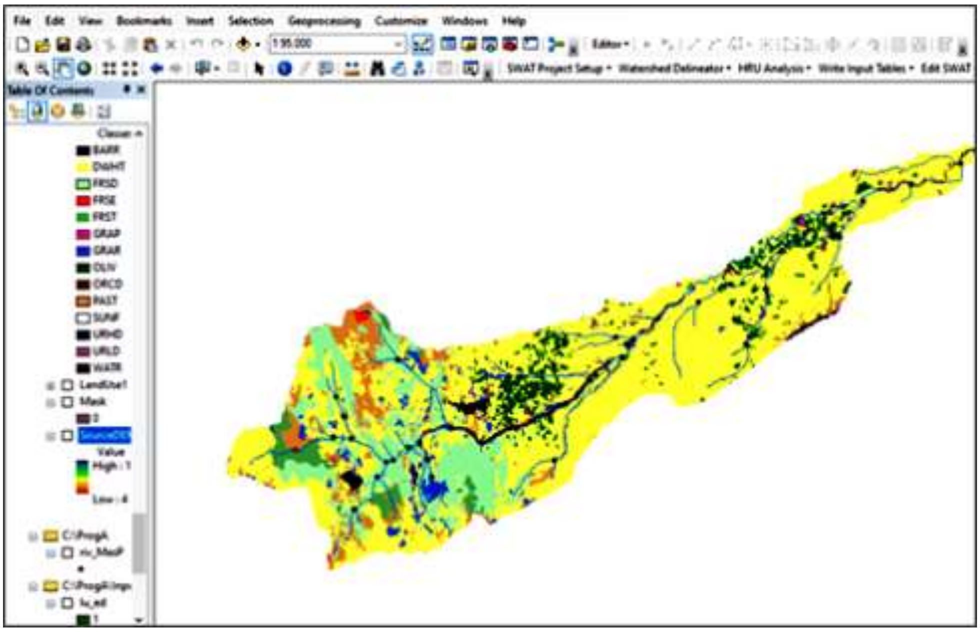

Figure 21. Study area: Celone River Basin (Italy)

Through a case study, a procedure was defined to assess the potential impact of wildfire with different severity levels on hydrology, soil losses, and sediment transport to the river network. In addition, the effects of possible rehabilitation measures on soil erosion and runoff were investigated by using the Soil and Water Assessment Tool model (SWAT), which proved to be effective for post-fire management. The study focuses on a high temporal and spatial scale with a management perspective. The study area (Figure 21), the Celone River Basin (Puglia, Italy), is classified at a high risk of fire due to weather conditions and ignition sources (deciduous and mixed forests).

At the outlet of the basin, the mean annual specific sediment yield (SSY) estimated over the period 1990 to 2011 was 5.60 t ha^{-1} y^{-1}, ranging from 3.03 t ha^{-1} y^{-1} to 13.82 t ha^{-1} y^{-1}. Most of the annual load was delivered during the wet season, from December to March. Land use and slope were the main factors influencing soil erosion.

At the sub-basin scale, the areas characterized by steep slopes and pasture or bare soil showed the highest values of soil losses. Among agricultural crops, durum wheat production in hilly areas, where up-and-down tillage was generally adopted, showed high values of soil losses.

The SWAT model has been developed for watershed management but not specifically for forest fire predictions. In the present study, it was adapted to estimate the effects of wildfire by modifying the hydrological and sedimentary parameters in order to represent changes in soil water repellency in burnt areas and in soil protection due to the damage of vegetation cover. The runoff increase was estimated by modifying parameters such as the Manning's roughness coefficient (OV_N), the initial SCS runoff Curve Number for soil moisture condition II (CNII), and saturated hydraulic conductivity (Sol_K). The reduction of soil protection was assessed by modifying the USLE C factor for water erosion of soil, the USLE equation support practice factor USLE_P, the USLE erodibility factor USLE_K.

Six different post-fire scenarios were analysed and the hydro-sedimentary response was estimated at various spatial scales for one year after a wildfire as follows:

Scen 1: high-severity fire and post-fire logging

Scen 2: high-severity fire and natural regeneration

Scen 3: high-severity fire and emergency stabilization (straw mulching and seeding)

Scen 4: moderate-severity fire and erosion barriers

Scen 5: low-severity fire and natural regeneration

Scen 6: very low-severity fire and natural regeneration

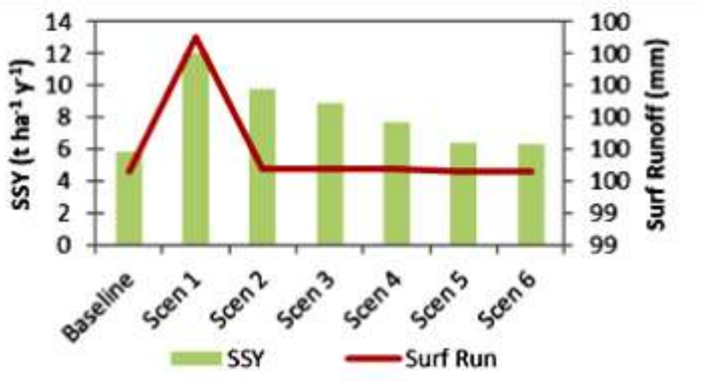

Figure 22. *Specific sediment yield (green bars, t ha^{-1} y^{-1}) and runoff (red line, mm) predicted for the post-fire scenarios.*

At the basin scale, considering a limited burnt area of (2.3% of the basin), the post-fire effect on surface runoff was negligible for all the scenarios except for Scen 1, and the impact on SSY was an increase, up to 12.05 t ha-1 y-1. The post-fire mitigation measures such as straw mulching and erosion barriers were effective to reduce soil erosion in moderate- and high -severity fires (8.94 t ha-1 y-1 and 7.66 t ha-1 y-1, respectively).

In the context of climate change, rising temperatures and changes in rainfall regimes are expected and with the increase of extreme events and dry summers, an increasing risk of wildfires is presumable. In the case study, forested areas are located in the upper part of the basin, which is the most important source of freshwater of the area, and the reservoir located in the middle course of the Celone River is an important source of water for agriculture. It is important to prevent wildfires and to monitor post-fire impacts since burned areas might represent a source of pollution to the reservoir and constitute a source of sediment load, whose increase could lead to the silting of the reservoir. An analysis of impact of the forest fire under climate change was estimated for the period 2030-2059 under the projections KNMI_RACMO_ECHAM5, MPI_REMO_ECHAM5, and SMHI_RCA_ECHAM5. An increase of sediment load ranging from 15% to 38% under high-severity fire is expected. The main cause of the increased sediment load is attributable to the fire severity, meanwhile, climate change seems to have a minor role. Based on these results, it is evident that mitigation measures are needed to reduce surface runoff and sediment loads after wildfires. The program of measures has to include burned-area emergency rehabilitation (i.e. straw mulching and seeding), erosion barriers, channel treatments, and contour log terraces.

9. A bias adjusted SPI seasonal forecast for the Mediterranean basin

Contribution by Pasqui Massimiliano, Quaresima Sara, Magno Ramona and Di Giuseppe Edmondo,

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In the last period of the SERV_FORFIRE project it has been developed an operational chain to forecast, at seasonal time scale, the Standardize Precipitation Index (SPI) to support drought and fire risks management. The forecast tool is based on the most recent and evolute version of the ECMWF numerical seasonal forecast system, named SEAS5 (Johnson et al., 2019). Each month, from 1993 to the present, SEAS5 provides an ensemble of daily simulations, lasting 7 months each; these simulations are free accessible from the Copernicus Data Store.

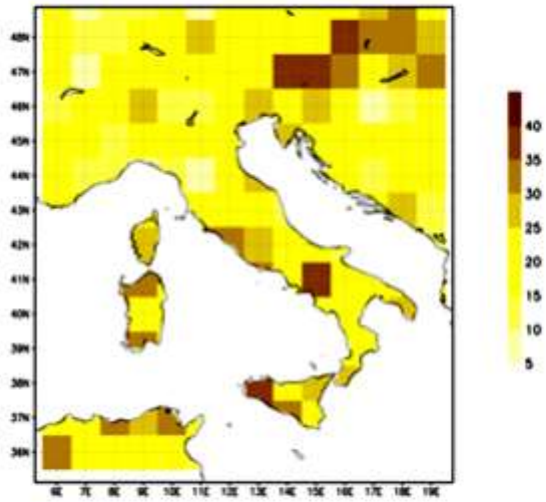
For the SERV_FORFIRE goals, the SEAS5 system is used to derive the seasonal predictions of the SPI index to evaluate drought conditions a few months in advance starting from the daily precipitation ensemble simulations. This effort is made for increasing the amount of forecast information available for decision making processes.

The SEAS5 daily precipitation seasonal forecasts, with a horizontal resolution of 1°x1°, are bias adjusted using the Multi-Source Weighted-Ensemble Precipitation (MSWEP) dataset (version 2.8, Beck et al., 2017 and Beck et al., 2019). MSWEP is a global precipitation product with an original 3-hourly, 0.1° resolution available from 1979 to the present; it merges gauge, satellite, and reanalysis data to obtain a high quality precipitation estimates at every location.

The bias adjustment is performed by using the CSTools R Package (CSTools: Assessing Skill of Climate Forecasts on Seasonal-to-Decadal Timescales) applying a quantile-quantile mapping algorithm (Nuria Peres-Zanon et al., 2020). This algorithm adjusts/corrects the quantiles of the modelled distribution (the raw SEAS5 daily precipitation distribution) by using an observed distribution set as reference (the MSWEP daily precipitation distribution). Thus each SEAS5 grid-points of each ensemble member is 1) reprojected onto the highest resolution MSWEP dataset, and then 2) the resulting high resolution daily time-series precipitation distribution is adjusted using a quantile transformation (Gudmundsson et al. 2012). A 1993 – 2016 period is used for the adjustment.

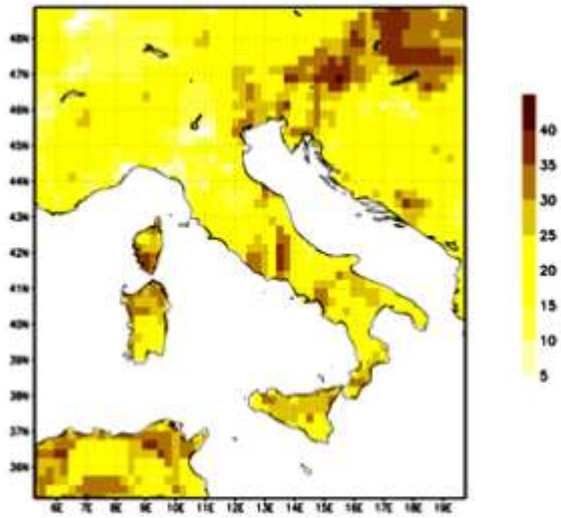
The resulting high resolution and bias-adjusted daily rainfall forecast dataset are then used to compute the SPI index for a series of timescales: 1, 2, 3, 4, 5 and 6 months, for the period 1993 to the present.

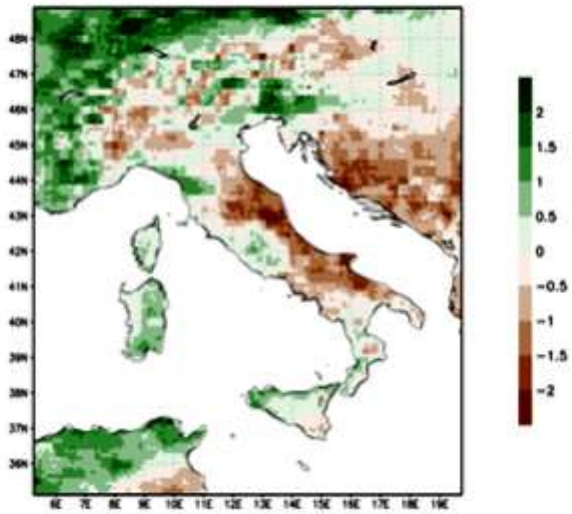
These new bias adjusted forecasts, along with the empirical seasonal forecasts and other monitoring drought and vegetation indices, are free accessible through the Drought Observatory Climate Service (DO - https://drought.climateservices.it) and described in Magno et al, 2018 and Vajda et al., 2020.



a)

b)





c)

__Figure 23.__ An example of the unbiased/raw SEAS5 data compared to the bias adjusted SEAS5 data with quantile-quantile mapping algorithm by using the MSWEP dataset and to the reference observed values: __a)__ Unbiased/raw SEAS5 SPI1 June 2021 probability values of exceeding the -1.0 moderate drought threshold; __b)__ bias adjusted SEAS5 SPI1 June probability values of exceeding the -1.0 moderate drought threshold. __c)__ Reference/observed SPI1 values for June 2021 from the MSWEP dataset . All the SPI1 values are based on the 1993-2021 time period and computed using a gamma distribution projection.

SERV_FORFIRE – INTEGRATED SERVICES AND APPROACHES FOR FIRE MONITORING

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