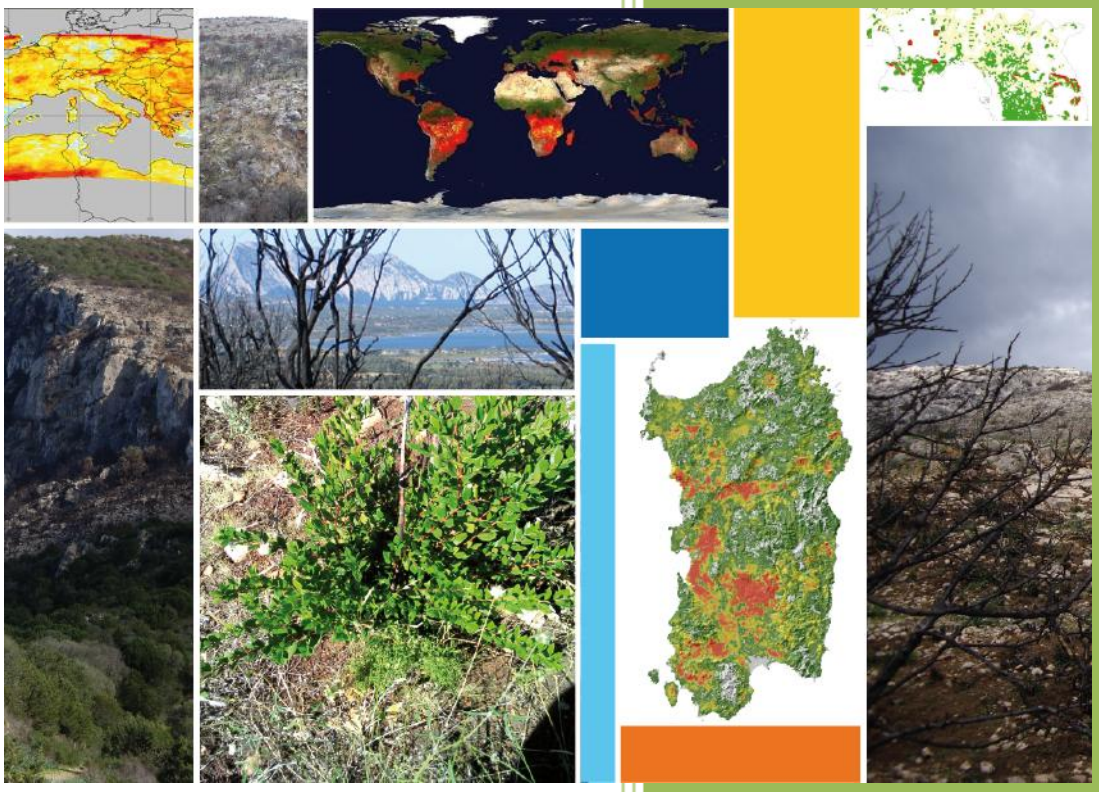
ICFBR 2015

II International Conference on Fire Behaviour and Risk



Alghero (Italy),
26-29 May 2015

Book of Abstracts

ICFBR 2015

International Conference on Fire Behaviour and Risk

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Supported by the EXTREME Project

"Development of methodologies and support systems for fire risk assessment in extreme weather conditions"

Sardinia Region (Regional Law n. 7/2007)

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Welcome Message

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Donatella Spano
Uniss-DIPNET
CMCC-IAFES

Marco Vannini
Uniss-DISEA

Antonio Navarra
CMCC

It is our great pleasure to welcome you to Alghero for attending ICFBR 2015, the second edition of the International Conference on Fire Behaviour and Risk.

ICFBR 2015 was organized by the Institute of Biometeorology of the National Research Council of Italy (CNR Ibimet, Sassari), the Departments of Science for Nature and Environmental Resources (DipNET) and Economic and Business Sciences (DiSEA) of the University of Sassari, and the Euro-Mediterranean Center on Climate Change (CMCC), with the purpose of involving scientists, researchers and policy makers whose activities are focused on different aspects of wildland fires and their impacts.

This year's conference continues its recent tradition of being one of the premier European forum for presentation of research results and experience reports on leading edge issues of the effects of fire on the environment and society, including modelling and monitoring, adaptation and mitigation strategies, and sustainable management. The mission of the conference is to discuss and share novel fire management policies to reduce the wildland and wildland-urban interface fire risk and identify new directions for future research and development. ICFBR 2015 gives researchers and practitioners a unique opportunity to share their perspectives with others interested in the various aspects of wildland fire behaviour and risk.

The conference is organized within the Extreme project (Development of methodologies and support systems for fire risk assessment in extreme weather conditions), funded by the Sardinia Region (Regional Law n. 7/2007), and under the patronage of the Italian Society for Climate Sciences (SISC) and the International Association of Wildland Fire (IAWF).

The call for papers attracted submissions not only from all over Europe (e.g., Portugal, Spain, France, Italy, Greece, Croatia, Czech Republic, UK, Romania, Switzerland, Finland) but also from Russia, USA, Canada, Brazil and Mexico, Australia and Singapore.

We also encourage attendees to attend the keynote and invited talk presentations. These valuable and insightful talks can and will guide us to a better understanding of the future.

Putting together ICFBR 2015 was a team effort. We first thank the authors for providing the content of the program. We are grateful to the scientific committee and the paper reviewers, who worked very hard in reviewing abstracts and providing feedback for authors. Finally, we would also like to express our personal thanks to all the components of the Organizing Committee and the Secretariat for the great effort and care during all the months that preceded the Conference days.

We hope that you will find this program interesting and thought-provoking and that the conference will provide you with a valuable opportunity to share ideas with other researchers and practitioners from institutions around the world.

Yours sincerely,

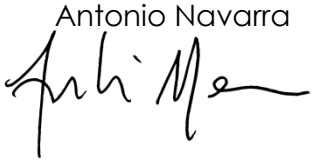
The Conveners of the Conference

Pierpaolo Duce

Donatella Spano

Marco Vannini

Antonio Navarra



Conferece aims

The II International Conference on Fire Behaviour and Risk, held in Alghero, Italy, from May 26th to 29th, 2015, aims to involve scientists, researchers and policy makers whose activities are focused on different aspects of fires and their impacts.

The main objectives of the Conference are to:

- Advance knowledge on interactions, relationships, feedbacks, and cascading effects of fire on environment and society;
- Encourage discussion and sharing on fire modelling and monitoring, adaptation and mitigation strategies, and sustainable management;
- Foster constructive and interdisciplinary dialogue between scientists, stakeholders, and policy makers;
- Promote international cooperation.

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Keynote Lectures

Mark Finney

Research Forester

USDA Forest Service, Rocky Mountain Research Station, Missoula, MT (USA)

Laboratory Experiments Lead to New Understanding of Wildfire Spread

Technology has improved our utilization of existing fire models but has contributed little to advancing knowledge of how fire spreads. The knowledge of physical processes, and their organization in producing fire spread, is essential to reliably modeling wildland fire behaviors beyond current capabilities (crown fire, thresholds etc.). To date, this knowledge has been so incomplete that physical models have been based on assumptions borrowed from other disciplines without considering the unique context of fire and fuels in wildlands. Even now, the roles of radiation and convection have yet to be conclusively determined. This presentation will report results of ongoing experimental research that has revealed how forward convective heating and particle ignition in spreading fires derives from buoyancy-induced instabilities and vorticity. The flame behaviors were discovered through laboratory experiments of spreading fires using highly uniform fuel beds made of laser-cut cardboard. For the first time, flame structures and their motions can be recognized as deriving from buoyancy-driven instabilities. This research is crucial to developing a verifiable theory of flame spread in wildfires and to someday producing simple but physically based models.

Dave Calkin

Research Forester

USDA Forest Service, Rocky Mountain Research Station, Missoula, MT (USA)

Breaking the Cycle of Increasing Wildfire Risk

Over the last several decades, in many areas of the world, wildfire activity, damage, and management cost have increased substantially. A number of factors have been identified as causal agents including fuel accumulation due to aggressive suppression, ex-urban development of the Wildland Urban Interface (WUI) in some areas, rural land abandonment in others, and more severe fire weather due to global climate change. The increasing wildfire work load has put substantial pressure on government agencies charged with wildfire management to continue and expand the policy of aggressive suppression. However, in many parts of the globe aggressive suppression is one of the major factors that drive the increased extent, intensity, and damage associated with the small number of large wildfires that escape containment efforts. Positive feedback loops within wildfire management systems lead to increasing suppression response demand while simultaneously increasing wildfire risk in the future. Despite a wealth of scientific research that demonstrates the limitations of the current management paradigm, pressure to maintain the existing system are well entrenched and driven by the existing social

systems that have evolved under our current practices. Societal expectations and existing management incentive structures result in policy implementation that is straining the resilience of fire adapted ecosystems and the communities that reside in and adjacent to them.

The self-reinforcing nature of the existing management structure drives the current increasing risk trajectory. Fortunately, many mitigation efforts designed to reduce future wildfire risk are self-reinforcing as well. That is, the more we invest in those activities in the current time period the lower future investments will need to be to reduce wildfire risk. For example landscape scale hazardous fuel reduction treatment programs appear to be subject to threshold effects. At low level of treatment expected reduction in wildfire risk is relatively low due to the low probability that a future wildfire will be influenced by a small treated area and the ease with which wildfire can spread around such treatments. However, as treated area increases the likelihood that fires and treated areas interact becomes much higher and a spreading wildfire may interact with multiple treated areas significantly slowing spread and increasing suppression effectiveness. Thus, once the threshold is reached the economic returns from fuel treatment investments may increase dramatically. Additionally, managerial experience and reduced cost of re-entry make maintaining these landscapes far less expensive than the initial investment level. Similarly, the self-reinforcing nature of allowing wildfires to burn freely has been well demonstrated on selected public lands. Within these remote areas, the more wildfire on the landscape the higher the likelihood that future fire spread will be impeded by previously burned areas, and thus pose lower risk to communities and other resource values that may be damaged by wildfire spreading from distant ignitions. It is critical to recognize that each high risk landscape will require a suite of locally tailored actions to reduce potential losses due to wildfire and reduce the demand for fire suppression response into the future.

Emilio Chuvieco

Professor

University of Alcalà, Spain

Advances in remote sensing for fire prevention, detection and impact assessment

Remotely sensed data has become a critical source of environmental information to better understand the Earth system. Technical developments in both sensor design and digital image processing are extending the range and efficacy of retrieved data to cope with a growing demand of updated and accurate information for diverse environmental fields. Assessment of fire risk conditions and fire impacts is a good example of the remote sensing contribution to improve land management.

This talk will present the current challenges of acquiring and integrating remote sensing data into fire management activities, from estimating risk conditions to detecting active fires and assessing fire impacts. Examples from these three topics will be presented, along with the most recent trends in satellite and airborne technologies: growingly use of UAV, integration of optical and radar data, synergy between active and passive systems, and scaling up processes. The last part of the talk will be dedicated to present a new global burned area product based on European sensors, developed under the Climate Change Initiative of ESA. Methods to generate and validate the product will be presented, along its use in atmospheric emissions and dynamic vegetation models.

Climate and Fire

Oral Presentations

CLF.01 - WEATHER, CLIMATE, CLIMATE CHANGE AND WILDLAND FIRE

Flannigan M.[1], Wotton M.[2,3], De Groot B.[4], Marshall G.[1]

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Fire activity is strongly influenced by four factors: fuels, climate–weather, ignition agents and people. Fuel amount, type, continuity, structure, and moisture content are critical elements for fire occurrence and spread. There are two common mechanisms for wildfire ignition - people and lightning. Globally it is estimated that over 90% of wildland fires are started by people. Weather and climate – including temperature, precipitation, wind, and atmospheric moisture – are critical aspects of fire activity. Weather is a key factor in its own right but it also influences fuel and ignitions. Fuel moisture, which may be the most important aspect of fuel, is a function of the weather, and weather and climate also in part determine the type and amount of vegetation (fuel) at any given location. Additionally, lightning as one of the two main causes for wildland fire is largely determined by the meteorological conditions. Weather and climate are arguably the best predictors of regional fire activity for time periods of a month or longer. Although wind speed may be the primary meteorological factor affecting fire growth of an individual fire, numerous studies suggest that temperature is the most important variable affecting overall annual wildland fire activity, with warmer temperatures leading to increased fire activity. The reason for the positive relationship between temperature and regional wildland fire is three-fold. First, warmer temperatures will increase evapotranspiration, as the ability for the atmosphere to hold moisture increases rapidly with higher temperatures, thereby lowering water table position and decreasing forest floor and dead fuel moisture content unless there are significant increases in precipitation. Second, warmer temperatures translate into more lightning activity that generally leads to increased ignitions. Lastly, warmer temperatures may lead to a lengthening of the fire season. This presentation will review the roles and impacts of weather and climate on global fire activity in terms of area burned, fire occurrence, fire intensity, fire severity and carbon emissions. Topics addressed will include surface synoptic conditions, upper air patterns (e.g., blocking ridges) including the vertical structure of the atmosphere, climate oscillations (ENSO) and the potential impact of climate change.

Keywords: area burned, fire occurrence, fire season, meteorology

CLF.02 - HI-RESOLUTION FIRE WEATHER AND CLIMATOLOGY FROM DYNAMICAL DOWNSCALING

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In situ observation networks more typically than not have inhomogeneities in time and space. Thus, there are some considerable barriers to basing a climatology on long-term meteorological observations. For wildfire applications, this is especially relevant because fire weather station observations can be sparse and not fully representing a region in complex terrain. Dynamical downscaling utilizing a mesoscale weather forecast model can provide regional high-resolution temporal (i.e., hourly) and spatially gridded fire weather and fire danger datasets. These outputs are homogeneous in that data are produced by a consistent methodology, though not without potential model bias and error that needs to be assessed and corrected where possible. Recently, two downscaled datasets have been produced for wildfire management and research purposes. The first is a 40-year (1972-2013) 4-km hourly gridded dataset for Victoria, Australia. The second is a 10-year (2004-2013) 2-km hourly gridded dataset for California and Nevada USA. Both were constructed using the Weather Research and Forecast (WRF) model, and include surface fire weather (e.g., temperature, humidity, wind) and upper-air variables (e.g., mixing height). The datasets provide baseline climatology information for risk management assessments, applied research and climate change adaptation planning (in particular for the longer Victoria dataset). This presentation describes the generation of the datasets, shows examples of output, and highlights use and relevance for fire management and research. The methodologies described have relevance globally where it is desired to provide hi-resolution gridded fire weather and climatology data.

Keywords: fire weather, fire danger, fire climatology, fire weather modeling

CLF.03 - POTENTIAL RESPONSES OF SURFACE FUEL LOAD AND FLAMMABILITY IN AUSTRALIAN FORESTS AND WOODLANDS TO GLOBAL CHANGE: CONSEQUENCES FOR THE TRAJECTORY FUTURE FIRE REGIMES

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Vegetation, weather and ignitions in the future may be altered by climate change, elevated CO_2 and human activity resulting in complex effects on fire regimes. To address some of these effects, we estimated future changes in litter fuel load across fire-prone ecosystems in south eastern Australia. We used an empirically based approach to project decadal scale changes (2000 to 2100) in litter fuel within major vegetation formations (rainforest, wet sclerophyll forest, dry sclerophyll forest, grassy woodlands). We also investigated aspects of flammability (e.g. ignition delay time, total heat output) in eucalypt leaves harvested from trees subjected to elevated CO_2 in combination with differing levels of temperature and drought exposure. Climatic controls of steady-state fine surface litter fuel load were explored within each vegetation formation using metadata derived from field studies. Changes in litter fuel load across the 21st century were then in estimated each vegetation formation (25 m grid resolution), using the fuel/climate models and climate projection trajectories from 4 GCMs under the A1F1 and A2 emissions scenarios. Summed estimates of total fuel load were produced using area weighted estimates for each vegetation formation. Steady-state surface fuel load was generally, negatively related to mean annual temperature but mean annual rainfall had divergent effects dependent on vegetation type: i.e. positive effect in low productivity dry sclerophyll forests and grassy woodlands versus negative effect in high productivity wet sclerophyll forests and rainforests. These influences of climate, in combination with climate projections produced by the GCMs resulted in a linear decline (5 to 25% by 2100) in total surface fine fuel load, under both emissions scenarios. The overall magnitude of the projected decline (i.e. at 2100 relative to 2000) was similar under both emissions scenarios with variation mainly due to differences produced by the alternative GCMs. Major declines in surface fuel load were predicted in dry and wet sclerophyll forests and grassy woodlands, whereas an increase in fuel load was predicted for rainforest. Leaves of Eucalyptus globulus grown under elevated CO_2 tended to be thicker than those grown under ambient CO_2. Ignition delay time was significantly increased in eCO_2 grown leaves, while total heat output and mass loss were also reduced though effects were contingent on temperature and water availability effects. These initial investigations therefore indicate potential for elevated CO_2 to reduce aspects of flammability of litter fuels in Australian forests and woodlands. Possible declines in surface fine fuel load and aspects of its flammability therefore have the potential to reduce future area burned in important Australian ecosystems. We hypothesize that the trajectory of change in fire during the 21st century across south eastern Australia is uncertain and possibly non-linear (i.e. an initial increase in fire followed by a decline).

Keywords: climate change, fuel load, carbon dioxide, flammability, Australia

CLF.04 - DIFFERENT APPROACHES TO MODEL FUTURE BURNT AREA IN THE IBERIAN PENINSULA

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Wildfires are the cause of major ecological and economic impacts in the Iberian Peninsula, and the increasing evidence of climate change consequences in this region raises concerns on the future impacts of fires in the Iberian forests ecosystems. Taking this into account, we used outputs from Regional Climate Model (from the ENSEMBLES project) with the aim of developing projections for future fire regimes in the Iberian Peninsula. Our results show that the inter-annual variability of total burnt area is mainly controlled by meteorological conditions, in spite of the current efforts for fire control and suppression, which may be able only to have an attenuation effect. We also show that this meteorology dominance over fire activity is not only true during the fire season itself, but also that certain specific meteorological backgrounds (such as prolonged droughts) enhance the risk for severe wildfire episodes in some areas. Based on a classification of the Iberian Peninsula into four distinct pyro-regions (Northwest, North, Southwest and East) we calibrated statistical models which reproduce about two thirds of the inter-annual variability of the burnt area. These relatively simple models use meteorological variables (from the ERA-Interim reanalysis) as predictors. Specific models were developed for each sub-domain, and their robustness for extrapolation under climate-change conditions was verified. Using an ensemble of state-of-the-art future climate scenarios from Regional Climate Models, we present future burnt area projections considering two alternative techniques of statistical correction of model data: 1) unbiasing method; 2) delta change method. Our results clearly project large increases in mean burnt areas for all the considered pyro-regions, despite some fluctuations regarding each considered technique. By 2075, mean burnt areas could be about two to three times larger than in the present, taking into account the current climate projections, and non-significant changes in other external factors, such as human activity, fire suppression or land use.

Keywords: wildfires, Iberian Peninsula, RCMs, future projections

CLF.05 - FOREST FIRE DANGER EVOLUTION IN THE ALPS ALONG THE EXPECTED CLIMATE CHANGE

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The fire regime is the result of complex interactions among fuel, weather characteristics and human behaviors. At a regional scale climatic parameters are mostly used to predict fire danger in terms of fire ignition and spread. Recent developments in high resolution (daily) climate scenarios open new opportunities for estimating the future evolution of fire danger. In this study we evaluated the trend in fire danger potential using several well-known fire danger indices and the recently developed Fire Niche approach along three regional climatic projections (from very dry to wet) for Switzerland (A1B emission scenario and global model ECHAM5). The expected changes in fire danger were calculated for different fire regimes (non-vegetative winter and vegetative summer season) and summarized for the periods 1981-2010, 2020-2049, 2045-2074 and 2070-2099. According to the current fire danger class distribution and assuming no changes in fire-inducing factors such as fuel (type, amount and distribution) and socio-economic conditions, legislation and fire prevention issues, we quantitatively estimated future fire frequencies and burnt area. The resulting trends in fire danger underline few or no changes in the non-vegetative season (December to April), but a generalized increase in fire danger for the vegetative one (May to November). Nonetheless, resulting trends display different sensitivities to the climatic scenarios according to the region and the variable (fire frequency or burnt area) considered.

Keywords: fire weather indices, fire niche, maxent, Switzerland, fire regime

CLF.06 - FOREST FIRES AND MONTHLY TELECONECTIONS WITH ENSO PHENOMENON

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Altered fire regimes cause great damage to ecosystems. The occurrence of forest fires is correlated with extreme variations in climate, among which highlights the ENSO phenomenon. The aim of this study was to evaluate the relationship between the number of fires in Durango, Mexico, with the monthly data of Multivariate ENSO Index (MEI). To determine the detailed influence of MEI on the number of fires (NF), a correlation analysis was conducted using Pearson's coefficient for the period 2001 to 2010. In addition, linear regression was used to generate a model for NF according to the monthly MEI value ($P < 0.01$). As a complementary analysis, we compared the degree of association of MEI with local seasonal precipitation (P). The results indicated that 39% of the variance model ($P=0.0542$) of NF was explained by the MEI of April of the previous year. P showed a strong association between ENSO and previous winter precipitation ($r > 0.5$, $p = 0.05$), indicating a positive relationship between warm ENSO phases and subsequent fires. It is concluded that ENSO is related to the occurrence of forest fires in northern Mexico and that MEI enables historical reconstructions of fire behavior in ecosystems. This emerges as an important tool to design strategies and make timely decisions for fire management.

Keywords: Northern Mexico, MEI, fire hazard, fire modeling

CLF.07 - ON THE IMPORTANCE OF ANTECEDENT DROUGHT ON FIRES IN MEDITERRANEAN EUROPE

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In Mediterranean Europe approximately 4500 km^2 burn each year, with severe damages to the natural environment and properties leading to important economic and life losses every year. Thus, a better understanding of the link between climate and wildfires is a key topic in risk assessment and for prevention/adaptation strategies. In this study, we analyze the impact of droughts on fires in European Mediterranean regions (Portugal, Spain, the south of France, Italy, and Greece). This goal will be achieved through three specific supporting objectives:

(1) Characterizing fire activities in this region;
(2) Evaluating different drought indices;
(3) Developing a statistical model to analyze the interaction between drought and fires.

We develop relatively simple regression models that link the fire activity to key drought variables. Specifically, we investigate the link between summer fires and current-year drought values (proxies for the climatic factors that affect fuel flammability) and to antecedent drought variables (proxies for the climatic factors influencing fine fuel structure, that is, availability and connectivity). This analysis highlights the importance of drought not only in regulating fuel flammability, but also fuel structure in most of the regions of the studied domain.

Keywords: forest fires, drought, Mediterranean Europe, fuel flammability, fuel availability

CLF.08 - NEW DEVELOPMENTS FOR FIRE WEATHER INDEX IN SPAIN (AEMET)

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The Fire Weather Index (FWI) is an index based on meteorology. The system consists of six components and it depends on weather variables taken each day at 12 UTC (or forecasted for 12 UTC): temperature, relative humidity, wind speed and rain during the previous 24 hours. The procedures for the calculation for Iberian Peninsula and Baleares Islands were initialized by AEMET in 2008 March, being executed daily without interruption since then. Canarias Islands procedures are being executed since 2013 May. Procedures include analysis for day D and forecasts for day D+1, D+2 and D+3 in a 0.5ºx0.5º horizontal resolution grid cells with data provided by the HIRLAM numerical weather prediction model. FWI values calculated for a determinate localization have no meaning for themselves. It is necessary to make a correspondence between the danger classes and those FWI values. Furthermore, non meteorological factors such as type, quantity and fuel distribution must be taken in account when assigning danger classes in the different areas. That's the reason because a calibration is required. Until 2013, the old calibration was performed with FWI daily values from a set of observatories and automatic meteorological stations as well as historical records of burned area and fire occurrences during 10 years period, by assigning five danger classes to the FWI values. Since 2013, a new calibration for FWI index has been developed. For this, the five danger classes split have been calculated only from a climatological point of view. Each class or risk level corresponds with a range of values of FWI between different percentiles. Thus, fire low risk corresponds with FWI values below its percentile 40; moderate risk with FWI values between percentile 40 and 65; high risk between percentile 65 and 85; very high risk between percentile 85 and 95 and extreme fire risk above its percentile 95. In the calculation of the different percentiles, a data period from May 2008 until December 2013 has been used. This period will be updated with most recent values according to the month pass. During 2015 it's foreseen to introduce a new way of representing the fire risk levels, besides the raster data used for the current one. By using the Spanish administrative division of counties and municipalities, maximum and mean level risk are calculated inside each division in order to have only one risk representative value. These risk values will be provided and sent daily to every region of the country.

Keywords: FWI, risk index, calibration, danger classes, Spain

CLF.09 - EFFECT OF MAP RESOLUTION ON WIND FIELD ACCURACY

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Forest fire propagation prediction is a key issue in mitigating forest fire effects. Several propagation models and simulators have been developed to provide accurate predictions of forest fire behavior. These models take elevation and vegetation maps, meteorological and fuel conditions, and initial fire front, and provide the evolution of the fire front. It is well known that wind is one of the parameters that most significantly affect forest fire propagation. Therefore, providing an accurate value of wind speed and direction are critical points to reach successful propagation predictions. In many cases, wind values are obtained or estimated from meteorological services that apply meteorological models to estimate the evolution of meteorological variables including wind speed and direction. These meteorological data are provided at low resolution (2.5 Km or even 4 Km). However, it is well known that wind is modified by terrain topography and 2.5 Km is a very low resolution that does not provide representative values for wind speed and direction considering forest fire propagation. So, several wind field models has been developed. Such models take the wind values provided by a meteorological service and calculate the wind on each point of the terrain map on the required resolution (for example, every 30 meters). The output of these wind field models can be used as input of forest fire propagation models so that the meteorological model, wind field model and forest fire propagation model are coupled in a common target of reaching accurate forest fire propagation prediction. So, it is feasible to use elevation and vegetation maps at 30 meters resolution, calculate the wind field at 30 meters resolution and estimate the fire behavior at the same resolution. The main drawback of this promising approach is that estimating meteorological models, calculating wind field and predicting forest fire propagation are heavy tasks from the computational point of view. In many real cases, the use of large terrain maps and the strict execution time operational requirements make the approach unfeasible. So, high performance platforms, parallel and distributed systems or multicore processors have been applied to speed up these processes and overcome time limitations. A way of reducing execution time in wind field calculation is to decrease map resolution, so that the map is covered with less number of cells. Actually, it has been demonstrated, in a previous work, that the execution time of a wind field simulator, WindNinja, depends linearly on the number of cells. So, reducing map resolution reduces wind field execution time. However, reducing map resolution provides less accurate wind fields that can provide inaccurate forest fire propagation prediction. In this work a study of map resolution is presented considering wind field calculation and its effect on forest fire propagation prediction. It has been stated that reducing map resolution provokes a smoothing effect on wind field and over a certain threshold wind field does not provide any advantage over a uniform wind value.

Keywords: forest fire propagation models, wind field model, coupling models, map resolution

CLF.10 - BIOCLIMATIC MAP OF SARDINIA (ITALY)

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Bioclimatology deals with the interrelation between climate and living organisms, in particular, plants and plant communities, considering the main climate variables that are relevant for species distribution. In this context, spatial interpolation of monthly temperature and precipitation data using 203 rain gauges and 68 temperature gauges for Sardinia (Italy) was undertaken. As interpolation technique, we used regression kriging which combines multiple linear regression (MLR) with ordinary kriging of the residuals. MLR procedures include as independent variables: altitude, latitude, longitude, coast distance and a topographic factor of relative elevation. Elevation data were obtained from digital elevation model at 40 m resolution. Following the approach of the Worldwide Bioclimatic Classification System, a bioclimatic diagnosis of the entire territory was derived using map algebra calculations of the bioclimatic indices proposed by Rivas-Martìnez et al. (2011). Following the bioclimatic hierarchical classification of Rivas Martìnez et al. (2011), the island has been classified by Canu et al. (2014) in two macrobioclimates (Mediterranean on the 99.14% of the area, and Temperate on the 0.86%), one macrobioclimatic variant (Submediterranean 0.74%), two bioclimates (Mediterranean Pluviseasonal Oceanic 99.14% and Temperate Oceanic 0.86%), four oceanic types (weak semihyperoceanic 0.73%, strong euoceanic 10.14%, weak euoceanic 78.55%, and weak semicontinental 10.58%), eight thermotypic horizons, also known as thermotypes or phytoclimatic belts (lower thermo-Mediterranean 0.56%, upper thermo-Mediterranean 30.84%, lower meso-Mesomediterranean 48.97%, upper meso-Mediterranean 17.57, lower supra-Mediterranean 1.2%, upper meso-Temperate 0.35%, lower supra-Temperate 0.51%, upper supra-Temperate 0.01%), and six ombrotypic horizons (lower dry 12.44%, upper dry 42.06%, lower subhumid 29.70%, upper subhumid 11.30%, lower humid 4.25%, upper humid 0.23%, and lower hyperhumid 0.01%), resulting in a combination of 43 isobioclimates. So that, overall the main bioclimatic traits of the island are the Mediterranean macrobioclimate, the Mediterranean Pluviseasonal Oceanic bioclimate, the weak euoceanic oceanic type, the lower meso-Mediterranean thermotype, and the upper dry ombrotype. The resulting map represents a useful environmental stratum, for regional planning, ecological modeling and biodiversity conservation, in a context of rapid climate change (Casazza et al., 2014).

Keywords: climate classification, ecoregion, Mediterranean region, phytoclimate, spatial interpolation

Climate and Fire

Poster Contributions

CLF.P.01 - INCREASED DROUGHT ALONE WILL NOT CHANGE FIRE RISK IN SOUTH-EASTERN FRANCE

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Fire risk is predicted to increase in southern Europe due to both socio-economic and climate changes as they would change patterns of fire ignition, land covers, and the occurrence of extreme weather conditions. Models of global change hypothesize that fire hazard and fire intensity would increase in many parts of the world but data are missing for fire-prone areas of France. Fire hazard and intensity should also be affected by fuel types and landscape patterning but interaction between the main landscape factors (vegetation cover and configuration, topography) and weather is not well understood. We aimed to point out how the severity increase of weather conditions acts on fire hazard and potential fire severity at a landscape level. Using a spatial simulator of fire growth FLAMMAP, we conducted 125,000 fire simulations per weather scenario within two fire-prone areas of Provence (south-eastern France), having similar climate but contrasted fuel types and landscape configuration. We combined the burn probability and fire behaviour metrics of each vegetation cell into a fire severity index (FSI). FSI crosses the likelihood of having a fire in a specific location, and the intensity and residence time of occurring fires. Overall, fire hazard and potential fire severity appeared similar for the two landscapes. Nevertheless, we found different patterns of fire hazard and severity considering the different vegetation types with heterogeneous responses to fire weather scenario. Multivariate variance partition indicated great dissimilarities of overall or interacting effects of landscape factors on fire hazard between the two landscapes. Fuel composition is the main factor of fire risk followed by a great influence of interaction processes with topography, weather scenario and vegetation configuration. Simulations highlighted that depending on fuel composition and landscape configuration, fire exposure and effect to fire of vegetation types can change with severity of weather scenario. The main fuel properties controlling the potential impact of fire in a given vegetated location is the surrounding average fuel depth, explaining more than 91% of burn probability variance and more than 86% of FSI variance for each weather scenario. We demonstrate that the climate change effect on fire risk can be very different in areas prone to similar climate forcing due to contrasting fuel composition and configuration and thus contrasting responses.

Keywords: fire simulation, climate change, vulnerability, landscape

CLF.P.02 - RELATION BETWEEN DROUGHT AND PATTERN OF LIVE FUEL MOISTURE CONTENT IN MEDITERRANEAN SHRUBLAND

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Wildland fires represent an important disturbance for ecosystems in the Mediterranean Basin. Although fire spread and behaviour are dependent on several factors, the water content of live fuel plays an important role in determining fire occurrence and spread, especially in the Mediterranean shrubland, where live fuel is often a relevant component of the available fuel which catches fire. In live plant, water content patterns are related to both environmental conditions (e.g. meteorological variables, soil water availability) and ecophysiological characteristics of the plant species. In addition, more prolonged drought seasons induced by climatic changes is likely to have important repercussions on fuel water status. As a consequence of these remarks, seasonal monitoring of vegetation moisture content, relative to the whole vegetation and the single species, in conjunction with better knowledge of the relationships between weather (i.e. air temperature rainfall, drought) and live fuel moisture content dynamic, can contribute to better understand the effects of prolonged drought season on fuel water status. The aims of this work were i) to analyze the influence of both weather seasonality and inter-annual weather variability on live fuel moisture content within and among some common Mediterranean species, and ii) to investigate the effects of both inter-annual weather variability and prolonged drought season on live moisture content dynamic. The study was carried out in North Sardinia (Italy). Moisture content of live fuel (LFMC) was determined periodically for 8 years on several shrub species. Meteorological variables were also recorded. Relationships between live fuel moisture content and environmental conditions (i.e. rainfall, air temperature and soil moisture) were investigated and the effects of different lengths of drought season on LFMC pattern were analyzed. This work received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under Grant Agreement 243888 ("FUME" Project - Forest fires under climate, social and economic changes in Europe, the Mediterranean and other fire-affected areas of the world).

Keywords: forest fuel, live fuel water status, maquis species, Mediterranean vegetation

CLF.P.03 - ASSESSING CLIMATE CHANGE IMPACTS ON WILDFIRE EXPOSURE IN SARDINIA (ITALY)

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We assessed climate change impacts on wildfires using fire modeling approach for three 30-years periods in the Mediterranean island of Sardinia (Italy). Climate projections based on the A1B IPCC emissions scenario have been carried out using the CMCC-CLM regional climate model (Rockel et al. 2008, spatial and temporal resolution of 14 km and 6 hours respectively) to derive the input data for fire spread modeling. The three studied periods were: baseline (1981-2010) and two future periods (2011-2040 and 2041-2070). To characterize the impacts of these projected changes in climate and fuel moisture conditions on fire behavior and exposure we applied a fire spread model based on the Minimum Travel Time algorithm (MTT, Finney 2002) called RANDIG. The fire simulations were run at 250 m of resolution, considering a set of 50,000 fire ignitions randomly sampled from the historical database provided by JRC. To evaluate the fire exposure variations only due to climate changes, we supposed no changes in land cover and in ignition patterns for the fire simulations. We then derived and analyzed fire exposure profiles (burn probability, conditional flame length, fire size) for the whole island. Results evidenced interesting spatial and temporal variations among the three studied periods, for both climate conditions and wildfire exposure, in the study area. In particular, the main findings of the work for future conditions in Sardinia were the potential lengthening of the fire season, the likely reduction of the days characterized by strong wind intensity, and the limited variations in terms of fire exposure factors. This methodology allows developing guidelines for fire management and prevention policies considering the future climate change projections in Mediterranean areas, and could be easily extended to other areas.

Keywords: climate change, fire exposure, fire modeling

CLF.P.04 - CLIMATE PROJECTION FOR THE MEDITERRANEAN AND RELATED IMPACTS ON DROUGHT AND WILDFIRE RISK

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This contribution, which presents results of the work being currently in progress, is an update of our presentation in the previous ICFBR conference held in 2011 in Alghero. The updates consist in (i) using new GCM data (CMIP5 are used instead of the old CMIP3), (b) inclusion of the drought indices into the climate change projection (motivated by the fact that the wildfire risk is closely correlated with drought occurrence), (iii) updated stochastic weather generator used to simulate Fire Weather Index (FWI), and (iv) enhanced weather-friendly climate change scenarios, which include changes in climate characteristics not accounted for in our earlier experiments. The contribution will consist of two parts. In the first part, the CMIP5 data are used to create the multi-GCM climate change scenarios for the whole of Mediterranean in terms of temperature, precipitation and selected drought indices (including PDSI and SPEI). In the second part, the climate change impacts in terms of FWI characteristics and set of drought-related indicators will be determined for stations in four south European regions (Sardinia, Apulia, Croatia and Spain). The input weather series will be produced by the updated stochastic weather generator M&Rfi. To represent the future climate, the WG parameters will be modified by GCM-based climate change scenarios. We will focus on two aspects of the methodology: (a) Validity of WG, which will be examined by comparing the indicators obtained with the synthetic weather series vs observed weather series. Various settings of the WG will be considered to optimize its model. (b) Climate change scenarios will include changes in low frequency (monthly) and high-frequency (diurnal and interdiurnal) weather variability, which is mostly not taken into account in the climate change impact studies. We will assess an effect of these changes on results of our impact experiment.

Keywords: climate change, Mediterranean, weather generator, drought, Fire Weather Index

CLF.P.05 - CLIMATE CHANGES AND FIRE RISKS IN ITALY

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Wildfire represents serious risks for human activities and infrastructures. Furthermore, they can degrade air quality and may exacerbate natural hazards, such as an enhancement of debris flows, erosion and avalanche danger. They also have serious economic implications in forest damage, costs of fire-fighting, damage to property and environment. Every year about 45000 forest fires break out across Europe. Moreover wildfire impacts are likely to become more serious in the future in response to the projected drier and warmer climate change. With focus over Italy, the effects of climate change on the fire risk have been characterized by analyzing the Fire Weather Index FWI (Van Wagner, 1987) for the present and future scenarios obtained under combination of global-regional climate model simulations. In line with previous experiments (Lung et. al. 2013; Schelhaas et al., 2010, Moriondo et al. 2006), fire risk is expected to increase. In particular, the results indicate an increase of fire risks of about 5-10 % in summer in the next decades in area where forest and land cover is high, as Apennines areas, North-Western Alpine Region.

Keywords: fire risks, regional modes, climate projections

CLF.P.06 - HIGH TEMPERATURE DAYS AND WILDLAND FIRE OCCURRENCE IN NORTH EAST SPAIN

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Significant relationships were found among high temperature days and wildland fire occurrence in the 1978 – 2011 period in Aragón (NE Spain). Temperature was examined at 850 hPa to characterize the low troposphere state, evading complications that affect surface reanalysis and providing regional coverage. A high temperature day was defined when air temperature was higher than 20 °C at 850 hPa. The number of these days increased significantly along the study period, growing the frequency of hostile weather conditions that could ease extreme fire behavior. In detail, these high temperature days are more common in June than they used to be. The effects of those high temperatures days in larger forest fire patterns were significant in terms of burned area, number of wildland fires and average size. The subjects of this study were those fires larger than 60ha. HTDs are more frequent in the last years that in the first years of our study period. Additionally, early June has now HTDs and that was nearly absent in earlier years (of the study period). This is a clear indication of a summer season starting earlier and furthermore it is a justification of a change in both suppression efforts increased earlier in the season and fire use restriction to farmers to start earlier too.

Keywords: wildfires, weather, extreme conditions, forestry

CLF.P.07 - PREDICTABILITY OF SUMMER FIRES IN CATALONIA (NE IBERIAN PENINSULA)

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Climate is a primary driver of the interannual variability of fires in Mediterranean-type ecosystems, controlling fuel flammability and fuel structure. That is, summer fires are linked to current-year climate values (proxies for the climatic factors that affect fuel flammability) and to antecedent climate variables (proxies for the climatic factors influencing fine fuel availability and connectivity). In our contribution, we explore the long-term predictability of wildfires in a Mediterranean environment, Catalonia (NE Spain), driving a multiple linear regression model with observed antecedent climate variables and with predicted variables from the ECMWF System-4 seasonal forecast. The approaches are evaluated through a leave-one-out cross-validation over the period 1983-2010. While the ECMWF System-4 proved of limited usefulness due to its limited skill, the model driven with antecedent climate variables alone allowed for satisfactory long-term prediction of above-normal fire activity, suggesting the feasibility of successful seasonal prediction of summer fires in Mediterranean-type regions.

Keywords: summer fires, predictability, ECMWF System 4

CLF.P.08 - VERTICAL PROFILES OF THE ATMOSPHERE DURING THE LARGE WILDFIRES

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Wildfires along the Adriatic coast can sometimes be catastrophic and surprise with their intensity and rapid expansion. Weather conditions and wildfires are closely related - similar as a relationship between weather, human activity and fuel material in a shorter period of time. Beside the longer dry period, a very important meteorological element that affects the emergence and spread of the wildfires is wind and the fire fighting control plan should be based on a forecast of its speed and direction. Classification of wildfires along the Adriatic coast in early meteorological analyzes were founded on weather conditions during which prevails a typical wind (NE, SE and NW). Behavior of the wildfires in all three situations was almost identical. It was observed that in all cases wind speed suddenly increased with height above 10 m/s in the lower layer of the troposphere, up to 1500 m. If the wind speed maximum in the lower troposphere exceeds 12 m/s it is defined as the low jet stream. Its appearance has an impact on the dynamic processes in the atmosphere and often precedes the passage of a cold front. In Croatia, past analysis of wildfire events showed that these two weather indicators can warn us about the extraordinary fire behavior. This study further analyzed vertical profiles during the large wildfire events on the Adriatic coast, which occurred during the period 2001-2010. Vertical profiles were simulated with a numerical model ALADIN/HR. The research revealed that low jet stream appeared in the six of an eight observed large wildfire events, in at least one term on the day wildfire started. Strong turbulence most likely appeared in the surface layer, below the wind speed maximum, which helped the spread of the fire front. The analysis of synoptic charts presented that the passage of the cold front occurred in all situations. This study confirmed that wildfires are associated with a strong turbulence under the low jet stream and their onset is ahead of the cold front passage. Therefore, in a situation where there is a very high risk for wildfires along the Adriatic, an additional criterion for warning would be an accurately predicted time of the cold front passage and well-defined wind speed maximum or lower jet stream in the boundary level, using modeled vertical wind speed profiles. Identifying these additional weather conditions would certainly be of a great help in alerting the fire services on preparedness. It would be possible to reduce damage caused by wildfires, protection of natural and material wealth and above all to save human lives.

Keywords: wildfires, weather conditions, vertical profiles, low jet stream

Fire Behaviour and Regime

Oral Presentations

FBR.01 - SUSTAINED FLAMING IGNITION FOR BOREAL FOREST FLOOR FUELS

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Flaming ignition sustainability testing was one of the earliest areas of research carried out by researchers at the beginning on modern fire research in the early part of the 20th century. Over about 4 decades in the mid-20th century Canadian Forest Service (CFS) fire researchers spent considerable time carrying out match drop ignition tests in a wide range of forest types and fuel beds at experimental stations across the country. During these tests they observed vigour of spread from flaming brand into varied fuel beds, numerous other characteristics of the ignition as well as moisture content of forest floor fuels and weather. The relationships between weather, moisture and ignition sustainability formed the basis of early fire hazard and danger rating tables in Canada; it was these sets of regional fire hazard and danger tables, each developed using the same field based small-scale ignition testing approach that evolved into the Canadian Forest Fire Weather Index (FWI) System still used operationally today. The sustainability of an ignition from a fire brand plays a significant role in influencing the number of new human-caused fire starts that fire management agencies have to manage on a day-to-day basis and can also, from a fire behaviour perspective, be critically important in assessing the potential for significant spot fire formation in advance of a large fire front. This presentation describes development of probability of ignition models for important boreal forest floor cover types or 'fuel beds' using CFS's historic test fire dataset. Across each of these fuel bed types we developed a common model form that characterizes the probability of ignition in terms of the key drivers of ignition, namely fuel moisture content and surface wind speed at the site of the ignition. The new fuel bed specific models of ignition depend on an estimate of moisture content of the litter layer within a set stand type and an explicit estimate of in-stand wind near the surface. We discuss how this reliance on moisture content of litter fuels and in-stand wind leads to more general models of ignition probability that can be extended to new or modified forest stands (e.g., thinned stands). We also explore the generalizability of ignition models across forest floor cover ('fuel bed') type using basic physical characteristics of the fuel bed, such as packing and surface-to-volume ratios.

Keywords: flammability, ignitability, litter, ignition probability

FBR.02 - FIREBRANDS INVESTIGATION DURING PRESCRIBED FIRES IN A PINE FOREST

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The problem of spreading wildfires that ignite houses and buildings in the wildland-urban interface (WUI) has been observed over the last several decades, with thousands of properties destroyed. The main factors that influence the ignition of structural fuels and fire spread in the WUI are heat transfer from the approaching flame (radiation and convection) and firebrands that can accumulate on the outer surface of a home, out-buildings, decks, fences, or pass through small openings in structures to reach easy-to-ignite fuels, such as through attic vents. The development of an efficient and systematic methodology to characterize firebrand production and landing will support solutions for preventing structural ignitions, and assist in an overall understanding of wildland fire behavior. Therefore, a study on the characterization of firebrand production was carried out, using experimental fires conducted as prescribed fires in the New Jersey Pine Barrens, USA in March of 2013 and 2014. Several preliminary techniques were tested to characterize the firebrand production in a section of the burn unit. Firebrands were collected from three plots for each year in the forest and analyzed for mass and size distribution. Thermal imagery was used to measure the velocity, size and number of firebrands. The distribution of firebrands was evaluated in a controlled volume during the experiment. It was found that not less than 70% of particles were bark slices and the rest were branches. The number of firebrands decreased with increasing firebrand area. A size analysis of firebrands shows that the majority (75%) were particles with a cross section area of 0-20 x $10^{(-5)}$ m^2. All collected firebrands were divided into different ranges by mass and area. For the area ranges of 20-30 x $10^{(-5)}$ m^2 and greater, the number of firebrands did not exceed 10 for each plot, and the same was true for the mass ranges of 50-100 mg and greater. Processing of infrared video showed that starting from a distance of 10 m from fire front, an increasing number of firebrands were observed in a controlled volume, starting from only a few up to 180 per second. The velocity of firebrands changed in the range 0.1-10 m/s, with an average value of 2.5 m/s.

Keywords: prescribed fire, firebrands, thermal imagery, characteristics

FBR.03 - PLANT TRAITS ARE PRIMARY DETERMINANTS OF WILDLAND FIRE BEHAVIOUR AND RISK

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A dynamical, process-driven model (Forest Flammability Model, FFM) is presented to calculate expected fire behaviour from plants, depending upon their structural and leaf traits. Studies defining the influence of leaf traits on their flammability were up-scaled to fire behaviour by modelling the capacity for flame from burning leaves to ignite new leaves in the same or other plants. The heat flux was modelled from the combustibility of leaves and the number of leaves burning, transferring convective heat along a vector defined by flame angle and declining in temperature with distance along the plume. Flame propagates when this vector intersects other leaves at a point where its temperature is sufficient to ignite those leaves with a time to ignition defined by traits such as thickness and moisture content. The duration of the heat source is limited by the sustainability of flame in the leaves already burning. Flame height predictions were validated against wildfire behaviour across diverse conditions and forest communities for 58 sites burnt by wildfire, with measured flame heights ranging from less than 1m to over 20m. Predictions were made using the successive inclusion of species information in the FFM to infer the scale of influence from each source, so that treatments beginning with surface fuel-load only (F) added first structure imposed by plant size and spacing (FS), then the leaf traits of the component species (FSL). Including structure (FS) produced correct flame height predictions 1.9 times more often than F ($\alpha < 0.01$), however the Mean Absolute Error was higher due to infrequent large errors. Including leaf traits (FSL) mostly corrected this, so that accurate predictions occurred 2.3 times more often than for F ($\alpha < 0.01$), and the MAE was 0.27 times that of F ($\alpha < 0.05$). F could not reproduce large flames, so that when a subset of sites with flames less than 1m was examined, FSL was correct 12.5 times more often ($\alpha < 0.01$). Fire risk is frequently assumed to increase with time since fire, however such assumptions do not account for plant species effects. To test the scale of these, average summer fire behaviour was modelled for one Australian Eucalypt community and compared qualitatively with historical fire records (53-years, 190,000 ha). The fire history exhibited a species-driven trend consistent with FFM modelling and contrary to conventional expectations. In the communities examined, plant traits were more important to fire behaviour and subsequent risk than was surface fuel load. The FFM provides a physical argument to show that plant species affect both community structure and the flammability of community components, and as these species exhibit diverse responses to external stimuli, diverse responses to planned or unplanned disturbances should be expected. It is argued that risk management will be significantly more effective if it accounts for component species and their ecology, rather than accepting simple fuel-age paradigms.

Keywords: leaf traits, flammability, fire ecology, forest flammability model

FBR.04 - HEAT RELEASE RATE AND RATE OF SMOKE PRODUCTION OF VEGETATION FUELS

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The scientific community has made considerable progress these last ten years in improving our understanding of wildfires and the risks they pose. Modelling has become an essential tool in forest fire research and becomes a crucial instrument in the studies of wildland–urban interface fires and real-time fire simulation. Simple models of fire spread have to be used if one wants to provide real time operational tools at landscape scale. Multidimensional numerical fluid-dynamical wildfire simulation models must be used to study the behavior of wildfire at local scale like wildland–urban interface fires. Both simple and detailed models of forest fire spread are investigating the prediction of smoke as an output in addition to the usual descriptors of the fire like rate of spread and intensity. Smoke production in fire represents a threat because fire smoke reduces visibility and because fire smoke is toxic. The combination of toxicity and obscuration presents the greatest threat during actual fire for firefighters and population. However, because of both computational cost and complexity of wildfire-chemistry interaction, detailed reaction mechanisms are not used within physical models of fire spread to predict the gaseous composition of smoke as well as the smoke opacity. Even the most advanced physical models of fire spread only consider a single global mechanism of combustion. Hence, smoke dispersion and visibility impairment is mainly calculated by using emission factors. In this work we investigated the combustion dynamics and the smoke production during the burning of pine needle litters of Pinus pinaster, a representative species of the Mediterranean area. This fuel was used for loads in the range of actual pineland litters. The aim of this study was twofold: to quantify the smoke production rate (SPR) of vegetation fuel and derived quantities like total smoke production (TSP) and to investigate the scale effect on the heat release rate HRR and the rate of smoke release (RSR) by analyzing the combustion of such litters for three experimental setups. Although extensive work has been done to determine emission factors from vegetation burning, conversely the relation between SPR and HRR has never been investigated. However, the HRR is a fundamental variable of fire with which almost all other emission properties are highly correlated. The main measuring devices used in these studies are the Cone Calorimeter and the Furniture calorimeter. Both devices are based on the oxygen consumption calorimetry principle but the scale of the samples is different. For the three experimental setups, the HRR was measured and the smoke obscuration was obtained in the exhaust ducts with white light and a photocell giving the SPR. This study is a first attempt for pointing out the scale effect as well as the effect of the combustion setup (static and spreading fire) on combustion dynamics and smoke production of burning vegetative fuels.

Keywords: combustion dynamics, heat release rate, smoke production rate, rate of smoke release, changing scale

FBR.05 - MEASURES OF THE POLLUTANTS EMITTED DURING THE COMBUSTION OF CISTUS MONSPELIENSIS TWIGS ACCORDING TO THE DIAMETERS OF THESE PARTICLES

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Our study aims to determine the particles size of plant involved in fire spread in order to estimate the amount of leaves, twigs, and wood implicated in fire spread. Thereby, it was determined from thermal parameters (HRR, mass loss, THR, efficiency) that the diameters of Cistus monspeliensis less than 4 mm, burn very quickly. These diameters are considered as elements that contribute to fire spread. This first result on the particle size (< 4mm) involved in fire spread will lead to better estimate the fuel load to be taken into account in the propagation models (percentage of real burden of vegetation on the ground according to the effective size of the particles and their fraction in the plant). This fuel load is an important parameter for determining the fire propagation, the calculation of its intensity and the interpretation of its impact. Moreover, we observed two humps of HRR from particle size above 5 mm. The second peak was increasingly important according to the growth of particles diameters. This result indicates a change in fire behavior of twigs between 4 and 5 mm. These particles size largely burn behind the flame front. The second part of this study is devoted to the characterization of pollutants emitted by Cistus monspeliensis twigs burned according to their sizes. It aims to determine the quantities of pollutants potentially inhalable by the personnel involved (firefighters) and the exposed population. Further, it has been shown that CO_2 is the major emitted gas with constant quantities according to the particles sizes. The emission factor (EF) was 1425 $g.kg^{-1}$. Other identified gases are CO, CH_4, NO_x with respectively the EF were 95, 0.55 and 3.1 $g.kg^{-1}$. 17 NMVOC were reported. Among them, benzene and hexane were dominant compounds.

Keywords: emissions factor, Gazes, VOC, Oxygen consumption calorimetry

FBR.06 - DISCRETE EVENT FRONT TRACKING SIMULATOR FOR WILDLAND FIRE INCLUDING TURBULENCE AND FIRE SPOTTING

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A recent formulation to include random effects as turbulence and fire spotting into models for wildland fire propagation, originally implemented into a framework based on the Level Set Method (LSM), is now implemented into a wildland fire front tracking simulator based on the Discrete EVent System Specification (DEVS). In such formulation the motion of the fire front line is randomized according to the probability density function of the interface particle displacement, which is established on the basis of turbulent transport and fire spotting statistical characteristics. In [1], the effective front position is obtained as the weighted mean of fronts calculated by means of the LSM, using the probability density function as weight-function. The resulting model emerges to be suitable for simulating effects due to turbulent convection, such as fire flank and backing fire, and also due to the actions of hot-air pre-heating and ember landing, such as the faster fire spread and the fire overcoming a fire-break zone. However, LSM approach is a time-driven technique, the domain is updated at each grid point at regular discrete time steps, and then it faces two major limitations: firstly, the update of the domain at each time step involves excessive computation and secondly the temporal resolution is constrained by the global time step restriction imposed by the CFL criteria. Unlike LSM, DEVS provides an asynchronous fire spread simulator so that the CFL condition only applies locally, given the speed of individual markers. Moreover, in comparison to LSM, DEVS models the temporal behaviour of the fire spread according to the occurrence of the "events", so that the markers are updated when it is required. The resulting DEVS-based simulator including turbulence and fire spotting can be implemented into ForeFire/Meso-NH simulator, an advanced forest fire simulator involving wildland fire/Atmosphere coupling.

Keywords: fire front propagation, fire spotting, turbulence, Discrete EVent System Specification (DEVS), random front

FBR.07 - PHOENIX RAPIDFIRE: LESSONS FROM THE IMPLEMENTATION OF A FULLY AUTOMATED OPERATIONAL FIRE PREDICTION SYSTEM

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The catastrophic Victorian bushfires of 7 February 2009 burnt over 400,000 hectares of public and private land, claimed 173 lives and thousands of homes. During that day, over 600 fire reports were logged which, together with the speed and size of the fires, quickly overwhelmed existing manual processes leading to breakdowns in vital communications. Timely, accurate and relevant public messaging is critical to informing the community of the location and potential impact of bushfires. Following the devastation of the February 2009 bushfires, there has been a concerted effort by Victorian fire agencies to improve their fire monitoring, reporting and prediction systems. Part of the response was the incorporation of the Phoenix RapidFire bushfire simulator into a fully automated web based fire predictions system. Developed at the University of Melbourne, Phoenix RapidFire is designed to quickly characterise the spread of large fast moving forest and grass fires in Australia. A key factor to its adoption is its ability to model extreme fires over 60,000 hectares in size in less than 5 minutes on a modern desktop computer. Triggered automatically as fires are reported, the system generates a 6-hour fire spread prediction which Fire Behavior Analysts approve or override as necessary. Results are then published internally and used to inform a range of internal processes and public messaging. This is the first automated fire prediction system of its kind and is now an integral part of bushfire emergency management in Victoria. Four years on since its inception in 2010, we examine the key factors to the systems success, the major challenges in its development, current issues, limitations and future directions.

Keywords: bushfire, wildfire, automated, prediction, simulation

FBR.08 - TOWARDS THE VALIDATION OF PHYSICALLY-BASED MODELS OF FIRE BEHAVIOR

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The strength of physically-based models of fire behavior relies on their potential to capture the basic physical process regardless of the scale. However, the widespread use of these models should be preceded by a validation process in order to verify that model outcomes represent the processes they aim to describe within acceptable error bounds. Thus, the validation of physically-based models of fire behavior requires comparing systematically and objectively simulated results and experimental observations in different scenarios, conditions and scales. Laboratory-scale experiments are appropriate to characterize the finest physical mechanisms involved in fire behavior and they can provide an important source of data for validating physically-based models at this particular scale. In addition, there are some fundamental parameters for understanding fire behavior such as the heat release rate that can only be accurately determined at laboratory-scale. The aim of this work is to address the consistency of a physically-based model to simulate spreading fires in a large-scale calorimeter paying special attention to the influence of both the experimental configuration and the numerical computation parameters. With this purpose, experimental data obtained in a large-scale calorimeter have been compared to the numerical results obtained with the Wildland urban interface Fire Dynamics Simulator – WFDS (Mell et al., 2007; Mell et al., 2009) developed by the National Institute of Standards and Technology (NIST) and the US Forest Service. The large-scale calorimeter is provided with a hood extraction system which collects the gases released from the combustion processes, to measure the oxygen consumption and thus determine the instantaneous heat release rate. In order to assess the suitability of the numerical implementation of the hood extraction system, and thus the flow it induces, a sensitivity analysis has been performed. Numerical results have been compared to measurements conducted with a hot wire anemometer. From this study the more appropriate grid resolution to capture the flow dynamics within the hood has been established. Concerning the set up of numerical computation parameters, the size of the calculation domain and the grid resolution are important factors that directly affect the calculation time and the simulation results. To define the domain size, which allows reaching a compromise between the precision of the results and the simulation time, different domains of calculation have been studied. Regarding the grid resolution, several grid sizes have been tested in order to find out the grid resolution with no effect on the outcomes of the model. A comparison of observed heat release rate and the computed heat release rate is presented for a particular case.

Keywords: fire modeling, WFDS, calorimetry

FBR.09 - AN INTEGRATED SYSTEM FOR THE FORECASTING OF WILDFIRE BEHAVIOR BASED ON CLOUD AND VIRTUALIZATION TECHNOLOGIES

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In this work, we illustrate some results in the field of wildfire modeling, achieved in the project "Cloud for Remote Visualization", financed by the Autonomous Region of Sardinia with the call PIA 2010 and developed in collaboration with Nice srl. The project consisted in the development of a system based on Cloud and Virtualization technologies for the remote visualization and handling of large 3D datasets. The architecture has been tested by means of an integrated system for the forecasting of wildfire behavior, producing large datasets to be examined remotely. A web portal has been therefore developed. It offers a user friendly interface that allows an easy interaction with the complex HPC computing operations required for wildfire simulation as well as for the analysis and evaluation of the results. The service allows the remote 3D visualization of the results through an application running on specific virtual machines, taking advantage of the hardware acceleration. The simulation system implements a fire propagation algorithm based on the Fast Marching Method specifically developed for the project, with the Rate of Spread calculated on the basis of the classic Rothermel models. The weather conditions necessary to drive the wildfire model are produced daily by means of a high resolution weather forecast chain. The assessment of the types of fuel is obtained by recasting the land cover Globalcover-2009 in standard NFFL fuel models and a specific fuel model is used for the Mediterranean brush. The accuracy of the model is assured by the high resolution of the terrain and vegetation maps and by the high performance numerical solver adopted for the fire spread. A higher accuracy of the simulation is further obtained with a dedicated fluid dynamic solver that calculates a high resolution wind pattern. This module is based on the mass-consistent approximation, allowing for a quick but efficient downscaling of the wind, from typical weather scales to grid resolutions compatible with the fire forecast requirements. The solver, based on the CFD library OpenFOAM, runs on demand over a virtual machine. In order to test the forecast system, some relevant wildfires happened in Sardinia were simulated. The simulations show reasonable evolution of typical fires in the Mediterranean area. The system is open to many improvements both in terms of computing efficiency and as forecast quality. The first depends on the available computing power as the system scales well in a parallel environment. For the latter we can have improvements stepping up, for instance, the accuracy of the vegetation and the fuel modeling for the Rate Of Spread computations. On the other hand, it is important to remark that the mass-consistent approximation we used for high resolution wind simulation is a CFD method that cannot handle nonlinear phenomena such as the turbulence and the interaction between atmospheric flow and fire.

Keywords: wildfire behavior modeling, Rothermel's fire spread model, mass-consistent downscaling, cloud computing, remote visualization

FBR.10 - MODEL REDUCTION APPROACH FOR WILDFIRE MULTI-SCENARIO ANALYSIS

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Wildfire models have been widely applied to the prediction of fire front evolution, in order to obtain useful information for evacuation plans and fire management. A major difficulty in treating forest wildfires is related to the complexity of the phenomena that are involved. In addition, it is difficult to obtain accurate input data for the models, especially in the case of on-going fire events. In fact, wind and weather data, available from meteorological stations, fuel characteristics and orographic characteristics data are often inaccurate. Furthermore, some of these data may change during the fire event, so a prediction is necessary. Results obtained from models are therefore affected by errors. Probabilistic approaches are useful in order to overcome some of these problems, but this requires the use of suitable models in order to perform large number of simulations. Over the last decades, empirical and physical based models have been proposed. Physical based models provide detailed results but require higher computational cost than empirical models. In order to use physical based models for risk analysis and multi-scenario analysis it is necessary to reduce their computational time, which can be achieved through model reduction techniques. In this paper, Proper Orthogonal Decomposition technique (POD) is applied to the reduction of a physical model. A two-dimensional physical model has been selected in order to test the approach. This model is based on conservation equations and it is built by setting some of the parameters through empirical data collected during field fire experiments. In this first work, slope and wind contribution are not considered. POD permits to extract the spatial basis of the problem and capture the main features of the system with reduced requirement of computational resources. A comparison shows that the results of the reduced model are close to that of the full model, but the computational time for solving the energy equation is reduced to about 10% of that required by the full model. Furthermore the paper reports also on work aimed at improving the accuracy and reliability of forestation analysis, especially during wildfire incidents.

Keywords: wildfire, reduced model, Proper Orthogonal Decomposition, fast physical model

FBR.11 - A WEB-BASED WILDFIRE SIMULATOR FOR OPERATIONAL APPLICATIONS

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Wildfire management agencies increasingly need to use wildfire simulators at landscape scale for real-time applications such as short-term fire prediction and fire management. Despite the large number of wildfire simulators developed and validated in the last years, a number of drawbacks which limit their applicability can be observed. Both physical models and quasi-empirical models suffer of a number of simplification regarding the chemistry and physics involved in the propagation. In addition, physical and quasi-physical models are in most cases several orders of magnitude slower than real-time, thus limiting their use for operational purposes. Quasi-empirical models showed clear advantages respect to physical and quasi-physical models, since they use both a structure that attempt to reproduce the physical processes involved in wildland fire, and a statistical parameterization based on experimental data, collected from actual wildfires and laboratory experiments, even though they are highly dependent on the conditions in which the fire data were collected and analyzed. In addition, they need a lower computational effort respect to the physical approach. A simulation technique is used in order to obtain a spatially explicit representation of the propagation. Several works proposed different fire simulation techniques to reduce the computational effort without decreases in accuracy (cellular automata and level-set). Moreover, some of these techniques are suitable as they provide a gain in computational time when using parallel computing techniques.The aim of this work is to develop a wildfire simulator specifically designed in order to be used by the wildfire management agencies. The simulator is mainly composed by four components. (1) A mass-consistent model to estimate the wind field using as initial conditions the data provided by the WRF mesoscale meteorological model, (2) the fire spread model of Rothermel, (3) a simulation technique based on the level-set approach, and (4) a graphical user interface based on the Google Maps Application Programming Interface. Some sub-codes of the simulator were designed to be portable to parallel computing environments. The validation activities performed at different temporal and spatial scales confirmed the efficacy of wildfire simulator as tool in wildfire analysis and management. The wind field obtained by the mass-consistent model nested with the meteorological model provided an increase in simulation accuracy respect to the use of wind speed and direction measured by nearby weather stations. The availability of accurate custom fuel models maps is a critical factor in wildfire spread and behavior prediction that need to be addressed, especially at regional scale.

Keywords: level-set, mass-consistent, meteorological models

FBR.12 - A SUB-CONTINENTAL ANALYSIS QUANTIFYING THE DRIVERS OF FIRE RISK

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Quantifying the key drivers of fire regimes is fundamental to determining the ability of management to manipulate the risk posed by wildfire to people and property. Annual area burned by wildfire is driven by four hypothetical switches – biomass, fuel moisture, fire weather and ignitions (Archibald et al. 2009; Bradstock 2010). Each of these is, in turn, influenced by a variety of anthropogenic and natural factors, only some of which can be altered by fire management actions. Many of these factors are not independent, having direct or indirect influences on each other. Traditional statistical methods are incapable of adequately capturing this complexity. Incorporation of correlated variables can result in spurious results in traditional modelling approaches. As a consequence, results in only a subset of variables are tested in any one study resulting in only partial consideration of the problem. Bayesian networks (BNs) provide a methodological framework for dealing with this problem. Arising from graph theory, BN are directional acyclic graphs which capable of depicting the complexity of environmental relationships and explicitly accounting for the uncertainty in the data. Outputs of the models are likelihoods which is why BNs are considered an ideal tool for risk management research. In this study, we derive a Bayesian Network for southern Australia to examine the relative importance of the four switches in southern Australia. Specifically, we ask two questions:

1. Which switch or switches have the greatest influence on annual area burned?
2. To what extent can humans influence the annual area burned and therefore alter risk?

The BN model was developed using published relationships and where necessary expert elicitation. Data for the model was collected for 60 000 5km square grid cells in southern Australia. These data were a mixture of satellite data, fire agency records, climatic records and publically available environmental data. Fire history and ignition data were compiled for the 20 year period from 1991-2010 and aggregated to the 5km grid. Across the entire study area, the biomass switch had the strongest influence on area burned, but the ability of fuel treatments to vary this was low. Fuel moisture and fire weather had similar levels of influence on annual area burned with ignitions having the smallest influence on area burned. The relative importance of the four switches varied between the arid zone (<600mm average rainfall) and the forested zones in the study area. In all areas, the relative influence of human factors was small compared to environmental and climatic factors. There was a high level of uncertainty, which highlights the difference between the potential extent of fire and the realised extent. Our approach provides a means for assessing the full complexity of the fire environment relationship. The model structure is readily transferred to other fire prone regions and could be used for a global assessment of the drivers of fire regimes.

Keywords: wildfire, risk, management, fuel treatment

FBR.13 - STATISTICAL CHARACTERIZATION OF LARGE FOREST FIRES: TAILS OR TALES?

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Forest fires are a major concern all over Europe, and Portugal is no exception, where large forest fires are responsible for relevant negative effects (environmental, social and economic). Therefore, management agencies should handle their limited resources more efficiently, not only with information concerning the most likely area burned conditions, but also with information regarding the extreme events. This context highlights the need to investigate the extreme fire events and understand the spatial distribution of these highest values of area burned. It is also of utmost importance to consider measures of risk assessment with a clear interpretation and, more importantly, that allow the comparison of several regional profiles. This work examines the Portuguese profile on extreme fire events and characterizes its regional variability, from the analysis of time series of daily area burned in 18 Portuguese districts (ha/day, 1980-2010). Here, extreme fire events are characterized by fitting a Generalized Pareto distribution (GDP) to the excesses above a high threshold, (in this work, fixed at the 95% sample quantile), and through the analysis of its corresponding shape (tail index) and scale σ parameters. From and σ point estimates for each district, return values can be obtained for m-years return periods, which correspond to the value of daily burned area expected to be exceeded on average once every interval of m years. The probability distribution of estimates and of return values, for each district, can be approximated by reproducing the Peak-over-Threshold (POT) procedure from bootstrap replicates, obtained by resampling with replacement the original set of exceedance values. Finally, a clustering procedure is applied to identity classes of Portuguese districts with similar probability distribution on estimates, i.e. similar patterns in the shape of the tail and/or long-term predictions of extreme fires (through the return values), in order to evaluate regional patterns. The results on tail index clustering identified three distinct groups with spatial pattern closely related to the percentage of shrub cover within each district. The results identified three distinct groups with spatial pattern closely related to the percentage of shrub cover within each district. Finally, clustering based on return values shows that the largest return levels of area burned are expected to occur in districts located in the centre and south of Portugal.

Keywords: statistical analysis, time series burnt area, spatial distribution, clustering

FBR.14 - INVESTIGATING TRENDS, CHANGES, AND INTERACTIONS OF FIRE DANGER IN ITALY

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A comprehensive understanding of trends in fire regimes is of utmost importance to assess the ecological effects of wildfire, to anticipate future trends and regulate their potential impacts. Several methods have been applied to reconstruct the fire regime, from dendrochronology of fire scars to fire statistic collections, to burned area mapping using historical series of satellite images. A valuable tool to examine past changes in fire potential and danger across fire regions is represented by fire weather indexes. These systems, combining relevant weather variables into suitable indexes, can estimate potentially dangerous conditions, such as fire intensity or large fire size, and help forest fire services in the effective prevention and response to forecasted danger. With this study, spanning from 1985 to 2008, we aimed to understand recent trends and patterns of fire danger in Italy. In addition, we investigated the interactions between the Canadian Fire Weather Index (FWI) System components and fire activity. In the first phase of the work, similar areas in terms of fire occurrence and climate (pyro-climatic areas) were identified through a hierarchical cluster analysis. Then, FWI was computed using daily averages of meteorological values as a surrogate for instantaneous values at 12:00. A percentile analysis of the fire indexes' dataset was computed on annual basis and per pyro-climatic areas. In the second phase of the work, we applied a number of statistical tests to evaluate the existence of trends and changes in all data series and to estimate fire activity at national and cluster level, using fire indexes components as predictors. The preliminary findings showed that, although time series trend analysis revealed a statistically significant increase in temperature, no clear pattern of fire danger increase was revealed. On the other hand, the number of days with high fire danger increased significantly, especially in central and southern Italy. Moreover, simple statistical models using as explanatory variables FWI components were able to reproduce an important part of the inter-annual fire variability, even if relevant differences across Italy were found. Although it is clear that fire activity in Italy is influenced by a number of factors not related to weather conditions, a clear comprehension of the relationships between these indexes and fire occurrence features is of paramount importance in the implementation of fire policies and management. In addition, this information is necessary to understand the future magnitude of the wildfire issue under climate changes and to develop new adaptation and mitigation strategies. This work was partially founded by the Sardinia Region under the Regional Law n. 7/2007 (EXTREME Project - "Development of methodologies and support systems for fire risk assessment in extreme weather conditions") and by the Italia-Francia Marittimo Programme (Proterina 2 Project).

Keywords: fire danger indexes, percentile analysis, trend analysis, FWI

FBR.15 - RECONSTRUCTING HISTORICAL AND NEW WILDFIRES (1950-2014) IN SOUTH SARDINIA (CAGLIARI PROVINCE) AND ANALYZING VARIATION IN FIRE PATTERNS AND REGIME

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Knowledge of historical temporal and spatial fire patterns is crucial to characterize and understand fire regimes in a given area or region. In fact, fire patterns vary and/or are altered by a number of driving factors, broadly ranging from forest and fire management to climate and socio-economics items. In this work, we reconstructed historical wildland fires that affected South Sardinia (Cagliari province), starting from the 50s. For such purpose, we gathered (in a project that involved the CFVA staff in 2013) fire reports, internal documents and any relevant piece of information from the archives of the Corpo Forestale e di Vigilanza Ambientale della Regione Sardegna (CFVA). Collecting and managing such information was challenging due to the differences in reporting and describing fire perimeters and spread from 1954 to more recent years. We focused our attention on all wildfires larger than 25 hectares that burned the actual province of Cagliari. After the first data collection and event selection phases, all wildfire were geo-referenced in a GIS environment and were associated to shapefiles. We then performed statistical analysis to investigate how fire size and location, synoptic weather conditions, topography and human activities influenced historical fire patterns and regime. Moreover, historical fire spread patterns were classified according to the GRAF of Catalunya methodology. This approach allows identifying earlier fire regime (1954-1985) and comparing it with more recent (1986-2000 and 2001-2014) regimes, as a basis for innovative and integrated planning system for a sustainable wildland fire prevention action. The methodology could be extended as well to other areas of the island, in order to identify and characterize historical fire regimes and patterns for the whole Sardinia.

Keywords: fire regime, Sardinia, Corpo Forestale

Fire Behaviour and Regime

Poster Contributions

FBR.P.01 - THE ROTHERMEL PACKAGE IN R

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We identified a need for scientists to run a seamless fire modeling workflow based on the Rothermel surface fire spread model, including input data preparation, iterative model runs, or plotting and statistically manipulating model results. For this purpose, we implemented a package for the Rothermel model in the R programming language that is available on the R-CRAN web repository. Currently, four functions compose the Rothermel package. The main function, ros(), computes the forward rate of spread at the head of a surface fire according to the imperial systems of equations of the Rothermel model, as implemented in the BehavePlus fire prediction system. The function rosunc() carries out uncertainty analysis of fire behaviour, which can generate information-rich, probabilistic predictions of fire spread, and can be coupled to spatially-explicit fire growth models. The function bestFM() estimates the fit of Standard Fuel Models developed by USDA to observed fire rate of spread, based on absolute bias and root mean square error. Finally, the function gaRoth() searches the set of fuel model parameters that maximizes the fit between simulated and observed fire rate of spread. This function allows exploration of a continuous space of fuel parameters, making fuel model calibration computationally effective and easily reproducible, and does not require fuel sampling. Advantages of the R implementation of Rothermel model include: open-source coding, cross-platform availability, high computational efficiency, and linking to other R packages to perform complex analyses on Rothermel fire predictions.

Keywords: fire behaviour, fuel model, wildfire, prescribed burning, fire modelling

FBR.P.02 - TIRAILLEUR - A FIRE PERIMETER SPREAD MODEL WHICH ALLOWS REVERSE SIMULATION

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We present Tirailleur: a geometric fire perimeter spread model. The fire perimeter is represented as simple closed polygon formed by a dynamic population of linked nodes. The perimeter spreads as the nodes move outwards from the fire origin in a series of simulation steps. The direction of movement for each node arises from the location of its neighboring nodes (not the local maximum spread rate direction). The spread rate for each node movement must be calculated for the movement direction. This geometric expansion loses no information. This means that if the spread rate is calculated from a simple, deterministic model, the spatial spread sequence is almost perfectly reversible. Trivially, this allows a simulation to be run forwards and backwards. More interesting is the possibility of running the simulation backwards only. This allows for the estimation a fire origin from an eventual perimeter. As with other dynamic perimeter polygon models, there are problems of emerging contortions (crossovers) as the fire line moves. The Tirailleur model offers no magic escape from such problems, but changes their nature slightly. Unburned islands are absorbed within the expanding burned area.

Keywords: model, perimeter, spread, fire

FBR.P.03 - EVALUATING THE PERFORMANCES OF FARSITE AND FLAMMAP MTT IN GOLESTAN NATIONAL PARK, NORTH EAST IRAN

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In this study, we applied FARSITE and FlamMap MTT, two fire spread models based on Rothermel's spread rate equation, and compared their outputs considering two fire events (YekeBermagh and Gharangi) that affected the southern part of Golestan National Park, Northeast Iran. The YekeBermagh fire (July 2011) affected an area of about 58 ha mostly covered by tall grass and dense Juniperus shrublands. The fire of Gharangi (March 2011) burned about 10 ha of timber understory in an area characterized by complex orography. We analyzed spatial and temporal variation in fire behavior estimates, focusing on fire perimeter, rate of spread (m min-1), and fireline intensity (kW m-1), which were simulated at a resolution of 10 m. For both case studies, FlamMap MTT simulations were more accurate than FARSITE ones for all indices, although the difference between the models was limited. Our analysis highlighted similar estimates of fire rate of spread and fireline intensity, with some differences among fuel types and slope classes. The better fit between FARSITE and FlamMap MTT simulations was observed for grass fuel types. The results can improve the capabilities and knowledge of policy makers and fire managers in Northern Iranian forest and inform fire risk mitigation strategies in the study areas.

Keywords: FARSITE, FlamMap MTT, Golestan National Park., fire behavior and spread

FBR.P.04 - DECIPHERING THE IMPACTS OF UNCERTAINTY IN THE ACCURACY OF FIRE SPREAD SIMULATIONS

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Environmental models should be accompanied by a thorough uncertantity and sensitivity analysis. Fire spread models have been commonly used to simulate fire growth, quantify fire risk and landscape management. However, some authors have highlight the importance integrating proper error and uncertainty quantification to fire spread simulations. In this work, we aim at quantifying uncertainty in input variables and parameters and identify the major drivers of fire spread simulation accuracy. We evaluate the impact of uncertainty in the rate-of-spread (ROS) and simulation error. Weather, ignitions, fuel and other landscape variables were selected as input variables for analysis. Adjustment factors, specific of each fuel model, were selected as model parameters for analysis. In a first stage, uncertainty was quantified for each input variable and parameter based on alternative sources of information (e.g. weather measured in meteorological stations), expert knowledge (e.g. fuels) and inverse modeling (e.g. adjustment factors). In a second stage, uncertainty was propagated through the fire spread model for eight real wildfire case studies. The ROS and error ratio were defined as the normalized ratio of resulting fire spread simulations divided by a reference simulation (%). The importance of each variable was quantified using the NISP methodology. We conclude that fuel parameterization and typology, wind speed, relative humidity and ignition location are the most important variables, significantly affecting the accuracy of fire spread simulations. Additionally, we also conclude that the adjustment factors are extremely relevant model parameters. This analysis allows researchers to target work to improve the most relevant variables and model parameters, which will likely lead to more accurate fire spread simulations.

Keywords: satellite, MODIS, rate of spread, error, sensitivity analysis

FBR.P.05 - HISTORICAL BEHAVIOR OF FOREST FIRES IN THE PROVINCE OF PINAR DEL RÍO (BRAZIL) IN THE PERIOD (1994-2013)

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Knowledge of the historical behavior of forest fires in a territory is useful for efficient planning of preventive measures appropriate for each territory, allowing establish the trend of occurrences of fires and their affectations, periods of the day and year with increased risk of emergence and spread, causes of emergence, the types of species and forest types according to their origin, most affected, while it is possible to analyze the effectiveness of service fire protection. The province of Pinar del Rio has a land area without internal waters of 862,500 ha and of which 393,800 ha are covered with forests representing 45.7% of the area covered by forest, making it the province with the largest forested area. Natural forests cover an area of 286,837 ha, established plantations has 106,917 and young plantations of 16,177 ha. Given its composition 46797 ha of natural forests and 86,133 ha of plantations of Pinus spp., In addition to 24, 182 ha and 819 ha of plantations of Eucalyptus spp. and Casuarina spp. respectively. Historically, the province is the most affected by the occurrence of forest fires and demonstrated in the records obtained in the period under study (1994 - 2013), reporting to the province a total of 1,466 fires and 31,882 ha burned areas, increasing considerably in the last five years. In Cuba in the last five years have occurred 2,310 fires have affected 45,058 ha, of which Pinar del Río is the first occurrence of fire with 17.45% (403 fires) and second in affected areas with a 18.43% (8,306 ha) respectively. Among other results may be mentioned that in the forests of Pinus spp., Eucalyptus spp. and Casuarina spp. occurred on 89.09% and they accounted for 95.32% of the damages. The behavior of the occurrence of fire highest values were found during completion of little rainy season and the beginning of the rainy season, where the combustible material tends to increase flammability by water saturation with the fibers, resulting in fire 1,466 and them 596 were caused by lightning and representing 41% of the fires occurred in the province Pinar del Río. In the case of the burned areas larger values between the months of April and May being the first where the middle of the fire burned areas had the highest values are concentrated. The distribution of the occurrences of fires during daylight hours was between 14:00 and 17:00 hours and occurring 62% of the fires. Significant difference for fire occurrences, burned areas and the middle areas burned by fire in each of the months was obtained.

Keywords: fire statistics, causes, forest fire prevention, fire occurrences, fire burned areas

FBR.P.06 - SIMULATION OF LARGE HISTORICAL FIRES BEHAVIOR IN A MEDITERRANEAN AREA THROUGH FARSITE SIMULATOR

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Wildfires represent a critical issue in the Mediterranean area. A small number of big fires is often responsible for most of the area burned and related economic and environmental damages, frequently associated with loss of human lives. This kind of fires usually occur under specific meteorological conditions, typically involving combinations of high temperature, low relative humidity, prolonged drought and strong winds. Large fire behaviour pattern (like crowing and spotting) is commonly not observed in small fires and, for this reason, firefighting of such events is very challenging. The work presented here has been carried out in the island of Sardinia (Italy). The main aims of the analysis are: to characterise the Sardinia fire regime in the period 2005-2012; to evaluate the FARSITE simulator for some representative large fires observed in Sardinia; to quantify fire's potential behaviour in relation with environmental condition observed during the wildfires and, finally, to analyse the environmental conditions effect on the behaviour and fire spread. We investigate 7 large wildfires that took place in Sardinia in 2007 (one case study), 2009 (5 cases studies) and in 2011 (one case study). These events were characterised by a burned area ≥ 2000 hectares that represents about the 1‰ of total wildfires burned area over the period 2005-2012 in the entire island. FARSITE gave good results in simulating the behaviour and spread of past large fires that occurred in extreme weather conditions. We found that these type of fires happened in days characterized by strong wind, with peak intensity and direction variable, high temperature and very low values of relative humidity. Another element is that these large fires occurred in days in which there were more ignitions at the same time and in different sites. Generally, fire spreading was very fast in the first hours after ignition and, although some fires did not exhibit high intensity values, the fight and control operations were particularly difficult. We found a great range of fire behaviours, such as rate of spread, fire line intensity, and flame length, that varied with the fuel model types and depending on topography. This work was partially founded by the Sardinia Region under the Regional Law n. 7/2007 (EXTREME Project - "Development of methodologies and support systems for fire risk assessment in extreme weather conditions") and by the Italia-Francia Marittimo Programme (Proterina 2 Project).

Keywords: Sardinia, historical fire simulation, extreme weather conditions, fire spread

FBR.P.07 - ANALYSIS OF THE FOREST FIRES IN VARIOUS REGIONS OF ITALY, PORTUGAL AND SPAIN

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Spain like Portugal and other Mediterranean countries are suffering the dramatic consequences of the forest fires, which in the last years have produced a big deforestation that provokes degradation of the environment and important socio-economical losses. Most of the total burned area and the largest numbers of fires in Europe are found in southern European countries, namely in Portugal, Spain, France, Italy and Greece. In recent years, there have been several studies on forest fires in the Mediterranean countries. This paper presents a comparative analysis of the variation in the burnt areas and number of fires in different regions of Italy, Portugal and Spain since 2005, using mathematical functions and comparing the results with data from the Mediterranean countries. The functions obtained for annual data are compared with the obtained functions for the mean data in several time intervals, of between 2 and 5 years. In the Iberian Peninsula and Italy, between 1980 and 2013, over 1.5 million fires with a burned area of about 12.5 million hectares occurred. The evolution in the number of fires (by means the proposed functions) in the Iberian Peninsula shows an increase until 2000 and in Italy until 1990, while the area burned grows up to 1986 in the Iberian Peninsula and up to 1985 in Italy. The regions with the highest number of forest fires in the Iberian Peninsula are northern Portugal and Galicia (northwestern Spain) with 55% of the total, while in Italy are Sicily, Calabria and Sardinia, which account for 45%. Thus, while in the Iberian Peninsula fires are concentrated in the northwest, in Italy take place in the Southwest. It appears that the authors will present a wide review of wildfire occurrence in Mediterranean countries and it will be of strong interest to the audience.
The social, managerial, and climatic factors that influence the results will be also included in the presentation.

Keywords: forest fires, Italy, Spain, Portugal

FBR.P.08 - FOREST FIRES: AN EVALUATION OF SPATIAL AUTOCORRELATION OF TOPOGRAPHY AND TEMPORALITY

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Each year forest fires affect woodland areas in Mexico. The aim of this project was to assess spatial autocorrelation of variables such as altitude, topographic position, aspect, slope, and timing of forest fires. Data from 1,004 fires (from the years 2001-2010) were analyzed. Moran's index results for aspect and timing of forest fire indicate a positive spatial autocorrelation with values of 0.95 and 0.99, respectively, showing a non-random trend of forest fires. Thus, the spatial analysis of fire occurrence is a key factor in understanding forest fire incidences in forest ecosystems.

Keywords: Moran's Index, spatial analysis, GIS, slope, aspect

FBR.P.09 - A SPATIO-TEMPORAL MARKED MODEL. AN APPLICATION ON WILDFIRE BURNED AREAS, CASTELLON (SPAIN)

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A wildfire may be defined as any uncontrolled fire in combustible vegetation that occurs in the countryside or a wilderness area. A wildfire differs from other fires in its extensive size, the speed at which it can spread out from its original source, its potential to change direction unexpectedly and its ability to jump gaps such as roads, rivers and fire breaks. Wildfires are characterized in terms of the cause of ignition, their physical properties such as speed of propagation, the physical properties of the combustible material present at fire location (humidity, quantity, continuity, diversity) and the effect of weather on the fire. Burned area is a very important topic to be analysed. Previous works present the analysis of wildfires using the burned area as a mark not as the main characteristic of the study. Indeed, this is a very important element for that people that is working on fires because not only is important to know its position but also the number of hectares burned. Our goal is to find and fit statistical models that could be useful for analysing the burned area using Bayesian statistics and to identify which factors are relevant to explain the spatial variation of burned area as a marked response variable in wildfire incidence. We analyzed the spatio-temporal pattern observed in wildfires occurred in the province of Castellon during the period 2001-2006 taking into account the burned area as a dependent variable. In particular, we considered only those fires with burned areas between ten and ten thousand square meters. The total number of fires recorded in the analysis was 663. The dataset includes information about the geographic coordinates of the centroid of the fire at its final size, the year, elevation, slope, aspect, land use and distance to nearest road to the wildfire's centroid. For our proposal, we described and took advantage of the Bayesian methodology including Integrated Nested Laplace Approximation (INLA) and Stochastic Partial Differential Equation (SPDE). This issue lend us to get prediction and describe wildfires in the region analysed using an easier and faster way. In particular, we have proved different models, all of them based on the Gamma distribution. The results of our analysis show that the best model is that one which includes all the elements such as, the covariates and three random effects: spatial, temporal and spatio-temporal interaction. In addition, we have proved that these random effects have a significative influence on the model. The model also allows us to confirm a relationship between the burned area and both topological variables and land cover. We have used a methodology that allows us to identify the best model for analysing the burned area and it also allows us to use the results for comparing the prediction maps with the real maps in order to prove its goodness. The resulting maps can provide assistance for reducing the burned area in future fires.

Keywords: bayesian methodology, risk mapping, spatio-temporal marked point pattern, wildfires

FBR.P.10 - AGGREGATE ANALYSIS ON FIRE OCCURRENCE IN SARDINIA APPLYING TWO DIFFERENT MODELS

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Fire risk evaluation is a key point for fire managers, particularly in the Mediterranean region, where summer seasons can be characterized by large and severe wildfires, often associated to specific conditions such as heat waves (high temperatures, strong winds and low humidity). Moreover, the process of afforestation of the different agricultural areas and the lack of fuel management have led to an increased vulnerability of the Mediterranean ecosystems to the risk of extreme fire behavior. Wildfire prevention and mitigation need therefore to be addressed so as to minimize risk and vulnerability of forests, highly valued resources and society. The objective of this work is to analyse and model the occurrence of fires of different size in Sardinia and, in particular, to identify the model that best fit the historical data.

For such purpose, we gathered fire occurrence in Sardinia from 1995 to 2009. In particular, we considered daily fire data at municipality level and we distinguished between four fire size categories: 10 ha, 25 ha, 50 ha and 100 ha. Within the study period, we analyzed all events occurred from June to September, being fires ignited from October to May relatively few in number and very small in size. We first analysed whether the distribution of individuals within the region was aggregated, uniform or random, so if the intensity of the events varied over the study area. Using the Ripley's K-function, for the whole time period analysed, we observed that observed data did not follow a random distribution: so, discarding random behaviour, we were able to model fires of different size. To analyse the distribution of fire data we used two different statistical models: Poisson and Gamma. We also described and took advantage of the Bayesian methodology including Integrated Nested Laplace Approximation (INLA) and of the Stochastic Partial Differential Equation (SPDE). Our preliminary results showed that, temperatures below 30 degrees had no influence on the occurrence of fires and that elevation had any effect on the ignition of fires bigger than 100 ha. Furthermore, our study showed that there are significant spatial variability, heterogeneity, temporal variation and differences in the fire patterns for the different size of fires. Overall, this methodology allowed quantifying and assessing possible spatial relationships between spatio-temporal fire ignitions and specific driving forces. These results may be useful in fire management, decision-making and planning.

Keywords: fire occurrence, Mediterranean areas, statistical models, spatial models, INLA

FBR.P.11 - FIRE CHARACTERISTICS IN MEDITERRANEAN EUROPE

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Forest fires are a serious environmental hazard in southern Europe. An assessment of fire statistics will offer insight for the development of adequate measures of prevention, adaptation and mitigation. In this study, we used a collection of homogenized databases from various sources, providing an assessment of the uncertainties/deviations associated with data inhomogeneity. Specifically, firstly we collect and describe the available fire datasets in European Mediterranean regions (Portugal, Spain, southern France, Italy, and Greece). We consider the fire database of the European Forest Fire Information System (EFFIS San-Miguel-Ayanz et al. 2012), which provides the official fire statistics of the European Union and represents a benchmark fire data set and, in addition, we analyse several other databases at different spatial/temporal resolutions obtained from various regional sources (e.g. Pereira et al. 2011; Koutsias et al. 2013), with special attention to data integrity and homogeneity. Secondly, we analyse the homogenised fire records obtained from these different databases, focusing on two standard fire indices, namely the burned area and the number of fires. Here we discuss the analysis of the spatial-temporal patterns (e.g. trend, seasonality) of recent (1985–2011) fire activity in Portugal, Spain, southern France, Italy and Greece. We find that, generally, the burned area as well as the number of fires displayed a general decreasing trend, and this trend is statistically significant in most of the domain considered, regardless of the datasets considered or the method used to assess the significance of the trends.

Keywords: forest fires, southern Europe, fire statistics

FBR.P.12 - DETERMINATION OF THE NORMAL FIRE SEASON IN THE URBAN ÁREA OF JUIZ DE FORA (MG), BRAZIL

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The fires in vegetation can provoke severe damage to the environment as well as considerable economic consequences, such as destruction of habitats, the burning of wood and costs for their combat. To establish politics for control and prevention, it is necessary to know the profile of fire. The statistics of occurrence of fires in vegetation are the main tools to draw your profile. With these data, we can plan to control more efficiently by reducing costs, time and risk in their combat. The objective of this study seeks the determination of the period of the year and schedule of larger occurrences of vegetations fires in the Juiz de Fora city (MG). For that, a 10 year temporary series was used (2004 - 2013) with data of occurrences of fires and climatic elements in the city. According to the results, it was characterized the period from June to October as the normal fire season. At hourly scale, the largest number of occurrences was concentrated from 10:00 to 20:00 hours, with peaks between 15:00 and 16:00 h.

Keywords: fires, combustible material, climatic conditions

FBR.P.13 - COUPLED INFLUENCE OF TOPOGRAPHY AND WIND ON FIRE SPREAD AND BEHAVIOR: THE WILDFIRE OF GOLFO ARANCI (SARDINIA, ITALY)

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The aim of this work is to analyze the case study of Golfo Aranci (Northeast Sardinia, Italy) wildfire. In this event, a strong influence of topography and wind on fire spread and behavior was observed and documented by the fire crews. The fire was ignited on June 24, 2013, at around 2.45 pm and was declared definitively controlled in the morning of June 25, although the most of the area was burned in a few hours. Overall, the final size of the event was around 195 ha. The area affected by the fire is of great natural value, because of the presence of the Site of Community Importance (SIC) of Capo Figari and Figarolo (Habitats Directive 92/43/CE). The vegetation of the site was mostly represented by tall and dense Mediterranean maquis, with a relevant presence of Arbutus unedo and Erica arborea. After the ignition, the flames spread quickly, driven by a strong wind from west (intensity close to 35-40 km/hour); the intensity of the fire was sustained by the flammability and the load of the fuels. In addition, atypical fire behavior, as for instance fire channeling and intensive spotting, was documented and reported in the ridges of the Golfo Aranci hill. Overall, terrestrial attacks were not possible due to the complex situation and the presence of a small and dangerous road at the bottom of the hill. Furthermore, the aircrafts that operated in this fire were not able to affect much the final perimeter, mostly because of the difficulties in operating and the aggressive fire spread. A complete and exhaustive analysis of environmental conditions, orography, weather, fire crews and aircrafts operations, and the observed fire spread and behavior will be presented in this poster.

Keywords: fire spread and behavior, fire channeling, spotting, fire environment, extreme fire behavior

FBR.P.14 - OBSERVATIONS ABOUT THE PHENOMENON OF FIRE SELF-EXTINGUISHING: THE INFLUENCE OF SLOPE AND FUEL BREAK ON FIRE BEHAVIOUR

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A number of real fire observations showed that a fire spreading upslope, in the absence of wind and spotting, stops and self-extinguishes when it reaches the ridge. This situation was observed, for example, at Segade (Coimbra, Portugal) in 2001, Seui (Ogliastra, Italy) in 2012, where also a narrow fire break was present at the ridge top. Green (1977) assumed that a fire spreading along a slope of 35°, in heavy brush fuel, with low humidity, and wind that produces flames 15 m long, fuel break with 60 m is sufficient to prevent skin burns on firefighters. However, as showed by real fire observations, protection from radiation could be afforded in less than 60 m large fuel breaks if a sharp ridge is located in the centre of the fuel break. For example, several times a forest road or maintained right-of-way such as a power or telephone line served as a firebreak (Brown and Davis 1973). Thus this work aims at analysing the effect of slope transition and the break in fuel continuity in the propagation of the fire and the phenomenon of self-extinguishing. Experimental tests were carried out at the Forest Fire Research Laboratory of the University of Coimbra on the Dihedral Table. This tool has two faces of 4x4m^2 each that can be inclined independently between -45° and +45°. The fuel bed was made of straw (fuel load of 0.6 kg m^{-2}). Several tests of fire behaviour and spread were performed with different combinations of slope angles in the two half-tables and considering various gaps in fuel continuity, always igniting the fire in the centre line of the first face above its lower edge. The rate of propagation (ROS) was measured with chronometer, the wind flow generated by the fire (U) with a pair of S Type pitot tubes equipped with thermocouples, flame height (H), flame length (L), flame depth (D) were estimated from video images processed with a special program (Microstation95). The analysis of data focused on the effects of slope, fuel gap, and interaction between wind flow and ROS. Preliminary results showed that fire spread across the two half-tables of the Dihedral Table only when the slope of the two faces is positive, and the fuel gap is equal to zero. Probability of fire crossing was 100% when the fuel gap is equal to 0, and this probability decreases when the fuel break is reduced. On the other hand, results showed that, although in the presence of a consistent fuel gap, the probability of fire crossing the two faces of the table increases when the slopes of the two faces increase.

Keywords: Fire behavior, slope effect, fuel break

Fuels and Post-Fire

Oral Presentations

FPF.01 - POTENTIAL APPLICATION OF TERRESTRIAL LASER SCANNING FOR FUEL TYPE CHARACTERIZATION IN BROADLEAF MEDITERRANEAN FOREST

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Information on forest canopy structure is required at a wide range of spatial scales for several environmental applications (ecosystem productivity model, ecological and forest management, disease and stress detection, fuel properties). Aerial laser scanner (ALS) demonstrated to be a promising techniques and an important source of accurate data and information in forestry studies. More recently several studies reported different potential applications of the terrestrial laser scanner (TLS) for forest stand and canopy variables estimation. The two systems can be seen as mutual: the plotwise forest data, collected through TLS, can be used as a reference for the calibration of large-area inventory data measured by aerial and space-borne remote sensing techniques, by ALS or multispectral scanners. TLS technology can represent an alternative to overcome limitations of the conventional ground based techniques, that are time consuming and characterized by a limited accuracy. TLS allows the collection of high resolution point clouds, which can potentially and productively be used to derive tree attributes. Post-processing of TLS point clouds enables extensive analysis of data by automatic or semi-automatic methods specifically developed. However, the operational use of TLS techniques for vegetation characterization of broadleaf forests needs further investigations. In particular, discriminating between laser pulses that were intercepted by woody material, leaves and small branches is a key factor to improve the accuracy of tree and canopy description. The main objective of this work was to develop a segmentation method for broadleaf tree species in order to automatically (or semi-automatically) extract branches and stems from foliage. A voxel-based approach was developed and tested using a TLS data set collected in field by multiple scanning on four cork oak trees. After using noise reduction filters, voxels were used as input to generate clusters through a point density algorithm. Clustering process led to the identification of wood and leaf voxels. Points belonging to each voxel were then classified and quantified as wood, foliage and noise. Experimental results show that the segmentation algorithm can accurately discriminate wood and foliage clusters and consequently give the points of cloud associated to foliage, trunk and main branches. In conclusion, the method proposed seems to be a promising approach for improving the estimate of both canopy density distribution and woody material volumes In addition, our findings suggest that the terrestrial laser scanner (TLS) can be conveniently applied to characterize forest canopy fuel characteristics at plot level.

Keywords: terrestrial lidar, forest inventory, tree volume, crown volume, broadleaf trees

FPF.02 - CHARACTERIZATION OF FUEL MODELS IN THE MOLISE REGION AND THEIR MAPPING BASED ON FOREST CATEGORIES

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In Against Forest Fires (AFF) plans, a basic role to assess the fire characteristics and its spread is related to fuels that are schematized in special models according to the pyrological features. The fuel types can be alike in different ecosystems, but each distinctive ecosystem may have different fuel models associated with them. Several models have been developed and adapted to specific local contexts over time (e.g. NFFL Behave model-US; FBP-Canada; etc.). The correlation of a fuel model to different forest types and crown coverage, allowed the wall-to-wall mapping of fuel models reducing costs related to field surveys and photo-interpretation. Moreover, this correlation allows fire risk downscaling from wide areas (e.g. at regional level) to local areas (e.g. at farm level), then facilitating the implementation of integrated AFF plans at various planning levels. The drawing of forest maps on typological bases is now widespread in Italian regions, among which the Molise one. This study aims at testing the suitability of the Behave classification system to the vegetation and ecological conditions of the Molise Region, mainly lying within Mediterranean-type environment. Based on data collected in 241 plots, the analysis of the parameters that characterize the different fuel models allowed us to define the features that the selected models could take in the investigated region. Eight new fuel models were defined following the known forest and pre-forest categories and mainly distinguished according to the degree of crown cover. The new fuel models cover about 170,646 ha (38.2% of the regional surface): 125,361 ha belonging to forest ecosystems (dominated by turkey oak - 57,393 ha - and downy oak - 45,285 ha - forests) and 45,285 ha to grasslands and pastures.

Keywords: fuel models, forest types, Mediterranean environment

FPF.03 - DEVELOPING FUEL MODELS FOR NORTHEASTERN ITALIAN FORESTS AND EVALUATING THEIR SKILLS IN SIMULATING REAL FIRE BEHAVIOR

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Standard fire behavior fuel models are often utilized in fire simulators (e.g., FARSITE, BehavePlus) in many parts of the world. Commonly used fire behavior fuel models were initially developed for use in the United States by Anderson (1982) and more recently by Scott and Burgan (2005). The use of these fuel models outside their original area requires local validation to ensure they are representative of local fuel conditions. If not then the derivation of custom fuel models may be required. In Europe the most studied forest types for fire behavior fuel models have been the Mediterranean scrubland (Pereira et al., 1995; Baeza et al., 1998; Cruz 2001; Bacciu 2008) and the Mediterranean pine forest (Fernandes 2009). Fuel conditions have seldom been studied in the common broadleaf forest types. The goal of this study was to improve the knowledge of fuel characteristics in warm temperate climate broadleaf forests and pine plantations in Northeastern Italy. Furthermore, we compared fire simulations using standard and custom fire behavior fuel models (derived by four different fuel classification approaches). Finally, we analyzed how much the different fuel classification methods affected fire simulation accuracy and outputs. In more detail, we selected as case studies eight small fires which occurred in the Euganei hills and Veneto Adriatic coast (Italy) during the period 2003 to 2012; we then applied FARSITE (Fire Area Simulator, Finney 2004) to simulate spread and behavior of such events. The main forest types burned were chestnut, hop hornbeam – manna ash – oak forest and pine plantations. To characterize fuels, field sampling and measurements of downed woody, litter, shrubs and herbaceous fuel load and their percent cover were collected, following Brown's method (1984), within buffer zones around the case studies. Custom fuel models were derived from field data using: a) single plot data, b) forest type classification, c) Prometheus (1998) classification, and d) cluster analysis. Finally, the custom fuel models were associated to the forest types using as reference the Veneto Region land-use map (Veneto Region 2007). For each fire, several simulations were carried out using both standard and custom fire behavior fuel models. Weather data were taken from three representative weather stations in close proximity to the previous fires. We finally compared FARSITE simulation outputs of selected fire behavior characteristics with fire behavior data collected by the Regional Forest Service. Comparing the simulated fire behavior outputs of the four fuel model classification approaches, showed little differences in flame length and crown fire activity and type (e.g., passive versus active). On the other hand, significant differences were observed in terms of burned area and rate of spread, with the custom fuel models having greater rates of spread than the standard fuel models in most simulations.

Keywords: fuel modelling, fire behaviour, forest fuels, farsite, forest fires

FPF.04 - LARGE SCALE ASSESSMENT OF FUEL DRYNESS USING HIGH FREQUENCY TEMPERATURE DATA FROM COMPENSATED FINE-WIRE THERMOCOUPLES

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Empirical functions based on weather variables are often used to assess fuel dryness for use in fire danger models. Most of these models estimate evapotranspiration and daily changes in soil moisture. Fuel dryness is assumed to dry as the soil dries; and the fire danger increases. While these models do provide some indication as to surface dryness, they are based on broad weather variables and there is little or no input information on the surface vegetation or soil characteristics. Consequently, a direct measurement of local sensible heat flux density (H) conditions is likely to provide a better measure of the surface moisture conditions. An in-situ measurement approach to quantification of surface fuel dryness based on measuring net radiation (Rn) and H was previously proposed, but the method was not widely adopted because the cost for sensors and data loggers to collect the necessary data were cost prohibitive. In the past, the surface renewal (SR) method, using high-frequency temperature measurements from fine-wire thermocouples to determine ramps in the temperature traces, provided an estimate of H (H'). While there is a correlation between H' and H measured with a sonic anemometer, calibration of H' against H readings was needed. Although SR measurement is easy and inexpensive, the sonic anemometer measurements are complicated and costly. Recently, a methodology to eliminate the need for SR calibration was developed. In that method, thermocouple frequency response compensation was found to cause convergence of the surface renewal alpha calibration factor. In this paper, we will discuss the fuel dryness index, the new methodology to estimate H, and methods to employ the SR technique to improve the spatial assessment of fuel dryness.

Keywords: heat flux, fire danger, energy balance, surface renewal

FPF.05 - A SEMI-MECHANISTIC MODEL OF DEAD FINE FUEL MOISTURE: FROM STANDS TO REGIONS

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The moisture content of vegetation and litter (fuel moisture) is an important determinant of fire risk, and predictions of dead fine fuel moisture content (fuel with a diameter < 25.4 mm) are particularly important. A variety of indices, as well as empirical and mechanistic models, have been proposed to predict fuel moisture, but these approaches have seldom been validated across temporally extensive datasets, or widely contrasting vegetation types. Moreover, landscape scale estimates of fuel moisture from remotely sensed data have largely been restricted to live fuels, with limited research on modelling DFMC from satellite datasets. Here, we describe a semi-mechanistic model, based on the exponential decline of fuel moisture content with atmospheric vapor pressure deficit, that predicts daily minimum fuel moisture content. We first calibrated the model at one site in New South Wales, Australia, and validated it with ground data at three contrasting ecosystem types in California, USA, where 10-hr fuel moisture content was continuously measured every 30 minutes over a year. We then developed the spatial application of the model satellite data and interpolated weather station data. We found that existing drought indices did not accurately predict fuel moisture, and that empirical and equilibrium models provided biased estimates. The mean absolute error (MAE) of the fuel moisture content predicted by our model across sites and years was 3.7%, which was substantially lower than for other, commonly used models. Our model's MAE dropped to 2.9% when fuel moisture was below 20%, and to 1.8% when fuel moisture was below 10%. Our model's MAE was comparable to instrumental MAE (3.1-2.5%), indicating that further improvement may be limited by measurement error. The simplicity, accuracy and precision of our model makes it suitable for a range of applications, such as operational fire management and the prediction of fire risk in vegetation models, without the need for site-specific calibrations.

Keywords: dead fine fuel moisture, model development, model validation, spatial scaling

FPF.06 - QUANTIFYING WILDFIRE INDUCED CHANGES IN CENTRAL SIBERIA: LINKING OF ATMOSPHERIC COMPOSITION AND CARBON UPTAKE OF FOREST ECOSYSTEMS

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Calculations of direct emissions of greenhouse gases from boreal wildfires remain uncertain due to problems with emission factors, available carbon, and imprecise estimates of burned areas. Even more varied and sparse are accurate in situ calculations of temporal changes in boreal forest carbon dynamics following fire. Linking simultaneous instrumental atmospheric observations, GIS-based estimates of burned areas, and ecosystem carbon uptake calculations is vital to fill this knowledge gap. Since 2006 ZOTTO (www.zottoproject.org) a research platform for large-scale climatic observations is operational in Central Siberia (60°48'N, 89°21'E). The data of ongoing greenhouse gases measurements at the tower are used in atmospheric inversions studies to infer the distribution of carbon sinks and sources over central Northern Eurasia. We present our contribution to reducing uncertainties in estimates of fire influence on atmospheric composition and post-fire ecosystem carbon uptake deduced from the large-scale fires that happened in 2012 in the tall tower footprint area. Assessment of air composition in fire plumes was based on time series of CO/CO2/CH4 mixing ratios measured at 300 m a.g.l.. Burned areas were estimated from Landsat ETM 5,8 satellite images, while fires were detected from Terra/Aqua MODIS satellite data. The magnitude of ecological change caused by fires was measured and mapped with a Normalized Burn Ratio (NBR) index and further calibrated by a complementary field based Composite Burn Index (CBI). Measures of fire radiative power (FRP) index provided information on fire heat release intensity and on the amount and completeness of biomass combustion. Based on the analyzed GIS data, the system of study plots was established in the five dominating ecosystem types where the estimation of carbon pools and their mapping was organized with a laser-based field instrumentation system. Based on the derived data set the biomass burning emissions from dominating ecosystem types in Central Siberia were calculated. Estimations of direct emissions were supplemented by soil respiration measurements within the plots by an automated soil flux system (LI 8100A). The highest biomass burning emissions were found in pine forests (1300-1850 gC/m^2). For mixed and dark forests fire emissions did not exceed 550-600 gC/m^2. In turn the maximal soil respiration rates (up to 3,2 $\mu molC/ m^2s^{-1}$) were found in wet and less disturbed mixed forest stand and could be attributed to autotrophic respiration, and the lowest rates (1-1,2 $\mu molC/m^2s^{-1}$) of primarily heterotrophic origin were typical within the dry pine stands with the highest burn severity.

Keywords: wildfires, ZOTTO project, atmospheric transport, biomass burning, soil flux

FPF.07 - FIRE EFFECTS IN PINUS UNCINATA RAM PLANTATIONS

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Knowing fire ecology of forest species is essential to manage the wildlands and also to evaluate effects due to changes in fire regime and under a global change scenario. Few references can be found about fire ecology of Pinus uncinata Ram (PU). PU specie lives in areas located in the Pyrinees or the Alps where large wildland fires did not occur frequently in the past and, specially, with a high fire behavior. However, several fires with extreme fire behavior affected these areas in last years and they could affect other forest in the future. We analyzed effects on the trees during three years, mainly mortality in relation to fire line intensity, scorched height, percentage of scorched crown, and bark char height around the tree perimeter. PU species is very tolerant to low fire line intensity but fire effects are very significant when fire line intensity is high. Mortality rate is from 15 to 30 % in medium fire line intensity and the death trees had the highest values of scorched height and percentage of scorched height. No significant relationships were found with bark char height. This work supports that prescribed burning could be used to decrease fuel load and continuity and suggest that extreme fire behavior have to be prevent in the future with fuel management.

Keywords: fire effects, Pinus uncinata Ram, tree plantations

FPF.08 - PRE AND POST FIRE REGENERATION DYNAMICS IN THE COASTAL STONE PINE (PINUS PINEA L.) IN ARBOREA (SARDINIA)

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Studies on the stone pine (Pinus pinea L.) put in evidence that this species has no efficient post-fire regeneration strategies: the long interval for having mature seeds, the high seed weight, too big for wind dispersal, and lack of serotiny make it particularly susceptible to the action of repeated fires (Tapias et al. 2001). For these reasons, the stone pine forests represent an extremely delicate ecosystem and, in many stations, are at great risk (Gallegos et al., 2003). This paper analyzes the post-fire dynamics of the coastal artificial stone pine stands (Pinus pinea L.) of Arborea (8 ° 32 'E, 39 ° 48' N) in the Gulf of Oristano (Sardinia, Italy), planted in 1933 on a total surface of about 433 hectares. Part of the stone pine forest was affected by a fire in 2007. The main objective of this research is to describe and quantify the after fire response of vegetation, in a pine forest characterized by different Mediterranean species with different regeneration strategies (seeder/resprouter), in order to propose possible post-fire silvicultural guidelines. In detail, the aim of the research was: to analyze the behavior of the coenoses after fire; to verify the post-fire growth and canopy recovery of the Mediterranean maquis; to evaluate natural regeneration of italian stone pine; to verify the effectiveness of italian stone pine plantation in enhancing the establishment of the natural forest cover and the evaluation of different post-fire restoration practices. Data were collected by the point-centered quarter method (PCQ) (Cottam and Curtis, 1956); as a plotless technique to estimate density it exhibits a variety of features and allows good results in the assessment of functionality and complexity before and after the fire. The survey considered the three components of regeneration, namely regeneration layer, shrub layer and trees layer. In the areas swept by fire a significant change from the structural point of view was observed. The nuclei of gamic regeneration are widely observed under the form of aggregates with a "leader tree", but there are also many single elements of regeneration. In not burned areas, under the higher density tree cover, regeneration of pine is almost absent. From the point of view of composition the prevalence of Cistus salviifolius L. and Pistacia lentiscus L. was observed in the areas affected by the fire, greater if compared to not covered areas.

Keywords: fire ecology, Pinus pinea, regeneration

FPF.09 - FACTORS AFFECTING THE POST-FIRE NATURAL REGENERATION AND RESILIENCE IN PINUS HALEPENSIS MILL.: IMPLICATIONS FOR POST-FIRE MANAGEMENT

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In the Mediterranean Basin, mainly in the last decades, global change, i.e. climate change and changes in land use, modified the fire regimes. Resilience is the capacity of an ecosystem to resist and recovering a disturbance, in a relatively short period of time. The ecosystem resilience is function of the resistance and adaptive strategies developed by species to cope with disturbances, such as wildfires. In South-eastern Spain, the global change and changes in fire regime induced a decrease in productivity and plant diversity, in addition to variations in spatial distribution and vegetation structure. Those changes in fire regime could relegate large areas to secondary stages of the ecological succession. In this scenario, the adaptive forest management, including post-fire restoration, should be focused into maintain and restore ecological resilience. To develop tools providing help to decision makers, we monitored, at landscape-scale, the natural regeneration of burned Aleppo pine forests. The vegetation monitoring in the medium-term will provide information to predict vegetation resilience, related to landform, vegetation status or fire characteristics, and related to management objectives. We proposed a field sampling campaign to validate a resilience quantification model (type curves) previously developed. We calculated the recovery of vegetation by relating measurements of Normalized Difference Vegetation Index (NDVI), obtained from LANDSAT imagery, and the potential changes in taxonomic composition according to the time elapsed after the fire. We also calculated fire severity, measured as differenced normalized burn ratio (dNBR) obtained from LANDSAT imagery. Combining both areas, we set twenty-four plots to record Aleppo pine sapling density, soil coverage and diversity indices. The plot results were related to micro-basins which were calculated by using a Digital Model Terrain (DTM) and Sextante tools. We will develop an integrative approach to provide planning tools for efficiently recognizing and prioritizing problems in fire-prone landscapes. We pretend to define areas which will be regenerated similarly to pre-fire conditions (no action is advised), areas where active restoration is needed (lower recovery or resilience than pre-fire conditions) and areas where assistance to natural regeneration will be necessary (excessive regeneration which will provide high intra and interspecific competition).

Keywords: adaptive forest management, plant diversity, micro-basin, post-fire restoration

FPF.10 - THE ROLE OF WILDFIRES AND FOREST SUCCESSION IN STREAM BIOGEOCHEMISTRY WITHIN THE CONTINUOUS PERMAFROST ZONE OF CENTRAL SIBERIA

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Fire can transform the subarctic forest landscapes, leading to the changes in organic matter and nutrient loading to receiving streams and rivers. The influence of fire-driven variability on nutrient retention and transformation is poorly understood within the permafrost terrains. To get an insight to the fire effect on hydrochemical characteristics of streams draining continuous permafrost terrains of Central Siberia (64o N 100o E), we have selected the chronosequence of basins which were severely disturbed by fires (>80% of basin area) in time range from 1 to 110 years ago. Stream waters were sampled continuously during frost free season (May-September) since 2010. Four streams are equipped with water level, temperature and conductivity probes for continuous monitoring. The strongest effects of wildfire on dissolved organic carbon (DOC) concentrations in streams occurred in freshet period (May-June): differences of DOC concentrations among "intact" (>100 years after fire) and recent fire basins (1 year) reached as much as 2-fold. Slightly less pronounced differentiation among basins occurred in mid-summer-fall season, as DOC-depleted solutes from deeper soil layers (not affected by fire) begun dominate in stream waters. However, elevated concentrations of DOC throughout the growing season in "intact" streams suggest that upper C-rich horizons play the role in stream DOC not only during the snowmelt season, but also during the rest frost-free season. DOC concentrations recovery rates based on seasonal mean values calculated against "intact" 115 year old basin demonstrated linear growth of DOC concentrations (0.12 mgC/a) with time after a fire up to 55 years and reached ca. 85% of initial values. An opposite trend (i.e. increasing load to streams after fire impact) was observed for dissolved inorganic carbon, major anions and cations. Sulfate was found to be a good tracer of fire affect as increased 200-fold in stream waters right after a fire and steady decreased at the rate [SO42-]=3.65 x(year after fire)^-0.75 as terrestrial ecosystems recovering after fire effect. For our study area, Cl- appears to be a strong indicator of permafrost degradation as it reflects talik formation and connection of a stream to underlying evaporitic deposits. While evidence of permafrost degradation is most apparent in the larger rivers of the region, we expect increasing concentrations of Cl- in the smaller streams as permafrost degrades due to decreased fire return interval and warming temperatures.

Keywords: continuous permafrost, basins, chronosequence of fires, stream biogeochemistry, indicators

Fuels and Post-Fire

Poster Contributions

FPF.P.01 - FUEL MODEL CHARACTERIZATION AND FINE SCALE MAPPING IN COASTAL WUIS OF NORTH-EASTERN SARDINIA (ITALY)

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The present study aims to develop and implement a new methodology for surface fuel model characterization and mapping in a 7,000 ha area located in north-eastern Sardinia (Italy), where recently large spreading wildfires threatened the scattered wildland-urban interfaces (WUI), touristic resorts and human lives. We used airborne Light Detection and Ranging (LiDAR) derived from fine resolution (1 m) Digital Surface Model (DSM) grid and on-site fuel sampling surveys to generate a fine resolution (10 m) surface fuel map, necessary for fire spread and behavior modeling and fire risk mapping on the WUI. Moreover, we derived a fuel map using the 1:25,000 land use land-cover (UDS) of 2008 as a reference, following the methodologies used in previous fire modeling studies. According to preliminary vegetation sampling, to main species composition and fuel model structural parameters, and in analogy with previous studies, we stratified the DSM grid into a number of fuel models using the vegetation height ranges associated to the different fuel models as a reference. We also gathered data for the crown characterization (i.e., canopy base height and canopy bulk density) in the different fuel models. Spatially explicit canopy cover and canopy height were directly derived from 1 m DSM grid smoothed interpolation, considering the pixels with > 3m height values as tree canopy covered surfaces. The final DSM derived fuel map was then compared with the UDS derived fuel map, in order to evaluate the spatial agreement or disagreement between the two maps and between fuel maps and real data. On the whole, we found some differences in the spatial agreement as well as in the absolute coverage incidence of the fuel types between the two methods. Overall, the LiDAR method allowed the creation of very detailed maps of vegetation. Other information on the vegetation characteristics (base height of the vegetation, foliage density, etc.) can be also obtained by this method, and this supports the creation of more accurate maps of fuel models. On the other hand, this methodology is not able to define other fuel characteristics, as for instance fuel load, fuel moisture or moisture of extinction, and therefore field sampling should be coupled to LiDAR methods to characterize fuel layers. The LiDAR methodology allows producing fine scale fuel model maps for wildfire spread and behavior simulation. The method represents a valuable support to landscape managers for the identification of high fire risk areas and for the implementation of fire risk mitigation measures. In addition, detailed fire hazard maps also could contribute for the development of strategies and tactics in fire extinction on the WUI areas (e.g., identification of safety areas, defensible vs. non defensible housing and confinement vs. evacuation measure implementation).

Keywords: fuel model mapping, LiDAR, wildland-urban interface, fire risk, fire suppression strategies and tactics

FPF.P.02 - DEAD FUEL MOISTURE MODELLING AND RELATIONSHIPS WITH WILDFIRES IN A MEDITERRANEAN REGION

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Southern Europe, and in particular the Mediterranean areas, heavily experiences summer wildfires. Although the active fire fighting activities are well organised, a lack in the forecast activities is still highlighted in these areas. In this context, the moisture content of fine dead fuels is a key variable in the wildfire studies, being related with fire ignition and spread and, definitively, conditioning fire danger. In this work, the dead fine fuel moisture was estimated at daily scale applying a set of models in a Mediterranean region (Sardinia, Italy) and comparing it with the fire occurrence (number of fires and burnt surface) for the period 2000-2007. Between the fire danger models available in literature, we chosen 6 empirical models requiring easily available weather variables as input data (i.e., air temperature, relative humidity, wind speed, precipitation). The FFMC (Fine Fuel Moisture Code), a module of the Canadian Fire Weather Index FWI was also enclosed in the analysis. Sardinia, the second largest island of the Mediterranean Sea heavily experiences summer fires. About half of the island surface is covered by forests and Mediterranean maquis. The weather input data come from the regional net of weather stations. The results showed a good agreement of the outputs obtained by most of the applied models. High relationships were found between the modeled fuel moisture and the fire occurrence, confirming the importance of the dead fine fuel moisture prediction to forecast fire occurrence and behavior of these areas.

Keywords: fuel moisture index, fire behaviour, fine fuel

FPF.P.03 - MONITORING LIVE FUEL MOISTURE CONTENT AND PHENOLOGICAL BEHAVIOUR OF MEDITERRANEAN SHRUBLAND SPECIES USING AN AUTOMATED DIGITAL SYSTEM

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Wildland fires are an important disturbance factor for natural ecosystems in the Mediterranean Basin. Wildland fire occurrence and behavior are determined by many different factors such as topography, weather, and fuel. Among them, vegetation type and water status are very important as drier fuel contributes to facilitate fire ignition and propagation. Shrublands are an important component of Mediterranean vegetation, which constitute the surface fuels primarily responsible for the ignition and the spread of wildland fires. As fires will easier propagate when live fuel moisture (LFM) is low, monitoring the plant water content of live vegetation can be a useful tool to identify critical periods of high ignition danger for Mediterranean ecosystems. However, because field surveys are expensive and time consuming, LFM is generally measured in the field at only a few discrete locations and time to determine the level of fire danger. Vegetation monitoring based on "near-surface" remote sensing techniques have been proposed in recent researches, in particular for monitoring the physiological and phenological status of vegetation communities. These techniques use radiometric instruments or imaging sensors to quantify, at high temporal resolution, the seasonal changes in the optical properties of the vegetation canopy. In this paper, an Automated Phenological Observation System (APOS), based on digital image sensors, used for monitoring the seasonal changes of vegetation water status and phenological behaviors of Mediterranean shrubland species is presented. The APOS system was developed under the EU-funded research infrastructure project INCREASE (an Integrated Network on Climate Change Research) and installed in a Mediterranean shrubland area. The APOS system is set to acquire a large panorama of vegetation every day at noon (36 shoots per panorama). The analysis of digital images and RGB (Red, Green and Blue) signal reveals both color variations related to the seasonal rhythms of plant phenology and those related to the physiological changes in the water status of vegetation. Primarily, this system would allow to (i) analyze digital images in the visible spectrum to evaluate physiological traits associated with the water status of plants and (ii) monitor the phenology and water status of vegetation based on technical of proximal sensing. The use of systems based on "near-surface" remote sensing techniques can provide new nonintrusive predictive tools to identify variation in the vegetation water status, and consequently in the LFM content seasonal pattern, which can allowed field surveys less expensive and time consuming than traditional monitoring. Moreover, they can be a valid support to identify critical periods of high ignition danger for Mediterranean ecosystems.

Keywords: near-surface remote sensing, digital image system, live fuel water status, Mediterranean shrubland

FPF.P.04 - THE USE OF NATIVE ORNAMENTAL SPECIES IN SOUTHERN BRAZIL AS FIREBREAKS AGAINST FOREST FIRES IN HIGHWAYS

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Road landscaping when well prepared can provide more than the road of integration with the landscape and enrich the existing beauty; it can contribute to the safety of drivers and landscape conservation own. Measures to prevent forest fires are one of these ways to promote greater safety for drivers and less damage to the local landscape. An example of these measures can be the implantation of a landscape project that contemplates the use of species with low flammability to serve of barrier against forest fires. The objective of this work was to evaluate the flammability of native ornamental species of the south of Brazil with potential for use in the forest fire prevention in the landscaping of the highways. For this four native species of Brazil with ornamental potential had been selected, even so are of natural occurrence in the areas next to the highways in the south to Brazil. Curassavica Asclepias L. (Apocynaceae) is an annual herbaceous species that presents ornamental potential due to beauty of its inflorescence of coloration orange and turns yellow. In the road landscaping, this plant can most be used in homogeneous composition in rotatory or seedbeds central offices, where little or no flow of pedestrians exists because is a toxic species. Eryngium elegans Cham. & Schltdl. (Apiaceae) is a perennial herbaceous plant with leaves with jagged edge arranged like a rose that provides a contrast with the white inflorescence of erect branches. Although the species has a rustic appearance, prefers moist habitat. In road landscaping it can be used as ground cover plant in composition with other shrub or tree species. Lantana camara L. (Verbenaceae) is a perennial, aromatic shrub that stands out more for the beauty of its leaves and flowers, forming orange, yellow or red mini-bouquets that are very showy until seen from a long distance. Leandra australis (Cham.) Cogn. (Melastomataceae) is a shrub with size ranging from 0.5 to 3.0 meters, with ornamental potential mainly because of its beautiful dark green leaves with visible ribs. The firing experiments were performed in epiradiator in airflow free site, and the collected variables were: frequency of ignition (FI) and time to ignition (TI). The flammability was determined based on the methodology proposed by Valette (1990). The results showed no statistical difference between the species for any of the variables. All species had low frequency of ignition. On average, the time to start ignition was greater than 60 seconds. Lantana camara was the species with the highest frequency of ignition (8.0%), followed by Eryngium elegans (4.0%), Leandra australis (2.0%) and Asclepias curassavica (zero). From the results, it could be inferred that the analyzed species have zero flammability. Thus, it is concluded that the species in addition to having aesthetic and functional characteristics suitable for a landscape composition on roads, also serve as a barrier against forest fires.

Keywords: flammability, road landscaping, native species, epiradiator, WUI

FPF.P.05 - EVALUATION OF BOUGAINVILLEA GLABRA CHOISY AND LIGUSTRUM LUCIDUM AITON FOR COMPOSITE OF FUELBREAK

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Wildfires cause many effects in the soil, fauna, flora, and in the atmosphere. They also cause economic losses and present risk to human life. One of the preventive actions regarding wildfires, suggested by the preventive silviculture, is the implementation of fuelbreaks. Fuelbreak is a plantation in lines with lower inflammability species comparing to the main culture, in order to reduce or avoid the fire spread. The present study aimed to evaluate the fire behavior of the species Bougainvillea glabra Choisy and Ligustrum lucidum Aiton for use in fuelbreak species in Southern Brazil. To do so, the species were assessed according to their moisture content, flame height, fire spread speed, and amount of combustible material consumed in experimental burnings. It is expected that the fuelbreak species used present lower parameters comparing to those presented by the main culture (or by the preferred species. For comparative purposes, taking into account the similarity of the meteorological conditions of temperature and relative humidity, the burning of the studied species were alternated with burnings of Pinus taeda, thereby making them paired burnings. The experiment was performed in the Wildfire Laboratory of the Federal University of Paraná (UFPR). The burnings were done within 1 m² plots, with a load of 1 kg of thin combustible material (diameter <7 mm), which dried in a kiln at 75° C for 48 hours. For each selected species were performed 10 burning repetitions, which resulted, because of sampling points, in: 10 moisture content values, 90 flame height values, 80 values of fire spread speed, and 10 values of combustible material consumed by fire. The results showed that B. glabra presented higher moisture content (208.70%) comparing to L. lucidum (157.2%). Regarding to the other fire behavior variables, the B. glabra presented an average speed of fire spread of 0.19 cm s^{-1}, an average flame height of 11.20 cm, and 29.15% of combustible material consumed by fire. The P. taeda presented values of 0.87 cm s^{-1}, 42.17 cm, and 72.88%, respectively. Regarding the species L. lucidum, it presented an average speed of fire spread of 0.29 cm s^{-1}, an average flame height of 19.41 cm, and 75.65% of combustible material consumed by fire, whereas the species P. taeda presented 1.40 cm s^{-1}, 34.25 cm, and 77.85%, respectively. Qualified by the obtained results about fire behavior, it is concluded that the species B. glabra and L. lucidum have potential use in fuelbreaks composition, due to their low inflammability characteristics.

Keywords: forest fires, fuelbreak, inflammability

FPF.P.06 - SUSCEPTIBILITY TO FIRES IN VEGETATION MAPPING USING GEOGRAPHIC INFORMATION SYSTEM

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The constant change in ecosystems promoted by humans has led to a change in fire behavior, especially when it does not occur naturally. Several factors affect and influence the spread of fires, among them: the combustible material, the moisture of the material, climatic conditions, topography and vegetation type. Despite years of scientific study and all the media attention in relation to forest fires, the effects they cause to the environment have also been ignored. It is essential to know where the fires occur to determine the areas of greatest risk establishing specific programs for these regions. Thus, the aim of this study was to produce a map of susceptibility to fires in vegetation within the urban perimeter of Uba (MG), with the use of information related to relief and the use and land cover, through technical GIS. From the validation of the generated cartogram, it was observed that 80% of the cases were located in areas of high and very high risk, 15% at medium risk and 5% in areas of low and very low risk. This mapping will serve as a tool for the government to establish prevention policies, operating in the public awareness and control measures in the areas of greatest risk.

Keywords: map, forest fires, risk, geoprocessing

FPF.P.07 - POST-FIRE DEBRIS FLOW POTENTIAL IN A FIRE PRONE MEDITERRANEAN LANDSCAPE

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Wildfires cause significant damage and economic losses on a yearly basis due to both the direct effects of the fires and the subsequent accelerated runoff, erosion, and debris flow in many countries worldwide. Wildfires can have profound effects on the hydrologic response of watersheds by changing vegetation cover properties, infiltration characteristics and soil erodibility, which in turn lead to decreased canopy interception and rainfall infiltration, significantly increased overland flow and runoff in channels, sharply decreased concentration time and soil movement. Especially for high erodible soils, debris-flow activity is among the most destructive consequences of these changes, often blocking natural waterways and causing extensive damage to human infrastructure. Several studies from Mediterranean basin, Western United States of America and Australia indicated that immediately after a fire event, a number of post fire processes, meteorological and geospatial factors lead to the generation of severe debris flow events. In this paper we demonstrate a methodology for assessing post-fire debris flow potential by employing a coupling of GIS modeling and satellite imagery for floodplain analysis of pre- and post-burned watersheds. The burned study area is located in Rafina catchment, which extends over 123 km^2 in Eastern Attica Region, about twenty-five miles north-east of the city of Athens, Greece, where a large wildfire burned in total 21000 ha in August 2009. Fire severity was estimated by calculating the temporal difference between pre- and post- fire Normalized Burn Ratio (NBR) index, while meteorological and geospatial ancillary data, such as slope, geology and precipitation has been generated as part of the analysis process. The spatial explicit values of the abovementioned spatial layers were reclassified into four distinct post fire debris flow risk and hazard classes. From the combination of the four maps (i.e. fire severity, slope, geology and precipitation) and category rating of the factor values, the post fire debris flow potential map was obtained. The resulting post fire debris flow potential map shows the spatial distribution of debris flow hazard and can be useful both in pre-fire planning and post-fire response. The mapping approach presented here identifies those basins that are most prone to debris-flow events and thus provides information necessary to prioritize areas for post fire erosion mitigation, warnings, and pre-fire management efforts. Although studies are currently underway to develop methods for characterizing post-fire debris flow hazard in Mediterranean ecosystems, additional field observations are necessary to gain a better understanding of the processes prevailing in burned watersheds and to relate these processes to the geologic and morphologic conditions within watersheds and the rainfall characteristics of debris-flow triggering events.

Keywords: debris flow, fire severity, post-fire hazard, Remote Sensing, GIS

FPF.P.08 - PERFORMANCE OF ERMIT IN POST FIRE SOIL EROSION MODELLING IN A NORTH SARDINIAN STUDY AREA

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The objective of the present work is to present preliminary results of the experimental activities carried out in order to measure sediments yield in a hilly burned area using the silt fence technique, and to evaluate ERMiT (Erosion Risk Management Tool) performance, comparing the results of simulation with soil erosion measured. The experimental area is located in the Mediterranean basin, on a steep slope in a hilly area of north-western Sardinia, Italy, where a human caused fire occurred in August 2013. *Quercus suber* and Mediterranean shrubs mainly cover the area. After the fire, sediment fences were installed to trap sediment eroded by natural rainfall. Rainfall was recorded using a tipping bucket rain gauge. Soil erosion rates from experimental plots were measured and estimated with silt fence technique taking into account vegetation distribution patterns. The aim of the study was to compare the results obtained by ERMIT modelling and post-fire sediment yields measured in the study area. ERMiT is a web-based application developed by USDA that uses WEPP (Water Erosion Prediction Project) technology to estimate erosion, in probabilistic terms, on burned lands with and without the application of erosion mitigation treatments. Data inputs are: climate parameters, vegetation type, soil type, topography, and soil burn severity class. The above parameters were applied to the ERMIT model and it was possible to predict the probable erosion risk for the next 5 years. Model results compared with field measurements show that ERMiT tends to overestimate erosion rates in Mediterranean vegetation and soil conditions due to the higher stability and typical stoniness of Sardinian old soils compared to younger soils where ERMiT was calibrated. Future experimental data are needed to confirm this assumption and to contribute to calibrating ERMiT in a Mediterranean typical vegetation, climate and soils with specific erodibility and conductivity.

Keywords: forest fire, soil erosion risk, erosion modelling, silt fence

FPF.P.09 - ADAPTIVE FOREST MANAGEMENT AND POST-FIRE RESTORATION: THINNING AND INDUCED DROUGHT EFFECTS ON SOIL AND VEGETATION DIVERSITY IN ALEPPO PINE FORESTS

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Aleppo pine forests occurring in the fire and drought prone areas of Mediterranean Basin. The time to reach the maturity phase of natural regenerated forests depends on growing between fires, influenced by drought periods and cone production. In addition, post-fire tree regeneration will depend on moisture conditions and how they are altered by fire recurrence and climate warming. Soil properties and plant species diversity are key elements of forest ecosystem functioning and resilience. We selected two locations in burned areas, in summer 1994, which were naturally regenerated. In each area, early heavy thinning was carried out (five years after fire, reducing more than 70% of pine biomass). During summer 2010, we set six plots were in both, treated and control areas, in each location. We induced drought by using rain-exclusion PVC gutter, covering 15% of the surface to intercept the same percentage of natural water supplied by rain. During three subsequent years, we recorded plant species diversity, physicochemical and soil microbiological properties and enzymatic activities in thinned Pinus halepensis Mill. stands occurring in two different climates, under two different silviculture treatments and two rainfall conditions. Physicochemical soil properties, soil microbial biomass carbon and diversity indices (Shannon and Simpson) were calculated. The silvicultural treatment to assist natural regeneration was not affecting microbiological soil properties nor soil enzyme activities but improved plant diversity. Induced drought affected soil coverage and floristic richness. We also found differences related to effects depending on climate, showing lower values of the selected indices in the driest location. Soil properties recovered in the mid-term under potential climate change conditions in both treatments but the plant community showed different responses depending on the forest management.

Keywords: soil properties, plant diversity, early thinning, microbiological activity, climate change

FPF.P.10 - POST-FIRE INITIAL SUCCESSION OF A PLANT COMMUNITY ON IRONSTONE OUTCROPS, SOUTHEAST BRAZIL

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Montane rock outcrop plants are adapted to a low-nutrient, low-water environment with high substrate temperatures. On the other hand, the vegetation does not catch fire as easily as the surrounding matrix. Ironstone outcrops (locally known as cangas) host species-rich plant communities. Because they are naturally isolated and endure several abiotic stressors, these saxicolous communities are thought to be very sensitive to factors that may promote further isolation or degradation. We analyzed the post-fire initial stages of succession in a plant community on ironstone outcrops in a previously monitored area in the Iron Quadrangle region, SE Brazil. Pre- and post-fire (up to 36 months) abundance and plant cover were measured in a 100 m2 plot. The original 2009 community consisted of 36 species from 22 families, of which Mimosa calodendron (Fabaceae) and Lychnophora pinaster (Asteraceae) dominated plant cover with 15 and 17.4 m^2 respectively. Only 18 species (13 families) after 6 months and 19 species after 12 months had established themselves. Most of these species were recruiters (68%), followed by resprouters (18%) or both (14%). In the first 12 months Ageratum fastigiatum (Asteraceae) was the species with highest cover (62 m^2) and its abundance was seven times higher than before the area burned. It was gradually substituted by woody species and covered only 3.8 m2 of the area after 24 months. Among the woody species Eriope macrostachya (Lamiaceae), Baccharis reticularia (Asteraceae), and M. calodendron predominated with 6, 4.5, and 4.4 m^2 respectively. The last two are recruiters and E. macrostachya is also a resprouter. In this same period (24 mo.) two species new to the original pre-fire community appeared, which could negatively affect self-recovery: the hemiparasite Tripodanthus acutifolia (Loranthaceae) and the alien molasses grass Melinis minutiflora (Poaceae). T. acutifolia attacks woody species and its preferred host is M. calodendron, one of the cover dominants. The invader M. minutiflora is a fast biomass accumulator with high contents of volatile oils in its blades, a combination that increases the frequency and intensity of fires. After 36 months, species abundance and cover still differed widely from the pre-fire community. The establishment of molasses grass on ironstone outcrops could negatively affect self-recovery, both by competing with native species and by increasing fire frequency in a species-rich plant community poorly adapted to fire episodes.

Keywords: Fire, Iron Quadrangle, Molasses grass, Self-recovery, Succession

FPF.P.11 - REGENERATION OF BURNED PINUS BRUTIA ECOSYSTEMS IN GREECE

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Greece has long suffered from frequent and severe wildfires that have led to extensive degradation of coastal pine forests and loss of their intrinsic ability to regenerate naturally. Reforestation practices were applied on terraces with satisfactory results for re-establishment of pines, but the ecological structure in these ecosystems is poor. The general objective of this research was the implementation of restoration and rehabilitation methods on burned/ degraded ecosystems, by testing in situ different reforestation methods in a pilot study on Lesvos Island, NE Aegean Sea. The vegetation of the study area prior to the wildfire event consisted of open/ degraded or dense Pinus brutia forests, high-shrub formations, maquis and olive trees. Reforestation was conducted in a post-fire resulted shrubland during the fall of 2012, either by application of seeding or by plantation of seedlings with genetic material taken from local Pinus brutia trees. Two different field treatments were applied for each of the two applications, dividing the total study area into four equal parts with about 200 experimental plots on each. For the two parts, a ripper with one knife was used to open parallel trenches every 3 m of about 30 cm deep; the ripper worked the ground and uprooted everything in its path. The second treatment included a complete clearing of vegetation in the surface, by using a combination of bulldozer and ripper inside the other two parts, similar to the first case. Two year old seedlings with roots of about 30 cm were planted in plots, either on trenches or inside conical holes of 30-40 cm deep. A soil belt of 5-10 cm height was created to retain the water in a sort of ditch. For the case of seeding, 15-20 seeds were planted on small plots of about 0.25x0.25 m, in very shallow depth with soil cover of about 2 cm. Fifty percent of the seeds were planted without any treatment, while the remaining seeds were swollen by immersion into water for 48 hrs. For both applications, each plantation was conducted at a distance of 3 m from the others across the sides. Field measurements were conducted during the next two growing seasons (i.e. early 2014 and 2015) to assess the success of each method. Several variables were measured at plot scale, such as the number and height of dead and live seedlings, the nearby vegetation species and the surface condition. Results revealed that there is a high germination rate for seeds and very low mortality of seedlings, with normal growing rates for the totally cleared parts. In contrast, partially cleared parts have high death rates for seedlings (>50%) and very high for seeds (>70%), while the remaining living plants struggle for their survival competing with the surrounding vegetation. Further comparisons of the four study blocks are expected to provide novel results on the most appropriate methods for successful large-scale restoration of pine forests following a stand replacing wildfire.

Keywords: reforestation, Lesvos Island, post-fire effects, degraded ecosystems

FPF.P.12 - MONITORING POST-FIRE VEGETATION RECOVERY IN A MEDITERRANEAN AREA

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The aim of this work is to study the possible effect of slope on post fire vegetation recovery. The experimental area is located in a hilly area of north-western Sardinia. The climate is characterized by water deficit conditions occurring from May through September and precipitation events mainly concentrated in autumn and winter. The area is covered by Quercus suber and Mediterranean shrubs and it was burned by wildfires that swept through the area in August 2013. The fire burned an area of 28 ha and was characterized by a moderate fire severity. Immediately after fire two areas characterized by different slopes (20% and 30%) were selected and ten 30 m^2 plots were installed. Percentage of vegetation cover was measured 1, 6 and 18 months after the fire by the line intercept method. In addition, ground cover ocular estimation (percentage of herbaceous, bare soil and stoniness surface) were made using a 1 m^2 point frame with wire intersections at 10 cm intervals with 3 repetitions per plot. The data were statistically treated to analyze the effects of slope on vegetation recovery.

Keywords: forest fire, Mediterranean ecosystem, vegetation regeneration, Sardinia

FPF.P.13 - POST-BURNING REGENERATION OF STEPPE VEGETATION IN PARANÁ STATE, BRAZIL

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The regeneration of susceptible vegetation to burning is directly related to the intrinsic ability of reaction of plants to fire, depending on the morphological and physiological adaptations that have. The southern Brazilian region is largely covered by Steppe (natural fields), vegetation that evolved under different disturbances, among others, the action of fire. Frequent fires, caused the development of anatomical and physiological characteristics in many plants, that facilitate the combustion of the aerial part, but not, of the underground part, facilitating thus the regeneration. This study aimed to conduct a post-burning monitoring at the regeneration of Steppe vegetation in the State of Paraná, Brazil. Thus, there was conducted a monitoring experiment to evaluate the increase of aerial dry biomass over a period of one year post-burning. The study was conducted in the Private Natural Heritage Reserve "Caminho das Tropas", located in Palmeira County, central-eastern region of Paraná State (coordinates UTMs = 620334 E and 7196739 S). The area of the reserve is covered by Steppe Grassy-Woody vegetation. The biomass samples were made with the use of one square wooden frame with 0.04 m2 in 60 points systematically distributed over an area of 1,200 m^2, at the 61^{th}, 125^{th}, 185^{th}, 243^{th}, 305^{th} and 367^{th} days after burning. Once collected, the biomass was dried in a laboratory oven at a constant temperature of 75 °C for 48 hours. With the values of dry matter, the moisture content (%) and the dry biomass increment (ton ha^{-1}) in the post-burning regeneration process were calculated. Before the burning, the average load of dry biomass from the experimental area was estimated at 14.90 ton ha^{-1}. After the burning, the residual material was calculated as 3.41 ton ha^{-1}. Subsequent to burning, the biomass presented average monthly increase at 1.92 ton ha^{-1} during the first six months, after which reached load value similar to before combustion, stabilizing after. The values recorded of biomass at the collect days after burning were: 61 days = 11.20 ton ha^{-1}; 125 days = 13.05 ton ha^{-1}; 185 days = 14.95 ton ha^{-1}; 243 days = 14.88 ton ha^{-1}; 305 days = 13.69 ton ha^{-1} and 367 days = 14.29 ton ha^{-1}. The average moisture content ranged from 243.98% in the first sampling to 56.18% in the last one, getting very close to the vegetation moisture content before to the burning, which was 50.45 %. The results showed that: the biomass increment of the vegetation of Steppe Grassy-Woody until reach the stabilization occurred in a short time, influenced by the weather and environmental variables of the study area; the reduction of the moisture content verified followed the pattern presented in the literature, that can vary from 300% in the first days at a regeneration cycle to less than 50% when the vegetation is about to die. The results obtained contributed with relevant information about the increase of biomass of the Steppe Grassy-Woody vegetation of Paraná state, after performing burned.

Keywords: regeneration after burning, steppe vegetation, biomass increase, Paraná state, Brasil

FPF.P.14 - PRESCRIBED BURNING EFFECTS ON ECOPHYSIOLOGICAL, ANATOMICAL AND STEM HYDRAULIC PROPERTIES IN PINUS PINEA L. PLANTATION

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Understanding prescribed burning effects on tree productivity and on plant ecophysiological responses is of crucial importance to define burn prescriptions aiming at reducing fire hazard in Mediterranean pine plantations, such as Pinus pinea L. stands. In this context, a combination of dendroecological, isotopic and wood-anatomical approaches can be highly useful to assess P. pinea strategies to respond to fire. Dendroecology provides information on tree growth response to environmental stress factors (such as fire), while the carbon and oxygen-stable isotope ratios supply information on the underlying ecophysiological processes. Further, anatomical features have been demonstrated to be good proxies for distinguishing different wood reaction tendencies after fire, and for better understanding changes in stem hydraulic properties. Indeed, heat associated with fire can potentially affect stem hydraulic transport capacity via cavitation and/or damage of xylem structures. Xylem cavitation can also occur due to a sudden decline in stem water potential caused by sudden increases in vapor pressure deficit (VPD) associated with high temperature plumes during the fire. Once xylem cavitation occurs it is hypothesized that stomatal conductance will decline on damaged trees. Furthermore, damaged xylem structures may increase the vulnerability to drought–induced embolism of surviving trees. A prescribed burn experiment was carried out in March 2014 at the Nature Reserve of Castel Volturno, Southern Italy. The experiment design consisted of 40 trees individuals: 20 at the prescribed fire site (ES), and 20 at an unburned control site (CS), adjacent to ES, of the same size, with the same tree density, the same aspect, elevation, and soil (to exclude other environmental influences on the stands apart from the prescribed burning). Before burning at the ES site, litter fuels were added around the trunk of ten trees to produce a gradient of heat treatment. Thermocouples K-type (0.4 mm) were placed at the stem base (50 cm above ground) as a proxy of fire heating. A broad gradient of heat treatment was attained, i.e. the residence time of temperatures above 50°C at the stem base ranged between 109 to 2239 seconds. Two weeks after the burn, tree sampling for ecophysiological analyses was realized at both ES and CS sites. Vulnerability analyses were performed on 20 cm long axial samples excised from the main stem. Further, the sampling for dendro and anatomical analyses was realized at the end of the vegetation season in December 2014. All monitored trees were cored at 50 cm maximum above ground, with an angle of 120° between them, for a total of 80 cores. Preliminary results indicate that temperatures reached during prescribed fire have minor impacts on the ecophysiology of surviving P. pinea trees. In particular, tree-rings and stem hydraulic system showed no reduction in radial growth and no alteration of xylem characteristics in trees exposed to prescribed burning.

Keywords: prescribed burning, tree-ring, wood anatomy, cavitation, stable isotopes

FPF.P.15 - ECOLOGICAL MONITORING OF SHORT AND MEDIUM TERM EFFECTS OF PRESCRIBED BURNING IN PINE PLANTATIONS OF CASTEL VOLTURNO NATURE RESERVE (SOUTHERN ITALY)

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Monitoring ecological effects of prescribed burning on ecosystem components is a crucial step to assess the sustainability of this practice on a short, medium and long term management perspective. In Mediterranean pine forests of Europe, prescribed burning is routinely used for fire hazard abatement. Monitoring studies have been mostly focused on fire effects on the tree, but very few on other important ecosystem components such as flora, soil and fauna. Moreover, as the impact of fire can be highly variable depending on several conditions, a thorough understanding of fire effects on specific ecosystem components in their own local characteristics (e.g. target or endemic species), is mandatory. The aim of this study was to evaluate the short and medium term effects of prescribed burning on vegetation, carabids and soil parameters in a Pinus pinea plantation of Castel Volturno Reserve (Southern Italy). Vegetation studies include pre and post-burn analysis of two topics: 1) understory plant composition; 2) wood growth and ecophysiological performance of pinus trees. The experimental design and results of the topic 2 have been submitted to another work presented at this congress (see Battipaglia et al.). Understory plant composition, carabid populations and soil have been sampled in the same stand treated by a low intensity prescribed burning (backfire; fireline intensity < 200 kW m^{-1}; flame length < 0.5 m). The effect of burning on understory plant composition was evaluated by means of phytosociological and dendrometric randomly located samplings before and after 6 months of treatment. The short-time effects of prescribed fire did not affect species density and richness. Moreover, no significant difference was observed in terms of individual mortality of understory shrubs. The study of carabids have been carried out by the use of fall traps (9 cm in diameter and 11cm high) monitored for species and individual number each month in burned and unburned plots. Carabid soil communities are increasingly used to assess the status of the environment for their several adaptive characteristics to habitat types or trophic resources. Only two species are detected (Calathus montivagus, Carabus rossii) in the study site both endemic of Italy. Preliminary results showed a community rather poor in species but higher both in species and individuals in burned plots compared to unburned. As concern soil analysis litter and fermentation layer weight was measured before and 3 hours after prescribed fire. Moreover, total microbial biomass and fungal mycelium were monitored several times since burn (3 hours; 1, 3, 6 months) in the fermentation layer and soil beneath (0-5 cm depth). Weight of fermentation layer was unaffected by prescribed fire and, generally, no negative effect was observed on total microbial biomass and fungal mycelium in fermentation layer, so too in the soil beneath, even sometimes microbial parameters increased in burned plot. Our first results highlight the sustainability of prescribed burning in Pinus pinea forests as showed by the high resistance and resilience of analyzed components.

Keywords: vegetation, carabids, soil, microbial biomass, pinus pinea

FPF.P.16 - ANALYSIS OF FIRST ORDER FIRE EFFECTS WITH A MODELLING APPROACH: THE LITTER CASE STUDY

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The main effects determined by fire can be evaluated in temporal or spatial terms (Eufirelab, 2013). According to the temporal evaluation, they can be divided into first order and second order fire effects. First order fire effects concern the direct or immediate consequences of fire. They are the direct result of the combustion process and the previous conditions of the event. Mainly, the first order fire effects are chemical processes led by the fire and linked to plant death, fuel consume, smoke emission and soil heating (Reinhardt et al., 2001). Second order fire effects, instead, are those that can occur in a longer time and they are considered as the fire indirect results like soil erosion, smoke spread and vegetation succession. The assessment of fire effects on ecosystem is neither simple nor direct. It depends on the complex interactions between the various ecosystem components and the fire environment and behaviour and, sometimes, it can also be influenced by the approach used during the analysis. In this sense, the modelling approach can be very useful and more practical to cope with this complexity, in order to appraise fire effects. Nevertheless, uncertainties in quantitative input data and the spatial variability of ecosystem and fire characteristics influence the fire effect estimates through models. For this reason, more comprehensive and accurate data inputs must be considered the first step in any attempt to predict fire behaviour and evaluate its possible consequences for the ecosystem (De Luis et al., 2004). Trying to move from this perspective, this study aims to model the main first order fire effects (fuel consumption, smoke production and soil heating) on a particular ecosystem pool, represented by the litter and dead downed woody. This approach was chosen because the majority of scientific works analyze the litter pool especially in relation to its deposition and decomposition dynamics, thus leading to a knowledge gap on other remarkable characteristics related to the fire occurrence. During the first phase of the work, we characterize the litter fuel load and composition from 10 Mediterranean maquis study sites in Sardinia (Italy). Then, we use these data to feed the First Order Fire Effects Model (FOFEM), developed by Reinhardt et al. in 1997. Our preliminary results showed a very strong correlation between the litter fuel load and the emissions in the atmosphere. The highest smoke emissions were represented first by CO and CO_2 and then by PM_{10} and $PM_{2,5}$. Furthermore, the model output showed that a quick litter fire does not heat the deeper soil layers but only the more superficial ones. In conclusion, this work tries to offer new tools and elements that could be helpful for managers working in the fire planning phases or during the prescribed burning operations.

Keywords: Mediterranean litter species, first order fire effects, fuel consumption, smoke emission, soil heating

Fire Risk and Management

Oral Presentations

FRM.01 - WILDLAND FIRE RISK MANAGEMENT IN THE UNITED STATES FOREST SERVICE

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The United states Forest Service manages over 90 million hectares of wildland and averages about 10,000 wildfires annually. Historically, the Forest Service Fire Management Program focused on raid response to quickly suppress all ignitions. Over the last 40 years it has become clear that new strategies for managing wildland fire are needed to avoid ecosystem degradation and to better account for firefighter and public safety in both the short term and the long term. A Risk Summit was conducted recently to evaluate means for consistently applying risk science to the management of wildland fire on U.S. Forest Service lands. We outline the results of that summit and describe the path forward for managing risk in U.S. Forest Service Wildland Fire Program.

Keywords: risk, wildfire, safety, firefighter

FRM.02 - ADVANCEMENTS IN SPATIAL WILDFIRE RISK ANALYSIS

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In this presentation, we review recent advancements in spatial wildfire risk analysis, focusing on the use of simulated fire perimeters. To date, stochastic fire spread models have more commonly been used to provide aggregate outputs such as gridded burn probabilities and flame length distributions, common inputs into spatial risk calculations. However, spatial analysis of the individual simulated events themselves - specifically their size, shape, and location - provides a complementary and richer characterization of patterns of risk. Our review begins with a discussion of the status of fire perimeter modeling and calibration efforts as they relate to a contemporary fire simulation system (FSim) used by the US Forest Service. Second, we describe the role of simulated perimeters for a range of applications and introduce three key risk modeling metrics: (1) conditional distributions of fire-level impacts; (2) exceedance probability charts; and (3) risk associated with ignition location. We illustrate perimeter-based assessment of risk to municipal watersheds and human communities, and identify opportunities for fuel treatment evaluation and spatial response planning. Third, we describe integration with fire economics modeling and the predictive improvements afforded by analysis of perimeters. To conclude we synthesize findings and identify opportunities for more complete identification, evaluation, and prioritization of cost-effective wildfire risk management options.

Keywords: fire modeling, risk, fire perimeters, FSim, spatial

FRM.03 - AEGIS - WILDFIRE PREVENTION AND MANAGEMENT INFORMATION SYSTEM

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A web-GIS wildfire prevention and management information system (AEGIS) has been developed, aiming at reducing potential socioeconomic and environmental losses (http://aegis.aegean.gr). AEGIS is a state-of-the-art, cost-effective and easy-to-use forest fire management system designed for civil protection. The AEGIS platform assists on early fire warning, fire control and coordination of firefighting forces by providing access to fire prediction data (risk and behavior), as well as to additional information such as socioeconomic activities, roads, land uses, water tanks, patrol routes, satellite images, detection cameras, vegetation types, terrain and weather data. All functionalities provided by AEGIS are accessible to local fire agencies and civil protection authorities through a modern graphical user interface. Main research outcomes were a fire danger rating system and a fire behavior modeling scheme. Structure of the algorithms relied on parallel processing techniques (high performance and Cloud computing), to ensure both scalability and promptness of the calculations. The proposed system was developed and applied in 7 different study areas from north to south of Greece with high-hazard, high-value and high-use forests and other multi-purpose sites. Artificial neural networks and innovative geo-spatial tools were utilized for fire danger estimation based on various parameters (i.e. latitude, longitude, altitude, month, day of week, distance from urban areas, distance from power lines, distance from main and secondary roads, distance from landfills, distance from agricultural areas, wind, rain, relative humidity and temperature). More specifically, for each study area various training methods, activation functions, pre-processing methods and network structures were evaluated to create the most suitable neural networks. The proposed methodologies were the Backpropagation Neural Networks (BPN), the Kohonen Networks (Self Organizing Maps) and 2 types of the Radial Basis Function (RBF) Networks. Outcomes revealed that the BPN networks achieved better performance compared to the other methodologies; and the BPNs were trained based on different training parameters for each study area. In all but one (due to the smaller training dataset) of the study areas, the Mean Square Error of the validation datasets was less than 12.1%, while the correct classification rate of ignition points was more than 80.3%. Sensitivity analysis of the trained BPNs proved that the initial choice of the study areas was justified because of the different wildfire ignition patterns that they were finally identified. Results showed that the distance from urban areas is mostly a critical parameter for the wildfire ignition, while temperature seemed to have the smallest influence compared to the rest of the parameters for all the study areas.

Keywords: forest fire risk, Web-GIS, artificial neural networks, parallel processing

FRM.04 - RISICO: FIRE DANGER INDEX FOR THE MEDITERRANEAN ENVIRONMENT

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The RISICO system provides the Italian Civil Protection Department (DPC) with daily wildland fire risk forecast maps relevant to the whole national territory since 2003.
The structure of RISICO is conceptually similar to the Canadian Fire Weather Index. This index is used almost everywhere in the world and it represents the reference model in EFFIS (European Forest Fire Information System). RISICO can be considered as an evolution and simplification of the FWI index, properly adapted for the Mediterranean environment. RISICO considers vegetation cover and topography as additional input to the system, considering different contributions to the potential fire behaviour due to different vegetation cover, slope and aspect. This allows taking into account different structure of the fuel available from the ground to the crown including important aspect related with the process of fire spread beyond the weather. The aim of this work is to describe the RISICO model and to perform a performance analysis of the overall system, also by comparing it to the Canadian FWI. The performances of the two models are evaluated on the basis of the Burned Area (BA) observed in Italy in the period 2007-2013, provided by National Civil Protection Department. The Relative Operating Characteristic (ROC) analysis is used to evaluate and compare the performances of the two models. The results of the analysis show that both the systems provide skilful forecast of the wildland fire risk distribution over the Italian territory. However, the performances of RISICO are always better than FWI concerning the capabilities of correctly identifying areas with higher or lower risk significantly reducing the number of false alert with respect to FWI, making it more reliable to the Mediterranean environment.

Keywords: fire danger index, Mediterranean, early warning

FRM.05 - CREATING A RISK ASSESSMENT TOOL FOR WILDLAND FIRES

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Dramatic increases in wildland fire complexity are presenting difficult problems and concerns for fire managers. As a result, decision-making is becoming more difficult and can involve sorting through a high volume of available information. To improve decision-making and management capability, managers need ready access to more and better information about changing fire dynamics. Numerous information management systems exist and others are under development to provide improved wildland fire information, but systems providing risk assessment information are currently lacking. As a result, the United States Forest Service Fire and Aviation Management staff has undertaken the exploration and creation of a new system to access and display wildland fire information assembled from a variety of sources. The Incident Risk Console (RisC), a data analytics dashboard and business intelligence tool for wildland fire decision makers, has been developed to provide national fire program managers with fire information beyond available fire statistics. RisC includes eight specific risk attributes that summarize a range of conditions and activities on a fire-by-fire basis. These are: values Inventory, jurisdictions, significant fire potential, relative risk, suppression capability, aviation exposure, modeled values at risk, and modeled suppression effectiveness. These variables together provide specific calculated values and indices used to present a visual risk assessment synopsis for wildland fires, an early alert/risk assessment for potential problem areas, and an overview summary of national and regional incidents. The first version of the Incident Risk Console represents the transformation of an idea into an actual system. The 2014 fire season allowed for a test and an evaluation of its applicability. It was found to have specific value in providing new information useful in: clarifying the overall fire situation, understanding individual fire dynamics, and improving understanding of the effects of management decisions. Lessons learned will be applied to future enhancements and continued development of this system.

Keywords: risk assessment, information technology, decision-making

FRM.06 - UNDERSTANDING COUPLED NATURAL AND HUMAN SYSTEMS ON FIRE PRONE LANDSCAPES: INTEGRATING WILDFIRE SIMULATION INTO AN AGENT BASED PLANNING SYSTEM

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Agent-based models (ABM) allow users to examine the long-term effects of agent decisions in complex systems where multiple agents and processes interact. This framework has potential application to study the dynamics of coupled natural and human systems where multiple stimuli determine trajectories over both space and time. In this paper we describe the application of Envision, a landscape based ABM, to analyze long-term wildfire dynamics on a 3.2 million ha fire pone landscape in Oregon, USA. We focus on the development and integration of a wildfire simulation module within Envision to study the effects of forest restoration and fuel management on wildfire dynamics over time. Specifically, we use the model to examine whether a tipping point can be detected in terms of a stable change in wildfire occurrence and burned area in response to specific rates and patterns of fuel management. We first integrated the semi-empirical Minimum Travel Time (MTT) fire spread algorithm into Envision and then built a fire prediction system based on the historical (1992 – 2013) fires within the study area. The fire prediction system was a GAM model that predicted daily fire occurrence as a function of location, energy release component, day of year, and ignition type (human versus natural). The prediction system was calibrated to replicate historic fire size distribution within the study area. We then simulated 6 alternative fuel reduction scenarios that varied in treatment type and rate over a 30-year period and examined the response in wildfire activity in terms of both variability and mean annual area burned. The fuel reduction treatments were based on actual management practices within the study area. Vegetation dynamics and fire effects were modeled using a state and transition model developed as part of the larger Forest People Fire project (http://fpf.forestry.oregonstate.edu/). The results illustrated possible future wildfire scenarios and fire regimes under different fuel management strategies on a large fire prone landscape. The outputs can be used by land managers to inform the development of long-term restoration strategies.

Keywords: landscape modeling, agent based models, fuels planning

FRM.07 - QUANTIFYING STANDARD FOREST TARGETS IN FIRE-PRONE PORTUGUESES LANDSCAPES: TOOLS FOR SUPPORTING A PROACTIVE FIRE MANAGEMENT

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Forests are a key element in the Portuguese landscape. Moreover, fire hazard is a central challenge at national context. How appropriate management can potentially change fire behaviour, fire damage and the difficulty of fire suppression? What are the causal relationships between fire proneness stand structure and forest stand composition? The common objective among the five studies is to address the above issues based on principles of creating fire-resistant forests, underlying factors and implications for active forest management, while sustaining effective fire prevention levels. The ultimate goal is to provide forest managers and policy makers with tools to support their decisions, and more effectively align management policies, plans, and practices across fire-prone landscapes. The first research phase, at a national level using a large dataset of forest stand and fires with a broad spatial and temporal coverage, aims respectively: (i) modelling the annual probability of wildfire occurrence of pure and even-aged eucalypt stands; (ii) developing a shrub biomass accumulation model, and (iii) a post-fire mortality model at stand level and the individual tree survival probability to mitigate damage in any forest stand structure. The second phase focused on specific case studies to forecast the potential effects of alternative forest management (i.e. public, private industrial forest and private collaborative forests), using logistic regression procedures and classification tree analysis (CART), introduces fire behaviour modeling (variables as input and output of FlamMap system) coupled with common stand variables as a tool to (iv) assess potential crown fire occurrence through stand structure/stand composition, and (v) draw guidelines that express the difficulty of fire suppression in those fire-prone forest stands. The methods and tools developed in this research have made several key contributions towards a deeper understanding of the biometric factors, across a range of scales from the individual tree to the stand scale that drive fire occurrence, fire damage and fire behaviour. In this sense, the accuracy of the research findings can provide an interesting insight to support hazard-reduction silvicultural practices in Portuguese ecosystems. In addition, it can ensure adequate technical support as a step forward in indicators for risk assessment to the forestry insurance market in their daily development of forest evaluation policies.

Keywords: annual wildfire risk, post-fire mortality/damage, crown fire occurrence, fire-resistant forests, preventive silviculture

FRM.08 - WILDFIRE RISK ASSESSMENT AND MANAGEMENT: INSIGHTS, CHALLENGES AND FUTURE PERSPECTIVES FOR SARDINIA, ITALY

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The large and severe wildfires that affected Mediterranean ecosystems over the past decades have led to extensive research and application of decision support tools for operational purposes. Like the rest of the Mediterranean region, Sardinia (Italy) has experienced substantial long- and short-term variation in fire regime and behavior. Overall, the island has seen marked reduction in area burned since the 1980s, with a sharp transition in the mid-1990s. In recent years Sardinia experiences on average about 2,500 fires annually that burn about 17,000 ha. Despite the downward trend of fire occurrence and area burned, localized areas and seasons of high wildfire risk still persist. Furthermore, recurring large wildfires still cause substantial financial losses, accidents and fatalities, and costs related to large wildfire suppression usually cover the most of the wildfire budgets. For example, about 7% of fires are responsible for 85% of the overall area burned, with the largest fires concentrated in a few extreme-weather days. As part of efforts to improve risk estimation and prevention efforts, we have calibrated and implemented a number of simulation models and applied them to better understand spatiotemporal patterns in fire behavior and risk. The models and tools are also being used to evaluate fuel treatment and other mitigation strategies. A key part of this work is the application of a compact fire simulation algorithm (minimum travel time, MTT) that makes computationally feasible to simulate thousands of fires and generate burn probability and intensity maps over large areas. The fire simulation outputs provide a way to study wildfire topology on complex landscapes under variable weather, and analyze uncertainty associated with wildfire events in terms of timing, location, intensity, and duration. We also coupled wildfire simulation models with geospatial interfaces to streamline preparation of inputs and post-process outputs. These latter tools also include spatial optimization software to design landscape fuel treatment projects. The result of the work is a substantial increase in landscape scale information to support wildland fire mitigation efforts. In addition, wildfire simulation outputs can provide data and information for a range of wildfire-related issues including hydrological impacts, habitat conservation, carbon offsets, WUI protection, and preservation of biodiversity. The models are also being used at regional scales to supporting large-scale climate and land-use change analyses as well as wildfire policy, management and mitigation issues. This work was partially founded by the Sardinia Region under the Regional Law n. 7/2007 (EXTREME Project - "Development of methodologies and support systems for fire risk assessment in extreme weather conditions") and by the Italia-Francia Marittimo Programme (Proterina 2 Project).

Keywords: wildfire risk and management, Mediterranean areas, MTT algorithm, fire simulation modeling, burn probability

FRM.09 - ECOSYSTEM VULNERABILITY TO FIRE IN THE NEW-CALEDONIAN BIODIVERSITY HOTSPOT

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New Caledonia (NC) has long been recognized as a remarkable biodiversity hotspot harboring ecosystems of high ecological and conservation value. However, fires have considerably transformed the landscape since the human settlement by Melanesians ca. 3000 BP and destroyed more than 50% of the original vegetation, and fire activity will likely increase due to climate change. Consequently, there is strong interest in assessing which ecosystems and areas of NC at vulnerable to present fires, and implementing this knowledge in predictive tools for biodiversity conservation. To address this, we assessed fire probability and fire behavior using spatially-explicit fire simulations with Flammap (Finney et al., 2012) throughout the NC. We computed the probability of gain or loss for the different ecosystems as a function of their exposure to fire, and their resistance and resilience to fire (i.e. the capacity of the dominant species to recover). Simulations indicate that sclerophyll forest and low-elevation rainforests and maquis in the center and the south of NC are the most vulnerable to fire because they constitute 'fire sinks' (i.e. areas having high probability to be burned by fires originating from elsewhere). In addition, these forests generally poorly recover after fire, thus shifting to thickets or maquis. The main fire sources (i.e. areas providing many ignitions and generating large burned areas) are located in savannas, maquis and thickets of the center-north and the south of NC. The present network of protected areas offers low protection against fire, especially for dry forests which are virtually unprotected and highly exposed to high-intensity fires.

Keywords: ecosystem vulnerability, flammap, biodiversity hotspot, rainforest, bushfire

FRM.10 - FINE SCALE FIRE RISK MAPPING IN FOREST OF CENTRAL NAVARRE (SPAIN)

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Recent wildfire events in central Navarre (Spain) caused substantial economic losses in forests to highly valued resources and assets, that provide timber sales (Pinus nigra afforestations) and firewood (Mediterranean Quercus spp. forests) for the local rural inhabitants. In attention to that socio-economic concern and aiming to monetize the potential wildfire effects, we used a wildfire simulation modeling approach combined with post-fire stand damage predictive model, and map this way, the expected timber economic loss in San Cristobal and Elchumendi mountains (3,000 ha) of central Navarre. The burning probability was obtained at 15 m pixel spatial resolution, by simulating 15,000 fires from a historically-based ignition pattern in an extended 20,000 ha frame, under wildfire season extreme weather conditions. A surface fuels input map was derived from the Agricultural Plots Geographic Information System and, spatially explicit canopy fuels were generated from low-density LIDAR point cloud. Pixel-level mortality within stands caused by fire was estimated, using pre-post fire inventory data based logistic regression models from other studies. We obtained required damage predictors and timber volumes in stands from the National Forest Inventory and studies carried out by the Regional Forest Service. The current market value for the different wood products on stands was derived from prices achieved on recent public timber auctions. Spatial variation in fire risk was very pronounced and strongly dependent on burn probability, species composition, timber volume on stands and value of forest products. A fire risk map for the target areas was produced with the goal of informing on economic changes that result in forests from fires that could assist local landscape managers in the implementation of fire prevention and mitigation strategies.

Keywords: fire risk, burn probability, stand fire damage, forest management

FRM.11 - FLEXIBLE DESIGN OF HELICOPTER BASING STRATEGIES: A CASE STUDY OF SARDINIA, ITALY

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Cost-effective strategic management of aerial firefighting assets entails decisions regarding basing locations and requires efficiently linking supply with demand. Assignment of aviation assets to air bases incommensurate with patterns of demand can lead to inefficiencies; the greater the degree of asymmetry in spatiotemporal patterns of fire load, the worse uniform asset location policies are likely to perform. We explore these themes and potential fire management implications, focusing on the island of Sardinia where helicopters play an integral role in suppression, and where evidence suggests asymmetries in wildfire activity. First, using fire occurrence and helicopter flight data from 2000-2009, we characterize spatiotemporal demand-supply patterns. Second, using both optimization and simulation-based approaches, we evaluate opportunities for efficiency gains using flexible helicopter basing strategies. To conclude we review limitations and identify opportunities for additional research.

Keywords: cost-effectiveness, aerial firefighting, optimization, flexible basing

FRM.12 - FIRE CLOUD - OPERATIONAL MANAGEMENT SYSTEM AND STATISTICAL ANALYSIS OF FIRE EVENTS

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Among the tasks of the Corpo forestale e di vigilanza ambientale (CFVA), one of the most important things is the collection of data and reports for all fires that affect the island, and the identification of ignition locations and fire perimeters. In addition, the suppression efforts carried out by terrestrial fire crews and aircrafts are gathered and associated to each fire event. This activity aims to structure harmonized fire database on a regional scale and to analyze from statistical and spatio-temporal point of view the fire issue in Sardinia. The data are then distributed in simple or elaborate reports that can be requested by institutional stakeholders or common users. In the past, the same information was put into heterogeneous systems, with higher possibilities of mistakes in registration procedures, data processing, or missing fields. The effect of this system was to have reports, synthesis, analysis, tables where the same data had different values. For these reasons, it was necessary to check several kinds of diverse databases in order to verify if the data were correct. These potential errors made data verification difficult and could negatively affect the quality of analyses, with impacts on determining factors such as fire risk prevision and prevention mechanisms. With the new "Fire Cloud" tool adopted in 2014, the data gathered are input into a standardized fire database from which a customized set of details, layers or information reports can be obtained. The tool was designed by the CFVA and implemented by an external partner and has several functions, as for instance:

1. entering the individual data in a single site;
2. the real-time sharing of all available data on a fire in progress by all involved Corps staff;
3. processing and synthesis reports;
4. organizing databases;
5. web GIS.

The system manages information and allows the operators to share the fire data through a web portal, established within the regional network, with all operational structure: CFVA stations, provincial operating centers, and a permanent, unified operational control room. The data are also available to the other forces that contribute to extinguishing fires, as for instance Civil Defense and Fire Department. The strength of the new system lies in the quality of the data, in the cross-checks carried out by the various operators and in the creation of a "fire dossier" which collects all the essential elements of a single fire event. The system will strongly implement the management of real-time events and the analysis of historical data. The CFVA is actively busy in the publication of all fire data collected from 1998 to 2013, which will be available on its corporate website in spreadsheet format (xls) and portable document format (pdf). Data will be organized at municipal, provincial and regional level.

Keywords: resource management, data processing, sharing

FRM.13 - TIGER MEG: A DSS TOOL TO ASSESS AREAS OF FIRE IGNITION

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Among operations carried out by European agencies in charge of investigating wildfires incidents there is the identification of the point (or area) of fire originated, allowing to gather sensitive information about the wildfire causes. In Italy, this procedure has considerable importance due to its economic and legal implications. In this context, a new Decision Support System (DSS), named TIGER MEG, was developed in collaboration with the Italian National forest service Corpo Forestale dello Stato (CFS). The system offers a new way to estimate the area of origin of forest fires, in support of the existing methods of analysis used by the investigators. The estimation starts from the burned area and simulates the fire dynamics in reverse, including the analysis of the effects of different environmental parameters (topography, fuel type and wind). The software integrates two sub-models: Rate Of Spread model (ROS) for calculating the fire speed in each point, and Fire Line Perimeter model (Tirailleur) for building the wildfire perimeter. The ROS model is derived by Rothermel's model using fuel models, slope and wind maps as inputs. The locally-varying wind field is calculated for each simulation step by the WAsP Engineering flow model, using general wind inputs. The Tirailleur model is a geometric spread pattern model in which nodes form a polygon to describe a fire perimeter. The node movements are reversible, allowing the fire to contract as well as expand. With the DSS Tiger MEG system it is possible to:

- Load and manage different orthophoto of the area of interest;
- Load or directly draw in the DSS the fuel model map (standard fuel models by Anderson classifications);
- Load or draw the final fire perimeter polygon (to start the reverse simulations).

The output of the DSS Tiger MEG are:
- Wind map (intensity and direction in each pixel of the considered area);
- Reverse fire polygon for each time step simulations;
- Some statistical analysis on fire (perimeter, area, burned fuel types) for each simulation time step;
- 3D fire line perimeters in Google Earth technology (as polygons in KML coordinates).

The digital elevation maps of Italy at 25m resolution are preloaded in the system.
The DSS runs on Windows and Android systems, and it is already available for the "Nucleo Investigativo Antincendio Boschivo" (NIAB) of CFS.

Keywords: fire perimeter, burned area, rothermel model, fire investigation, wind model

FRM.14 - INCLUDING THE BURNT AREA CRITERION IN FIRE DANGER RATING

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The capability to predict the daily risk of fire occurrence and propagation and to allocate fire-fighting resources consequently is of central importance in a modern fire danger rating system. Several fire danger indices have been developed worldwide to predict fire occurrence considering daily meteorological variables. Unfortunately, despite the fact that large fires induce the highest damages and suppression costs only few methods have been proposed to additionally relate climatic conditions to the expected burnt area. In this work we propose to consider the burnt area as an additional criterion when evaluating the predicting power of fire weather indices, namely the shape of the cumulative burnt area when plotted against the fire occurrences ranked for fire danger values. This performance indicator increases when days with large fires correspond to high danger levels. We implemented the approach in regions with different climatic and pyrological characteristics: a low to intermediate fire prone Alpine region (Canton Ticino, southern Switzerland) and three Mediterranean fire prone regions (two areas in Sardinia and one in Campania, Italy). We analyzed the logistic models' performances of some of the most well-known fire danger indices, according to the AUC (Area Under the ROC Curves) and to the burnt area criterion for the seasons of higher fire risk. Three variable options were considered for the burnt area, i.e. an untransformed one and two with a logarithmic or rank transformation, respectively. The results underline the usefulness of the proposed method to identify the most suitable index for predicting both fire occurrence and the danger of large fires, thus allowing the optimization of the fire management means and strategies to be adopted.

Keywords: fire danger indices, logistic model, AUC, burnt area, fire regime

FRM.15 - FUSION OF WILDFIRE RISK INDEX AND AUTOMATIC VIDEO BASED WILDFIRE SURVEILLANCE SYSTEMS

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Determining the probability of fire occurrence and fire spread at certain area and time could be useful for all fire-fighting activities. A numerical measure used to describe this probability is usually referred to as a wildfire risk index, and as such is traditionally used to enhance human vigilance to wildfires in the pre-fire phase. Higher values of wildfire risk index require elevated level of alertness and increased concentration not only for fire-fighters, but also for observers responsible for the early detection of wildfire. In this paper, our focus is primarily on the application of wildfire risk index estimation in the early detection of wildfires. Two types of wildfire surveillance co-exist today: the traditional human based wildfire surveillance and a more advanced video based wildfire surveillance with implemented automatic fire and smoke detection. These advanced video based systems are increasingly evolving and applied in more and more regions affected by wildfires. The importance of wildfire risk index estimation in traditional human based wildfire surveillance is quite well known - the wildfire risk index estimation is generally used to increase the wildfire observer's concentration. On the other hand, wildfire risk index estimation is still not widely used in automatic video based wildfire surveillance systems. Because of this, this paper focuses more on the following topic: How can the wildfire risk index be used to improve automatic video-based wildfire surveillance systems? To successfully introduce wildfire risk index into automatic wildfire surveillance, the estimated index should have as high spatial resolution as possible. General, low-resolution wildfire risk indexes calculated in most of the countries exposed to wildfires are not adequate for this purpose. The wildfire risk index should be calculated on a micro location scale. One example of such index is the Site-Specific Wildfire Risk Index (SWRI). In the first part of this paper we shortly introduce the method of calculating the Site-specific Wildfire Risk Index (SWRI). In the following, we specify how this Site-Specific Wildfire Risk Index maps could be used in automatic video based wildfire surveillance systems. We primarily focus on the problem that is equivalent to human based wildfire surveillance - how to increase (or decrease) the wildfire observer's concentration, but in this case - how to increase (or decrease) the automatic video based wildfire surveillance detection sensitivity. Detection quality of most wildfire surveillance systems depends largely on chosen sensitivity parameters. High sensitivity may result in a large number of false alarms, while a low sensitivity may result in a missed detection. Human observers rarely change those sensitivity parameters manually. It can be shown that wildfire risk information can be used to dynamically change those parameters in order to achieve a better detection. Various approaches are discussed, such as the sensitivity adjustment based on the average risk index in the visible image, as well as the more complicated one based on Augmented Reality (AR). These topics are the subject of research of our Department in the last couple of years.

Keywords: wildfire risk index, wildfire surveillance, video based smoke detection, detection sensitivity, augmented reality

FRM.16 - LESSONS LEARNED IN 14 YEARS OF PRESCRIBED BURNING IN CATALONIA, NE SPAIN

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At present the use of fire in Catalonia is implemented almost entirely by Forest Actions Support Group (GRAF) of the Fire Department of the Interior, Catalonia, Spain. Checking the status of this tool is necessary to analyze and describe the actions planned and executed by GRAF since 1998 to the present (2013), covering a period of 15 years. The methodology is based on the recovery and upgrading of the database on prescribed burning as well as using GIS programs on that dataset to observe and infer trends and to develop characterizations. Thus it has been observed that 1) during this period, only a small proportion of planned burn were implemented; 2) Most plots (burn units) are between 1 to 5 ha in size; 3) The main purpose was to enhance grazing potential; 4) Mostly medium or high elevation sites in mountains; 5) Mostly, southern slopes; and 6) Mostly executed from February to March. Site selection and experimental design: Prescribed burning (PB) in Catalonia is carried out by the GRAF. The GRAF has compiled a database documenting all PB that have been conducted since 1998 to date. The database information comprises information about fire characteristics (data of burning, times of initiation and termination, ignition pattern, burnt area) and the assigned human resources, a shape with the perimeter of the burnt area and photographs taken in selected points. From the PB dataset, we pre-selected about 12 forest sites (trees >10% of canopy), treated with fire between the years 2002 and 2010, and no re-burnt after. Site pre-selection was done after checking for potential paired control plots with the same slope, aspect and historic land-use (by comparing current and historic ortho-photo-maps). All burnt and paired control plots have been forest since at least mid 60's. Definitive site and plot selection was done after field visit, when plots showing traces of clear-cutting or mechanical management were discarded.

Keywords: prescribed burn, NE Spain, trend in time

FRM.17 - EFFECTIVE PRESCRIBED BURNING STRATEGIES FOR EUCALYPT FORESTS IN SOUTHERN AUSTRALIA

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Prescribed burning (PB) is a common strategy for wildfire risk reduction and its use is increasing in many parts of the world. Evidence about the effectiveness in influencing fire behaviour has increased greatly over the past decade. Here I review this evidence from eucalypt forests in southern Australia in order to highlight the most effective spatial and temporal design. The evidence shows: 1) the majority of ignitions occur close to the Wildland Urban Interface (WUI); 2) PB rarely stops a wildfire but can reduce ignition likelihood, fire severity, rate of spread and area; 3) treatments need to be applied every ~5 years to maintain their effect while treatments every 20 years may intensify fire behaviour; 4) in extreme fire weather, much of the advantage of PB is lost; 5) treatment effectiveness varies geographically mostly due to variation in the extent of wildfire; 6) in wet forests, recent PB increases fire severity. Simulation studies corroborate many of these findings. These patterns have important implications for PB treatment strategies. Treating all forests every 5 years is both impractical and ecologically unsustainable. In any case, treatments in wilderness areas, far removed from assets, have minimal benefit for risk reduction. The best strategy is to treat areas in areas where it is important that they are stopped, where fire-fighters can take advantage of reduced intensity to suppress fires. In most cases, these areas are at the WUI. This strategy may reduce the ecological values of the WUI areas, but forests further from assets can be managed for ecological values without affecting human risk. Treatment effort should differ according to region and vegetation type. Fire management agencies and the public should also understand that PB can reduce but not eliminate the risk of damaging wildfire.

Keywords: hazard reduction, fire management, management effectiveness, optimisation, wildland urban interface

FRM.18 - CHALLENGES AND TRENDS IN FIRE USE AND TRAINING IN SOUTH EUROPE AND LATINAMERICA

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Wildfire presents a challenge to natural resources managers the world over, and the intentional setting of fires ("prescribed" burning) can be used to alleviate some of the challenges associated with wildfire management. Prescribed burning can be used prior to wildfires, to reduce fuel loads and promote ecological integrity in fire-adapted systems, or counter fires can help firefighters control the direction, extent, and intensity of wildfire behavior. In both cases, the success of prescribed fire use depends on training, knowledge, experience, and institutional and social support for prescribed burning. The influence of these factors can significantly impact whether fire use is perceived as positive or negative, increasing or decreasing, and whether managers are supportive of its incorporation into their management decision-making and planning. Perceived impediments to fire use are likely to differ based on location, level of training and experience, and even the culture of fire management specific to different job positions in natural resource management. In order to explore how managers and stakeholders across the world perceive prescribed fire use, we surveyed over 700 respondents from 12 countries and 3 continents. This study represents the largest survey of perceptions on prescribed fire ever conducted. Perceptions differed across age categories, job positions, and regions. Countries or regions with higher levels of wildfire acreage burned tended to be more supportive of fire use in suppression, while countries with less wildfire had less positive perceptions of fire use for either prevention or suppression. Bureaucracy and social perceptions were identified as impediments to using prescribed fire for fuels reduction (i.e. prevention), but neither were identified as impediments to fire use during suppression procedures. Across the countries, fire use in suppression was viewed more positively than fire use in prevention.

Keywords: wildland fire, prescribed burning, fire treatments, backfiring, perceptions

FRM.19 - THE WHY, WHERE AND HOW OF PRESCRIBED BURNING IN ITALY

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In Italy, increasing wildfire impacts due to changes in society, land-use and climate, require a change in wildfire-related policies. Indeed, emergency wildfire suppression, rural fire use ban, and fire exclusion, appear inadequate to cope with expected extremes in wildfire characteristics, urban expansion, fuels build-up, and loss of agro-pastoral cultural landscapes. Prescribed burning (PB) could be a useful tool to face several land management issues in Italy, such as: (i) the high wildfire incidence, increasing fire risks at the rural-urban interface, and unsustainable wildfire suppression costs of many territories; here, the use of PB for wildfire hazard abatement in strategic zones could have a high leverage (>1) on wildfire extent, severity and costs; (ii) the considerable number of wildfires due to clandestine burning for pasture management and others agro-forestry scopes; the regulation of these burns by planned PB could reduce wildfire suppression costs, negative impacts and alleviate rural conflicts; (iii) the growing need of advanced professional training in fire handling techniques; PB could be used to build expertise in suppression-fire use; (iv) the loss of habitats of conservation interest due to the lack of traditional management practices (pastoral fire, mowing, grazing); PB based on traditional ecological knowledge could be used for nature conservation as a substitute of abandoned practices; (v) the need to develop "disturbance based" silvicultural treatments to enhance forest resilience in view of global changes; PB could be a tool for forest management systems which foster "creative disturbance". For these reasons, PB has attracted a growing interest in the last decade throughout Italy. It has been tested for wildfire hazard abatement, pasture management, habitat conservation and silvicultural goals in Mediterranean, Temperate and Alpine forests, grasslands and shrublands, in public and private lands, and in nature reserves. Several training programs, targeted to fire and forestry personnel, have been carried out

by State and Regional Forest and Civil Protection Services, Universities, private enterprises, in collaboration with European and extra-EU experts. Some Italian Regions have regulated PB planning and implementation, authorization processes and liability. Research programs have monitored experimental burn effects on vegetation, fauna and soil, assessed PB effectiveness in mitigating fire hazard, and transferred new knowledge to the scientific community, land managers and the general Italian public. However, several constraints hamper PB use in Italy, which are both connate to the technique (fear of fire; lack of knowledge; environmental concerns; effort to build expertise) and of external origin (lack of interest in wildfire prevention and natural resources management; confuse laws; lack of funds; risk adverse policies). This translates in a very slow regulatory process coupled to reluctance by management agencies to acquire the competence. Despite impediments, a number of people is working on PB. The present contribute intends to take stock of past and ongoing Italian operational and research programs, and to report lessons learnt. It also aims favoring the networking between people and programs, to increase the capacity building on fire management in Italy.

Keywords: fire management, nature conservation, forestry, fire ecology, fuel management

FRM.20 - USE OF FIRE FOR WILDFIRE SUPPRESSION DURING THE FIRES OF 2007 IN GREECE

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In 2007 Greece faced its worst forest fire season on record. It started early in June and continued until late September. Especially in the period of August 24-27 many of the fires could be described as megafires since, according to the definition, they "exhibited fire behavior characteristics that exceeded all efforts at control". During those days fighting the fire fronts using direct attack was practically impossible. As use of fire for firefighting is not recognized and explicitly legislated for in the Greek law, and it was not one of the firefighting tools that the Greek Fire Brigades had prepared and trained for, even indirect attack was not an option. Thus fires run completely out of control. The total burned area reached 270,000 ha, more than 100 villages and towns were affected, and the death toll reached 79 people including citizens, firefighters and Greek Air-Force pilots. However, amidst the chaos, in a series of cases, people used fire unofficially as a last resort measure for controlling fire fronts or saving properties. We became aware of these events while following some of these fires to document their behaviour. There were also some short references to such events in the TV broadcasts, which run continuously during those days. Combining our first-hand experience with post fire interviews and on-site visits that we carried out in the first weeks after the fires, we developed a dataset of 18 documented cases with dependable information. Many more cases were recorded but omitted because we were not completely sure about the details, or the information was incomplete. The dataset included such variables as location, date and time of the use of fire and type of the operation (backfire or burn-out operation), vegetation type, slope, relative humidity, wind speed, type of fire (crown/surface), number of people involved and if professionals participated, if mechanical equipment were used, length of the operation (m) and its duration, and the final outcome (success/failure) distinguishing "global success" (if it stopped a fire front) or "local success" if it achieved to protect a settlement. The dataset was analyzed mainly through descriptive statistics. It was found that 71% of the fires that were carried out in nighttime were successful, whereas this percentage dropped to 44% for daytime operations. Furthermore, and in spite of the small sample size, we developed a probit model for evaluating the contribution of various factors to the probability of success when using fire for fire control. Wind speed and vegetation type were identified as the two most influential factors affecting this probability. The most interesting conclusion of the work is that overall, even in such extreme conditions, the use of fire to stop a wildfire is not an effort done in vain. It appears that it is a much better option than doing nothing in such an otherwise hopeless situation. Obviously, the alternatives have to be weighed very carefully and safety must not be compromised.

Keywords: backfire, burn-out, firefighting, indirect attack, megafires

Fire Risk and Management

Poster Contributions

FRM.P.01 - PROBABILISTIC FIRE SPREAD MODELLING IN SUPPORT OF FIRE-SUPPRESSION DECISIONS

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Spatially explicit wildfire spread models are an effective tool to understand the intertwined relationships between fire, weather, and fuels, and are commonly used to simulate fire spread and behavior. Coupling fire spread models with satellite data for large multi-day wildfires has remarkable potential to provide crucial information to stakeholders, by anticipating fire growth dynamics in the subsequent hours. This information is relevant to minimize the impacts of large wildfire by supporting tactical fire-suppression decisions. We generated maps showing the probability that a given location (i.e. a pixel) will burn during the next hours by propagating uncertainties in input variables/parameters through the model and creating multiple fire spread simulations. The probability was defined as the number of times the pixel is classified as burned in the multiple fire spread simulations over the total number of simulations. Simulations were done for a show case, the Tavira 2012 wildfire, that burned around 25000 ha in Southern Portugal. We explored an innovative optimization procedure to determine the set of optimal adjustment factors for each satellite overpass, and integrated it in subsequent fire spread simulations. The optimization aimed at selecting the set of adjustment that maximized the estimated fire spread probabilities in previously detected satellite active fires and minimized the probabilities in fire-free locations. Results show that the probabilistic fire spread simulations coupled with satellite active fire data, can spatially and temporally anticipate fire growth in the subsequent hours. Optimization of adjustment factors, for each satellite overpass, showed promising improvements on model performance. Results highlight the potential of combining both, fire spread models and satellite data, to produce short-term probabilistic predictions that may aid suppression decisions in an operational context by accurately anticipating subsequent fire spread dynamics.

Keywords: satellite data, MODIS, fire fighting, uncertainty

FRM.P.02 - A NEW STATISTICAL APPROACH FOR WILDFIRE RISK MAPPING BASED ON OBSERVED BURNED AREAS

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High topographic and vegetation heterogeneity makes Italy vulnerable to forest fires both in summer and winter. In particular, northern regions are predominantly characterized by a winter fire regime, mainly due to frequent dry winds from the north, while southern and central regions and the large islands are characterized by a severe summer fire regime, because of the higher temperatures and prolonged lack of precipitation. The threat of wildfires in Italy is not confined to wooded areas as they extend to agricultural areas and urban-forest interface areas. In view of the limited availability of fire risk management resources, most of which are used in the management of national and regional air services, it is necessary to precisely identify the areas most vulnerable to fire risk. The few resources available can thus be used on a yearly basis to mitigate problems in the areas at highest risk by defining a program of forest management interventions, which is expected to make a significant contribution to the problem in a few years time. Given the availability at national scale of fire perimeters mapped over a period spanning from 5 to 10 years, depending on the region, a statistical procedure was defined in order to assess areas at risk based on objective criteria by observing past fire events. The availability of fire perimeters combined with a detailed knowledge of topography and land cover allowed us to understand which are the main features involved in forest fire occurrences and behaviour. The seasonality of the fire regime was also considered, partitioning the analysis into two macro-seasons (November- April and May- October). In addition, the total precipitation obtained from the interpolation of 30 years-long time series from 460 raingauges and the average air temperature obtained downscaling 30 years ERA-INTERIM data series were considered. The analysis consists of the subdivision of the territory in classes based on the named information layers (elevation, slope, rainfall height, temperature, etc.) with a recursive algorithm that ensures the equal representativeness of each class. The number of fires occurring in each class is then assessed based on time series in the last decade, in order to have an estimation of the fire hazard with a constant statistical confidence. The analysis was carried out at national level at a spatial resolution of 500 m on the whole Italian territory by using a dataset of fire occurrences that spans from 2007 to 2013. The same analysis has been performed at regional level in Liguria at a spatial resolution of 50 m using a longer time series of burned areas (1997-2013) in order to draw considerations about the effect of spatial scaling. Some strictly dependences among fire spread and climate and geomorphological parameters have been identified. Such dependences are more evident reducing spatial resolution. The results show that the methodology is able to identify a limited number of multivariate classes containing most of the burned areas.

Keywords: wildfire risk mapping, statistical analysis, climate effect

FRM.P.03 - WILDFIRE RISK MANAGEMENT IN LIGURIA REGION

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At a regional scale, potential danger forecasting makes it possible to alert the volunteer squads and actors involved in fire suppression enhancing monitoring and protection of the territory that may prevent the ignition of fires and, in any case, makes it possible to significantly reduce the elapsed time following the detection of a wildfire. In this context, Regione Liguria is surely the Italian region that has reached the most mature level of activity in the use of forecasting tools. Regione Liguria is among the few regions affected by fire risk both in the summer, as many of the central south regions, and in the winter, as many of the northern regions. The frequency of wildfires and the constant pressure of the phenomenon throughout the year led Regione Liguria to acquire tools and procedures intended for a more efficient risk management in advance of many other Italian regions. Since 1987 the number of wildfires and the total area affected by fire per year have shown great variability, with maximum values recorded between 1989 and 1990. 1,690 wildfires occurred in 1989 and an area affected by fire of over 20,000 ha was recorded the following year, respectively. The number of wildfires observed in the region over the past 5 years has averaged just over 300 wildfires per year for a total covered area lower than 1,000 ha per year. Although the data of the 2014 season are not yet final, the first estimates show a number of fires just over 100 for a total burned area of around 100 ha, which can be considered negligible compared to an area of 20000 ha of 20 years ago. Liguria region make use autonomously of RISICO customized at regional scale within the Regional Service for Wildfire Prediction (SPIRL). Regione Liguria and Corpo Forestale dello Stato, entrusted with the coordination of activities for preventing and extinguishing forest fires by Regione Liguria under a specific convention, developed protocols and operating procedures aimed at improving preventive measures, which have been applied throughout the region during periods of increased risk of fire for several years. These preventive measures are mainly implemented through the active participation of the volunteer forest fire fighting and civil protection services, which have played a more and more decisive role for the protection of forests and territory in Liguria in recent years. Prevention activities allow for a better management of the resources allocated to forest fire prevention, especially in times of very limited financial resources. In this paper, the logical framework of wildfire risk management in Liguria is described in detail. A cost benefit analysis has been performed in order to evaluate the effectiveness of the prediction and prevention measures. Cost related to preventing monitoring and patrolling activities have been considered and compared with the reduction of damages and fire suppression costs.

Keywords: prediction, prevention, fire risk management

FRM.P.04 - OPERATIONAL USE OF RISICO IN PUGLIA REGION: TEST AND VALIDATION

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To the end of improving capacity in wildfire prevention activities, Regione Puglia adopted in 2014 a new tool for the automatic issue of a daily fire danger bulletin. During the summer season of 2014 the new tool has been tested within the regional operational chain for forest fire management. The new tool provides, since July 2014, daily maps at regional scale of the fire danger index defined by RISICO. The maps refer to the fire danger situation of today, tomorrow and after tomorrow defined over administrative areas corresponding to the alert zones. A deep validation phase has been performed comparing data on fire occurrences and firefighting effort, collected from the Regional Operational Room (SOUP), and the fire danger index forecasted by RISICO. A first validation has been conducted using the chi-square test comparing the frequencies of the fire danger classes provided by RISICO (Low, Medium, Moderate) with the observed daily fire danger. Actually, RISICO has two additional fire danger classes, High and Extreme, but during the summer season of 2014 did not occurred. Fire occurrence is classified in three classes as follow: Low (<4 fires per day), Medium (5-12 fires per day), Moderate (>12 fires per day). The hypothesis of independence between the forecasted fire danger classes and the observed fire occurrence classes has been rejected proving the skill of RISICO. A more careful validation has been conducted considering all the information available from the ground including the firefighting efforts. Four different criteria have been defined: fire duration, type of fire, emergency code, number of firefighters involved. A multicriteria analysis has been performer in order to compare fire danger forecasts with fire occurrences considering some aspects of the fire behavior. An Analytical Hierarchy Analysis (AHP) has been used in order to define the validation criteria. For each fire a danger index has been defined and compared with the forecasted fire danger index. >From the complete dataset of 2480 wildfires, the analysis has been performed on the subset of 335 forest fires, excluding from the analysis shrubs, grassland and stubble fires. For the considered subset of forest fires the Mann–Whitney U test has been applied. This test has greater efficiency than the chi-square on non-normal distributions. Also in this case the results show a very good skill of RISICO in the prediction of fire danger for the day after.

Keywords: test statistics, fire danger index, prediction

FRM.P.05 - ASSESSING SPATIO-TEMPORAL CHANGES IN FIRE RISK ACROSS COMPLEX MEDITERRANEAN ECOSYSTEMS OF GREECE

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Wildfire plays a key role in structuring vegetation and landscapes worldwide, and represents a significant threat to human values in fire-prone landscapes. Examining historical changes in fire risk and regime in relation to factors such as fuels and weather can lead to the understanding of the future potential impacts from the growing wildfire problem in a certain area. The aim of this study is to assess the spatiotemporal changes in wildfire risk in two fire- prone Mediterranean areas of Greece between three historical periods (1945, 1960 and 1996) scenarios. We created site-specific fuel models by measuring the field fuel parameters in representative natural fuel complexes, and we determined the spatial extent of the different fuel types in the study areas by using photointerpretation procedures. Fire risk was then analyzed using a sound modeling approach based on the MTT algorithm as it is embedded in FlamMap and ArcFuels fire behavior and risk tools. Wildfire simulations were run by using historical fire spots and random ignitions in order to estimate major fire risk components such as Burn Probability (BP), Conditional Flame Length (CFL), Fire Size (FS) and Source to Sink Ratio (SSR) at landscape-scale (30 m) resolution; considering ignition, fuel and weather inputs from the three time frames to reflect the different conditions during the studied periods. Our analysis highlighted changes in spatiotemporal fire risk components between the study periods, which have greatly influenced fire exposure and regime at the landscape scale. Statistical significance differences of the fire risk components among the three time periods were assessed by performing the Kruskall-Wallis non-parametric test. The results obtained represent an important guide for fire management and planning activities in Greece and the methods employed can serve as a template for similar studies elsewhere in the Mediterranean region. This study can also contribute to a better understanding of wildfire threats and potential impacts in fire prone Mediterranean areas in relation to changes in factors affecting fire occurrence and spread.

Keywords: fire risk, spatiotemporal analysis, landscape fire modeling

FRM.P.06 - ENHANCED WILDFIRE RISK ASSESSMENT THROUGH THE USE OF FIRE BEHAVIOR MODELS

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Wildfire risk assessments are increasingly important in wildfire management and planning. They provide a forecast of the expected economic and environmental cost of wildfires impact in a certain region and can help decision-makers to take decisions about the most suitable mitigation treatments to reduce risk. The basis for a quantitative analysis of wildfire risk has been established for many years, but present enhancements of fire behavior models and analysis aim to increase the value and help that these assessments represent to fire managers. This work presents an operational wildfire risk assessment methodology being implemented in the software Wildfire AnalystTM. Such as in other risk assessments, the core data is obtained in a stochastic manner carrying out hundreds to thousands of different fire simulations in which the weather conditions and/or ignition sources are modified in order to measure the expected impact and likelihood of events such as wildfires with ignition on overhead power lines. Weather variations are obtained either from historical data or by a Gaussian variation of existing weather conditions. An innovative characteristic of the analysis is the use of Wildfire Analyst's evacuation mode as an underlying engine, which allows the risk analysis to focus on specific valuable or vulnerable assets. This approach is possible because the evacuation mode computes the time that a fire requires to spread from any cell in the domain to the user defined asset, instead of showing the usual time a fire would take to spread from a set of user defined input cells (ignition sources) to any cell in the domain. In this way, every independent simulation using an asset as an input provides an x-hour fireshed around the asset. In addition, its associated Minimum Travel Time output reflects the expected paths that the fire is expected to follow to reach that asset. Another innovative feature consists on the accumulated economical fire path output. This output is similar to the usual fire paths provided in known software like Flammap, but instead of representing the fire burned area they represent the economical impact of the fire. This output therefore provides a very quick and easy way to see which are the main paths followed by the fire to reduce economical impact as well as human losses.

Keywords: economical impact, overhead power lines, risk assessment, vulnerable assets, wildfire analyst

FRM.P.07 - WILDFIRE RISK AND LAND COVER/LAND USE CHANGES IN MONTI AURUNCI REGIONAL PARK: FUTURE PROSPECTIVE OF MANAGEMENT AND POLICY INSTRUMENTS

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Several studies evidence strong relationships between wildfire risk and Land Use/Land Cover changes (Moreira et al. 2011). The regrowth of natural vegetation within abandoned fields and the resulting fuel load increase, the reduction of traditional management practices such as clearing shrublands, the persistence of other activities linked to fire, like maintenance of pastures and agricultural burning, combined with climate changes and urban expansion, increase fire risk (Moreira et al. 2009, Martinez et al. 2009). This is particularly relevant in protected areas where several studies show an increase in wildfire severity and a consequent high rate of vulnerability of habitat and landscape biodiversity. From an ecological and social point of view, there is a major interest to use a fire management approach to address these issues in protected areas, including the (re)use of traditional burning, in order to attain target fire regime fundamental to the landscape sustainability (Pereira et al. 2012). In this paper, we present the results of a study in the Monti Aurunci Nature Regional Park (MARP), an area of 19379 ha in southern Lazio (Italy) with the highest fire risk level in that Region. The objective of this work was to study the relationship between Land Cover/Land Use dynamics, fire risk and socio-economic factors. In particular, the relationship between fire regime and pasture activity on Ampelodesmos mauritanicus grassland is described. In this context, we analyzed fire as a tool for pastures management, discussing the inadequacy of actual national and regional legislation and the need for new policies including prescribed burning to this aim. Land-cover dynamics were analyzed in GIS environment (arcgis/Esri), overlaying the land-cover maps of three different years (1960-2000-2008) to produce a transition matrix. A database of 1620 wildfires occurred (ignition points) in the MARP was used to perform a selectivity analysis (Manly, 1993) to asses if fire could be considered as an herbivore proxy (Moreira et al. 2001; Nunes et al. 2005), that exerts different pressures according to vegetation types and fuel loads. Data were correlated to mapped grazed areas, livestock texture and distribution. In the study area, between 1960 and 2008, the agricultural areas decreased by 32.5% changing to forests, Ampelodesmos mauritanicus grassland and Mediterranean shrubland. About 85% of wildfires was arson and due to anthropogenic and socio-economic factors; among them, the most important seemed to be related to the clandestine use of fire for pastures renewal and maintenance practices. In this perspective, the future strategies, for a well-built environmental management of the MARP area, should not be limited on the sole wildfire suppression approach, but should be more directed towards prevention, including fire management strategies such as prescribed burning application for pasture management to be defined as a legalized and regulated cultural practice.

Keywords: fire risk, prescribed burning, land use/land cover dynamics, Monti Aurunci, manteinance of pastures

FRM.P.08 - IMPROVING SELVICULTURAL MANAGEMENT TROUGH FIRE BEHAVIOUR MODELLING USING LIDAR-DERIVED CANOPY FUEL COMPLEX CHARACTERISTICS: AN APPLICATION FOR MEDITERRANEAN FOREST IN SOUTH WEST SPAIN

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The risk of fire should be considered in ordinary silvicultural management and forest planning to minimize fire damages. In this sense, fire behaviour characteristics are known to be very important for assessing wildfire potential, and therefore they should be considered in evaluating the effectiveness of fuel management programmes. A detailed study for estimating canopy fuel complex characteristics with LiDAR in SW Spain forest types, allows reliable canopy fuel maps as inputs for use in spatial explicit fire behaviour simulator systems. Further, the application of fire behaviour modelling along with forest management actions provide a tool to accomplish forest planning purposes under wildfire risk context. In this sense, this research aims in a first step to assess the potential use of very low density airborne LiDAR (Light Detection and Ranging) data (0.5 first returns m^{-2}) to estimate canopy fuel complex characteristics in stone pine forest in SW Spain. The first modelling phase established empirical relationships, by forest type, between metrics derived from LiDAR data and field measured stand variables using 191 ground reference sample plots. Forest type specific models were used to estimate the main canopy fuel complex characteristics, namely: canopy base height (CBH, m), canopy fuel load (CFL, kg m^{-2}), canopy bulk density (CBD, kg m^{-3}), stand height (SH, m) and canopy cover (CC, %). As a direct follow up, the LiDAR derived canopy fuel and topographic layers required as input, together with information on custom fuel models distribution were incorporated into the FlamMap system to assess the potential fire behaviour across those forest stands for "wildfire conditions" (i.e. a critical scenario that represent moisture and wind speed of 4% and 40 km h^{-1}, respectively). Commonly, the published studies aim to quantify fuel treatment effectiveness of distinct forest stands relying solely on fire behavior simulations. Here, a step further introduces fire behavior modeling variables (initial landscape data and fire behavior characteristics from FlamMap simulations) coupled with standard stand predictors easily gathered through forest inventories (e.g. basal area – G, m^2 ha^{-1} –) to create, using ArcGIS software, a database that are homogeneous according to the above attributes. In the second modelling phase, a classification tree analysis (CART) was used to detect significant fire landscape interactions between stand level features (biometric and fuel data) and fire behavior characteristics as a tool to enable researchers and forest managers to (i) assess potential crown fire occurrence through stand structure, and (ii) draw guidelines that express the difficulty of fire suppression. In addition, quantitative target stands structures that can be achieved with silvicultural practices were identified. The accuracy of the research findings are instrumental for selecting priority intervention areas and designing effective fire prevention strategies, addressing the identification of thresholds for radical change in fire behavior in those fire prone stands.

Keywords: Airborne Laser Scanning (ALS, forest inventory, stone pine, Mediterranean forests, silvicultural practices

FRM.P.09 - NETWORK ANALYSIS OF WILDFIRE RISK FOR COMMUNITY MITIGATION PLANNING

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We apply network analyses to understand the topology of wildfire risk to communities on a 3.2 million ha Fire-prone landscape in central Oregon, USA. Historic wildfires within the study and elsewhere in the western US frequently burn over long distances (e.g., 20–50 km) through highly fragmented landscapes with respect to ownership, fuels, management intensity, population density, and ecological conditions. The collective arrangement of fuel loadings in concert with weather and suppression efforts ultimately determines containment and the resulting fire perimeter. While spatial interactions among land parcels in terms of fire spread and intensity have been frequently noted by fire managers, quantifying risk and exposure transmission is not well understood. In this paper we used simulation modeling to quantify wildfire transmission and built a transmission network among and within land owners and communities within the study area. The results suggested that 84% of the predicted area burned within the 25 communities in the study area was from simulated fires that ignited on federal lands. The wildland urban interface surrounding the communities was predicted to burn at a rate of 2% per year, with 57% of the area burned from fires ignited on federal lands. The node degree for communities indicated that simulated fires originated on about 6 different landowners. Network analyses in general revealed independent variation in transmitted fire among landowners in terms of both node degree (diversity of landowners exchanging fire) and transmitted fire, indicating that both the spatial grain of land ownership and wildfire topology contribute to transmission among land parcels. We discuss how network analyses of wildfire transmission can inform fire management goals for creating fire adapted communities, conserving biodiversity, and resolving competing demands for fire-prone ecosystem services. We also discuss how biophysical fire networks can potentially be coupled with social fire networks to improve wildfire mitigation planning.

Keywords: risk transmission, network analysis, fire networks

FRM.P.10 - WILDFIRE PREDICTION ACTIVITIES IN SARDINIA, ITALY

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The aim of this paper is to illustrate the wildfire prediction activities, summarized in a daily bulletin processed from June 1st up to October 15th by the Risk Forecast and Prevention Service of the Sardinian General Directorate of Civil Protection. The purpose of prediction is to evaluate daily the probability that any fire can spread more or less rapidly in a given area due to forecast weather conditions. The wildfire prediction has as priority objective to provide guidance on the type of events expected in the reference area, in order to allow the fire fighting apparatus to identify the most suitable location and arrangement of the strategic staff (ex.patrols) and resources necessary to deal with wildfire. The prevision phase is scientifically based on models application and elaboration, such as IFI Index (Ichnusa Fire Index), Forestry Corps Rapid Model (Modello Speditivo CFVA), and RISICO Model (RISChio Incendi Coordinamento). The input of these models are daily provided by the Regional Agency of Environmental Protection, Meteo-Climatic Department, which deliver information about weather forecast, particularly focused on the weather variables, such as temperature, wind and humidity. The models output show a scenario of forecast events, spread over the entire region, with counties details, depicting areas of awareness levels, useful to determine the best way to face and fight the wildfires. This output allows to geographically localize and to deploy strategically the teams, involved in the wildfire-extinguishing. The prevision output is split into four levels: low, average, high and extreme.

For each awareness level, the following information are reported:
1) Phenological probability to start a wildfire;
2) Prevention activities to be undertaken to reduce the awareness level;
3) Deployment of teams and forces to fight the wildfires, appropriate to the level of the awareness.

The prevision bulletin is published at 2 pm at the website of the Regional Civil Protection. They are public, in order to assign responsibility to the entire population in regard of the forecast danger and to address people to behave correctly, avoiding any additional cause of firelet activation. Moreover the institutions and the organizations, involved in the wildfire flight, make use of the bulletin to activate programmed actions, depending on the seriousness of the awareness. The challenge of the department is to publish a daily bulletin, including the forecast prediction not only for the next day, but for the following two or three days. A further goal is to provide a bulletin expended to areas delimited not only based on the geographical county details, but on the adjacency of the environmental homogenous areas, defined by several criteria. The meaning of the prediction is to cut the cost of the structured system to fight the wildfire and to reduce the environmental damages.

Keywords: fire management, wildfire prediction, model

FRM.P.11 - MAPPING WILDFIRE DEFENCE PRIORITIES IN THE PYRENEES LANDSCAPES: SANTA JULIÀ DE LÒRIA CASE STUDY (ANDORRA)

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Along last centuries, the Pyrenean landscape has been dominated by an equilibrium between the traditional socio-economic activities (cattle, agriculture and forestry) and the natural dynamics events (avalanche, flash floods, landslides). However, during the last 50 years a new paradigm has taken place as a consequence of a generalized and unprecedented land use change, motivated by the loss of traditional activities toward the tourism and business economy. In addition, forestland have experienced an increase on the demand of its social services and the wildland urban interface as well bringing with it an anthropogenic ignition probability rise, even more within the climate change context. This situation could involve worst wildfires seasons in terms of frequency and severity at the Pyrenean landscape level. Wildland forest management and protection program budgets are limited, and managers are requesting help in finding ways to objectively assign their limited protection resources based on the intrinsic environmental characteristics of the site and the available firefighting resources. A Defence Priority Index against wildfire, integrating information on the historical fire risk (Historical Risk Index), the potential fire behaviour (Potential Fire Behaviour Index), the potential ignition risk caused by human activities (Potential Risk Index), the goods and forest services damages due to fire (Potential Damage Index) and the fire suppression difficulty (Suppression Difficulty Index), provides managers with fundamental information for strategic planning and development of tactical operations to protect the natural values and human infrastructures across the landscape. This methodology has been applied for first time in Pyrenees region, at province level of Sant Julià de Lòria, Principality of Andorra, having been calculated so far the first three indices, and the others are still being implemented.
Preliminary results showed two significant historical fire scenarios (winter ends and summer), both with a low to moderate fire behaviour risk. According to these results, the highest defence priority was found on the wildland urban interface surrounded by evergreen oak formations. In these locations, preventive silvicultural treatments focused on vegetation are strongly recommended in order to reduce the flame length and the rate of spread, as well as self-protection guidelines to perform and improve the owner's resilience.

Keywords: defence priorities index, principality of Andorra, wildfire risk map

FRM.P.12 - EVALUATING THE CAPABILITIES OF FOAMS IN LIMITING FIRE SPREAD

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A limited number of scientific studies was devoted to evaluate the ability of fire suppressant foams to improve fire control, although this technique can bring out new opportunities for fire management. The goal of this work was to analyze the capabilities of foam concentrates to slow down or stop the heading and flanking fire spread, as well as to evaluate the steadiness of safe areas and anchor points delimited by foams. Furthermore, the present study aimed to analyze how much the main environmental factors (e.g. wind speed, air temperature, relative humidity) influenced the efficacy of foam concentrates. The trial was conducted on September 2014 in a flat area of about five hectares located in central-western Sardinia. In the area, mainly covered by grasslands, forty-four experimental burning plots were established and a foam line around each plot was realized using foam concentrates. A different combination of foam treatments was used for each burning plot: type of formulation, concentration, time elapsed between application and fire ignition, foam line depth. Fuel load and moisture content were determined by collecting data from random samples nearby the experimental plots. Weather conditions before, during and after the experiments were monitored and gathered. The main fire behavior indicators were estimated by direct observations and video footage. The analysis of the experimental data was performed by using different statistical approaches as analysis of variance, non-linear models, and non-parametric models. The analysis of the experimental results highlighted that both the foam line depth and the time elapsed between application and fire ignition were the most relevant factors affecting the effectiveness of the foam line. Also, increasing amount and concentration of foams resulted in a better containment of the barriers. Moreover, when fuel loads in the plots were relatively higher than the average, the energy of the fires was higher and reduced the evaporation time of foams. Work is in progress to perform new trials in the next summer seasons in order to evaluate foam performances over fuel types with higher fuel loads (i.e., tall grasslands, garrigue and low shrublands). This work was partially founded by the Sardinia Region under the Regional Law n. 7/2007 (EXTREME Project - "Development of methodologies and support systems for fire risk assessment in extreme weather conditions") and by the Italia-Francia Marittimo Programme (Proterina 2 Project).

Keywords: fireline, retardant, prescribed fires

FRM.P.13 - AN INTEGRATED SYSTEM FOR FIREFIGHTERS SMOKE EXPOSURE ESTIMATION

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Firefighters have to deal, in their quotidian, with dangerous situations, exposing themselves to extreme environmental conditions, which put their lives at high risk. Extreme heat exposure, smoke inhalation and reduced visibility are among the most significant hazards to firefighters involved in the suppression of forest fires. Decisions made by firefighters in these severe conditions during suppression operations are highly dependent on personal judgement, experience, and senses. Despite the advances on the numerical simulation of fire progression and smoke dispersion, operational models for assisting with decision are still limited in accuracy, resolution, and performance. Meteorological and smoke forecasts can provide some additional help but they are limited to coarse spatial and temporal resolutions. Recent scientific and technological advances, however, offer a vast number of possibilities towards advanced emergency preparedness during firefighting operations. This paper describes the development of an integrated system that allows the online estimation of firefighters exposure to smoke, helping the firefighters to preserve their personal health and safety. Hardware technology (e.g. wearable, mobile, and communications) was combined with a numerical modelling system that runs under a user interactive interface. The system is composed of the following features:

- capture of 'live' sensor data from a set of wearable monitoring equipment based on a previously developed certified medical wearable technology named "VitalJacket®";
- capture of meteorological observations from a mast placed in one of the vehicles;
- predictions of fire progression, smoke levels and critical exposure in a predefined time-step (up to 30 minutes);
- interpretation of results in an easy and intuitive form to be used by fire managers or firefighters involved in operations.

The numerical modelling architecture is composed of 4 independent models, which compose the main cores of the numerical system. These models are responsible for the simulation of local meteorological fields, fire progression, fuel consumption, smoke production and atmospheric dispersion, and human exposure. All these modelling components of the system have been tested and evaluated individually with data from experimental field fires. The system delivers, for each identified fire ignition location, the visualization of terrain characteristics, including fuel, wind field, fire progression lines, smoke dispersion surface fields, visibility impairment patterns and finally individual exposure to smoke pollutants for specified firefighters. Results from the system are available through mobile devices. The system was applied to a past fire event and discussed among fire fighters brigades to understand its main capabilities and usefulness. This paper presents the developed system, its application and discusses its main advantages and improvements to be done.

Keywords: smoke exposure, numerical modelling, fire safety

FRM.P.14 - FOREST FIRE FACING PLANS: FROM THE RESEARCH INVESTIGATIONS TO AN OPERATIONAL APPLICATION

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In the framework of the E.U. research and cooperation programmes, the problem of wildfires has been approached by the investigation on ecological, physical, technical aspects but also economical consequences or applicative sw tools. The aspect of Prevention and Fight Plans efficacy and updating has been engaged only recently, with the aims to turn the research inquiries in operative improvements; the base to approach a gradual change in National Wildfire Plans is constituted by an exhaustive analysis concerning characteristics, pro & cons aspects, range of applications but also the real perception, by the stakeholders and operators, on the efficacy in use. The E.U. Project FUME Forest fires under climate, social and economic changes in Europe, the Mediterranean and other fire-affected areas of the world (FP7-ENVIRONMENT 2010-2014 ref. 243888) designated the Project Module 4 staff to collect, analyze and summarize, at E.U. level, the Wildfire Operational Plans main elements in order to define common aspects, national structure organizations and opinions on effective applicability by different typologies of stakeholders. The work methodologies has been based on a set of questionnaires, defined by the workgroup and focused on the main prevention and fight aspects, aimed to focus the variables considered, the spatial resolution of data and indications and the improvements in wildfire services efficiency, with a special focus on Wildland Urban Interface (WUI). The investigation involved different types of operators in Italy, Spain, France and Greece (countries characterized by high level of wildfire risk and occurrence), operators selected to cover all the steps, roles and duties in the national forest fire chains. Indications, results and lessons learned by this project activity have been received by the Tuscany Region fire-fight Dept., actively involved during the questionnaire campaign, and converted in an advisory/operative action focused on define, classify and manage (by the clear definition in the Regional Plan) the forest fire fight intervention and the civil protection actions during the suppression phases, in order to avoid lacks or overlapping of responsibilities, interventions and roles. The action planned by the Region Dept. is to constitute a stakeholders working group, including civil protection and wildfire management structures and also research and University Institutions - a sort of informal community of practices. This working group will compare and discuss the wildfire prevention/suppression chain, both on the base of indications and procedures included in the Plans and on the experiences and real cases, to take shape competences, operative indications and organizations improvements to draft the next Official Regional Plans. This project of Tuscany Region fire-fight Structure, active since long-time with good results in innovative wildfire fight strategies, represents the practical application of research results turning into practices and operational strategies in order to upgrade and enhance the institutional activities for the citizenry and natural patrimony safeguard.

Keywords: wildfire regional plan, operational aspects, prevention, suppression

FRM.P.15 - FORESTRY SCHOOL ACTIVITIES REGARDING FOREST FIRE FIGHTING

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The Regional School of Corpo forestale di vigilanza ambientale (CFVA) is an essential resource that provides knowledge and tools for training, upgrading and specialization of CFVA staff. School manages the specialized training of the CFVA members through knowledge, deepening and updating competence of the CFVA as required by law. Programming activities are carried out through annual scheduled training including educational programs for each course. The School as teachers avails himself both CFVA specialists and outside experts. Teaching is carried out through classroom lectures, role playing, field classes with practical exercises, outdoor training and e-learning. The CFVA has a fundamental and irreplaceable role in fire fighting. It is responsible for coordinating, extinguishing, surveillance and police investigations for rural and forest fires in Sardinia.
Forestry School carries out a lead role in scientific and educational matters, particularly in prevention, control and analysis of forest fires and fire behaviour. Training is done through specialized courses and targeted updates delivered to staff. It allows CFVA staff to improve professional skills and techniques, and to build on their experience. Scientific preparation and technical capability to assess fire spread and behavior allows CFVA members to act on forest fires safely and more efficiently. School also employs its expertise to organize training courses for external voluntary associations and rural police companies that collaborate with the CFVA in fighting forest fires.

So far the School has planned, organized and carried out:
1. Course on "Forest fire analysts": 5 editions, 280 people trained.
Objective: To deepen technical and scientific skills through the study of the fire behaviour on vegetation and improving decision support;

2. Annual refresher course on extinguishing operational techniques, self-training: 3 editions, 600 people trained.
Objective: updating CFVA firefighters about analysis, decision processes, team leadership and safety;

3. Training courses for volunteers and rural police companies: 18 editions, 1200 volunteers and 570 rural police companies members.
Objective: to train and update volunteers and rural police companies about safety and forest fire fighting;

4. Course on "Direttore delle Operazioni di Spegnimento (DOS) - Director of Extinguishing Operations", in e-learning mode. This experimental basic course is addressed to all CFVA members (about 1,300).
Objective: to train and specialize CFVA personnel about analysis, management and coordination of the operations required to extinguish forest fires.

Keywords: knowledge, knowhow, sharing

FRM.P.16 - THE 'POCKET WARDEN': PROTOTYPING AND EVALUATING A SMART WATCH FIRE MANAGEMENT APP

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Wearable computing is a rapidly emerging technology segment. Until recently it has been limited to expensive proprietary devices, simple fitness trackers and notification based devices. In June 2014, Google released 'Android Wear', a specific software platform for wearable devices targeted primarily at smart watches. Apple has also announced a similar software and hardware platform due for release in April 2015. Smart phones and mobile applications or 'apps' are increasingly being used in emergency fire management. We prototyped and evaluated the 'Pocket Warden' bushfire emergency management app over the 2014/2015 bushfire season in Victoria, Australia. Targeting the Android Wear platform, the Pocket Warden interfaces with a server based automated fire prediction system that monitors new fire reports and predicts resulting fire spread and property impact potential. The Pocket Warden notifies the wearer of new fire spread predictions within 60 seconds of completion. Utilizing the customizable haptic feedback function of the Android Wear platform, the Pocket Warden associates specific vibration patterns to key events and thresholds to inform the wearer of new fire predictions and their potential impact. Summary prediction details are also displayed on the watch face where they can be viewed and acted on. Early indications are that the use of tailored haptic feedback and simplified smart watch targeted icons can reduce the cognitive load of the wearer. With future smart watches incorporating GPS, heart rate and temperature monitoring functionality it is likely smart watches will experience a similar up take to smart phones. Wide spread adoption will provide fire management agencies with new opportunities in fire management system integration, personnel tracking and monitoring and community messaging.

Keywords: bushfire, wildfire, prediction, wearable, app

FRM.P.17 - EVALUATING TRADEOFFS AMONG COMPETING FUEL TREATMENT STRATEGIES TO MITIGATE WILDFIRE LOSSES: A CASE STUDY FROM NORTH SARDINIA, ITALY

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Wildfires represent a substantial threat to Mediterranean forests and ecosystems and cause extensive losses to anthropic infrastructures and values. In Sardinia, humans play a key role on influencing fire regimes, since more than 90% of ignitions are human caused. Changing land use patterns, including concentration of anthropic activities and population in main towns and coastal areas, has contributed to increased ignition sources in WUI areas and to forest-land abandonment. As a result, shrublands and woodlands in areas previously exploited for wood products are increasing fuel load and fuel bed continuity, then creating fire conditions that can overwhelm fire crew capabilities, especially with extreme weather conditions. Fire risk management strategies employ a combination of silvicultural practices, fuel management, prescribed fires, and creation of infrastructures and safe areas. Of particular importance are large investments in wildland fuel reduction projects in an effort to reduce human and ecological losses from wildfires, although the implementation of these programs challenges fire organizations as they attempt to manage fuels over extensive areas while addressing land use laws, diverse management and protection objectives, and public expectations with finite budgets. As part of a larger effort to develop a scientific basis and guidelines for landscape fuel treatment programs in Mediterranean ecosystems, we are using wildfire simulation and geospatial modeling tools to experiment with alternative management strategies on a 68,000 ha fire prone landscape in Sardinia (Italy). The study area is located in northeast Sardinia and has extensive areas classified as European Site of Community Interest (SCI, 20% of land); the area is mostly surrounded by oak forests (Quercus ilex L., Quercus suber L.) and high Mediterranean maquis. We used spatial optimization software to generate optimized fuel management scenarios based on predicted fire occurrence models. We then modeled fuel treatments and analyzed how the different scenarios affected burn probability, wildfire intensity and size, as well as other exposure indices. Furthermore, we measured the change in exposure from treatments to residential structures and highly valued forests. The results revealed tradeoffs among different fuel treatment strategies at the landscape scale. The methodology presented in this work can be adopted elsewhere in the Mediterranean basin to support fuel management and risk mitigation programs. This work was partially founded by the Sardinia Region under the Regional Law n. 7/2007 (EXTREME Project - "Development of methodologies and support systems for fire risk assessment in extreme weather conditions") and by the Italia-Francia Marittimo Programme (Proterina 2 Project).

Keywords: fire management, fuel treatment strategies, wildfire risk mitigation, fire spread modeling, Mediterranean area

FRM.P.18 - STUDY OF EMERGENCY EGRESS FOR TUNNEL FIRES WITH MULTI-AGENT AND CFD SIMULATIONS

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Tunnel fires represent a complex multidisciplinary problem of great importance for Safety Engineering, where different aspects converge and add difficulties in studying and modeling the phenomenon. Firstly, fire accidents are extreme actions, that lie outside from the traditional probabilistic approach usually applied in civil engineering for structural or accidental loads. Traffic characteristics, particularly the percentage of HGVs, determine the probability of occurrence of the accident. Moreover, the geometry of the tunnel, in terms of dimensions, and the specific safety measures influence both the occurrence of a fire accident and its development and extinction phases. Generally, a fire could be extinguished without difficulties in the first minutes after ignition, but it becomes quickly unmanageable and a simple accident can change into a disaster, in terms of human lives and economic loss. Each of these aspects contributes to make tunnel systems highly dangerous and risky, especially because of the presence of humans inside vehicles. For what regards egress studies, details like people composition in terms of gender and age, psychological characteristics, familiarity with the environment, panic behaviour and presence of disabled people are fundamental and require careful analysis because they influence the outcome of the whole egress process. From the egress point of view, two situations can be used to describe what happens to humans during tunnel fires. If the situation was ideal and theoretical, people would have a complete knowledge of the tunnel environment: they know perfectly where the emergency exits are, which is the closest, where the fire extinguishers and the SOS stations are placed, etc. Human behaviour would be perfectly rational, people would act without fear and would be able to fight the fire, send the alarm and escape in short time. This is not what happens in reality. In fact, people do not have a complete knowledge of the tunnel: also habitual users do not usually pay attention to the details of tunnel geometry and safety equipment, because tunnel is always considered something to cross in order to reach a destination. In case of accident, people are caught by panic, they do not know how to act and lose precious time in the decision – making process. The pre – evacuation time (from the ignition to the movement time towards an exit) changes from person to person and can be very high. Fire and smoke complicate the situation, causing lack of visibility and impossibility of using some escape routes. Modern numerical codes allow to model these realistic situations. Different scenarios can be assessed and the egress simulation, called multi – agent, can be fully coupled with the CFD simulation, describing fire – driven fluid flow. The aim of this paper is to highlight the importance of these concepts for the Fire Safety Engineering and the possibility of its modeling with numerical codes as FDS+Evac, giving as example the study of different fire and egress scenarios for a 3 km – long – tunnel placed in the Catania – Syracuse highway.

Keywords: evacuation, tunnel fires, human behaviour, fire safety engineering, FDS+Evac

Research Projects on Fires

Oral Presentations

PRJ.01 - PROJECT ON AN EFFICIENT MULTI-HAZARD EMERGENCY MANAGEMENT SERVICE PLATFORM DESIGN

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The project focuses on developing a sustainable, pre-operational open service platform, which integrates space, based observation, communications and navigation technologies to provide innovative services for a wide variety of users and application domains. Multi-hazard applications such as the prediction/early detection of emergencies, population alerting, environmental monitoring, crisis management and risk assessment are managed through a single, user friendly interface, targeting several users. While the service platform is designed to be multi-hazard, the specific developments for the pre-operational system and pilot demonstration will be focused on the forest fire scenario. The project provides highly efficient tools and enhanced services to the following user profiles:

- Core user profile: civil protection and emergency management entities for environmental monitoring, risk assessment, detection, monitoring and management of emergency situations;
- Secondary user profile: academic/research, insurance companies, operators of critical infrastructure for environmental monitoring and risk assessment.

Through a flexible, scalable and modular architecture, the platform is able to integrate the following services, which are broadly based on innovative technologies available within the consortium:
- Satellite Earth Observation data access and in-situ sensors and processing;
- Decision support services based on data fusion and situation assessment techniques;
- A simulation platform for hazard modelling and risk assessment;
- An alert message gateway to alert the population through a variety of communications means.

A novel energy-efficient satellite uplink optimised for long messages will be added to in-situ sensors improving their availability and deployment flexibility. Location information from remote responders will be integrated into the common operational picture and global navigation satellite system (GNSS) services will be applied to disseminate alert messages to the population. A free-space optical downlink will be used to download data from a real EO satellite, achieving throughput in the order of Gigabits per second (Gbps). The provided services and products can be used in an integrated manner by emergency professionals, but also subsets of products can be acquired for specific use, e.g. by operators of critical infrastructures for risk assessment and by the scientific community or by the public in general for isolated services. Interaction through workshops with the Advisory Board and end users is one of the pillars on which the XX project is based. The focus of the first workshops has been to understand current operational procedures and to identify room for improvement in order to gather and refine user and system requirements, so to avoid omitting important conceptual and technical aspects related to the development of the system. The remaining workshops will focus on the analysis of the first system implementation in order to identify flaws and propose modifications and on the evaluation of the pre-operational services during the demonstration. The pre-operational demonstration will be in a realistic forest fire exercise, organised and controlled by fire brigades, during which the entire platform will be challenged and all services will be validated by end users. The results will be fed back into the business case and sustainability roadmap to ensure the sustainability and

commercial viability of the project in the long term.

Keywords: Space, forest fires, platform, multi-hazard, emergency management

PRJ.02 - PREFER: AN EUROPEAN SERVICE PROVIDING FOREST FIRE MANAGEMENT SUPPORT PRODUCTS

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PREFER is a Copernicus project of the EC-FP7 program that aims developing spatial information products that may support fire prevention and burned areas restoration decisions and establish a relevant web-based regional service for making these products available to fire management stakeholders. PREFER service focuses to the Mediterranean region, where fire risk is high and damages from wildfires are quite important, and develop its products for pilot areas located in Spain, Portugal, Italy, France and Greece. The main objective of PREFER is to allow fire managers to have access to online resources developed by the consortium, which shall facilitate fire prevention measures, fire hazard and risk assessment, estimation of fire impact and damages caused by wildfire as well as support monitoring of post-fire regeneration and vegetation recovery. The project makes use of a variety of products delivered by space borne sensors and develops seasonal and daily products using multi-payload, multi-scale and multi-temporal analysis of EO data. The PREFER Service portfolio consists of two main suite of products. The first refers to mapping products for supporting decisions concerning the Preparedness/Prevention Phase (ISP Service). The service delivers Fuel, Hazard and Fire risk maps for this purpose. Furthermore the PREFER portfolio includes Post-fire vegetation recovery, burn scar maps, damage severity and 3D fire damage assessment products in order to support relative assessments required in context of the Recovery/Reconstruction Phase (ISR Service) of fire management. PREFER service is currently undergoing the validation phase in the pilot areas in cooperation with end users whereas the demonstration phase will be carried out during the 2015 fires season. The service will be ready for operational use at the end of the project, as a new powerful tool at the disposal of the authorities in charge of forest fire management in the Mediterranean area. The paper aims at presenting the PREFER portfolio products and the results of the validation activity.

Keywords: remote sensing, forest, wildfire, risk, GIS

PRJ.03 - THE OFIDIA PROJECT: AN OPERATIONAL FIRE DANGER PREVENTION PLATFORM

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Prevention is one of the most important stages in wildfire and other natural hazard management. Fire danger rating systems have been adopted by many countries to enhance wildfire prevention and suppression planning. OFIDIA (Operational FIre Danger preventIon plAtform) is a two-year project started in May 2013 funded by the European Territorial Cooperation Programme Greece Italy (2007 – 2013). It aims at developing an operational fire danger prevention platform, with the ability for near real-time fire danger forecast and fire behaviour analysis. The project partners are the Euro Mediterranean Center on Climate Change (Italy - Lead partner), the University of Ioannina (Greece), the Decentralized Administration of Epirus-Western Macedonia (Greece), and the Lecce and Bari Provinces (Italy). The main objectives of the project are: i) to improve the operational capability of forecasting, preventing, and fighting forest wildfires, ii) to enhance the cross-border cooperation for fire danger assessment, iii) to encourage cross-border knowledge sharing among research institutions and stakeholders, and iv) to advance the sustainable life quality and economic prosperity in the area. The following activities will be performed to achieve the main project objectives: i) the installation and operation of hardware equipment for automated weather monitoring (weather stations and wi-fi sensors) and visual forest patrolling (video cameras), ii) the installation and operation of control rooms for the operational coordination of forest fire prevention and fighting, iii) the joint development of integrated operational IT infrastructure for data storage, weather modelling, fire danger forecasting, visualization of historical and forecasted data on geographical maps and iv) sharing of knowledge about scientific and operational best practises through cross-border planned visits between the research institutions and stakeholders. The operational fire danger platform will provide the end-users (e.g. national fire corps, civil protection, etc.) with a system running different fire danger models, coupled with fire behaviour modelling. In particular, the following three fire danger indices will be implemented: Fire Weather Index, Fosberg Fire Weather Index, and Integrated Fire Danger Index. The system will provide a near real time decision support (1-4 days; hourly or sub-hourly resolution) with a hourly/daily response type. The implemented fire danger models will exploit weather forecasts datasets and/or environmental wireless sensors data (related to the real time monitoring of specific areas in the Greek and Apulia regions) to provide high-resolution coloured maps of different fire danger indices, available through the project website. In particular, six new weather stations with multiple sensors will be installed in the Apulia region (three in the Province of Lecce and three in the Province of Brindisi) and then connected by a wireless sensors network. Three additional weather stations of the Civil Protection network in Bari Province will be involved. Further information can be found on the OFIDIA web site (www.ofidia.eu).

Keywords: fire danger index, fire danger model, fire behaviour model, fire danger rating system, high performance data management platform

PRJ.04 - WUIWATCH: AN OBSERVATORY ON PREVENTION AND DEFENCE AGAINST FOREST FIRES AFFECTING WILDLAND-URBAN INTERFACES (WUI) IN EUROPE

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The objective of the project is to create and consolidate a European Observatory on prevention and defence against forest fires affecting urban areas and communities in the so called Wildland-Urban Interfaces (WUI) in Europe by assembling a permanent forum and a special interest group. The observatory embraces the main European actors in this type of emergencies, through the design and implementation of tools and mechanisms for the gathering, interchange and capitalisation of experience, the elaboration of protocols, guides and recommendations on prevention, safety and operations. Together with the creation of the permanent forum and several databases on historical fires affecting WUI areas, two sets of experiments will be designed and carried out, in particular the study of local fire behaviour and how this influences in the house survivability by means of laboratory experiments with firebrand generators, and on the other hand the relationship between the local fire behaviour and firecrews safety in WUI environments. International workshops are being celebrated as periodical meetings where experts from different regions exchange information and best practices, and will continue on a yearly basis after the project operational period is over. In particular, 2015 will hold a workshop on house vulnerability in Portugal and in 2016 a workshop on fire safety in WUI operations will take place in France. This paper presents the overall approach of the project and, in particular, the design and objectives of experiments on local forest fire behaviour in the WUI environments and its relationship with vulnerability and safety. The outcome of WUIWATCH activities will provide a good baseline onto which found a common approach to the problem of forest fires in the WUI in Europe and to promote the adoption of common and appropriate European wide methods, protocols, regulations and tools amongst all involved actors and stakeholders in such civil protection emergencies. The Partners of WUIWATCH are: METEOGRID, (coordinator), Madrid (Spain); ADAI, Associação para o Desenvolvimento da Aerodinâmica Industrial, Coimbra (Portugal); Pau Costa Foundation, Tivissa (Spain); CEREN Centre d'Essa et Recherche de l'Entente pour la Foret Meditérranéenne, Gardanne (France); DIPNET, University of Sassari, Sassari (Italy).

Keywords: wildfires, rural urban interface, civil protection

PRJ.05 - HOLISTIC FOREST FIRE PROTECTION - IPA ADRIATIC PROJECT 2014-2016

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The coastal area of Adriatic and its neighboring areas belong to regions with high risk from forest fires, especially during the summer due to very warm climate with low level of humidity, densely spaced conifer forests, lot of tourists visiting various coastal regions and islands, and many other case specific and organizational reasons. Although the fire fighting professionals are quite good organized and coordinated, the existing fire prevention/protection measures in the Adriatic region are far from being satisfactory. They are not existing, not implemented in the whole area, or not economically implemented. Therefore, Split-Dalmatia County from Croatia has initiated in 2007 preparation of strategic project target to Adriatic IPA funds, based on Split-Dalmatia County holistic approach to forest fires protection and prevention. HOLISTIC project was finally in 2013 accepted as Adriatic IPA project under priority 2 Natural and Cultural Resources and Risk Prevention, measure 2.2 Natural and cultural resource management and prevention of natural and technological risks. HOLISTIC project, with full name Adriatic Holistic Forest Fire Protection, has been expanded to include also earthquakes, another natural catastrophe important for Adriatic region. Now it is focuses on the prevention and damages mitigation of the natural risks, with special focus on wildfire and earthquake risks, aiming at improvement, promotion and strengthening of institutional capabilities in implementing policies and actions to reducing the causes and potential start of natural breakdowns to improve reaction and intervention readiness, to reduce the damages in areas of regions facing the Adriatic. The project has started on 1st January 2013 and its duration will be 30 months. It has gathered 20 partners from Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Montenegro, Serbia and Slovenia, leaded and coordinated by Split-Dalmatia County with the total project budget of about 9.3 million €. The project plans to develop common guidelines and standard procedures for policy and institutional enhancement, legislative and institutional regulations, prevention management codes and procedures in the domain of sustainable fire protection and prevention and public and historical buildings earthquake protection.

They will lead to improved:

- Legislation by the national and/or regional public bodies,
- Codes of conduct by the Forest, Fire Fighting and Civil Protection Administration/Corps,
- Operational methods by all technical and academic bodies involved in the project as beneficiaries and associates, as well as enhanced educational capacities.

They will therefore ensure political sustainability after the end of the project in order to guarantee a long term benefits and impacts to the directly involved territories. The project plans to develop and experiment model by pilot projects in wildfire part of:

- Wood life cycle based on commercial biomass use produced by fire prevention actions,
- Indirect prevention campaign,
- Fire risks predictive models and algorithms on micro-location scale adapted and tuned for Adriatic region,
- Fire behavior modeling and spread simulation adapted and tuned for Adriatic region,
- Monitoring, surveillance and fire outbreaks early warning system adapted and tuned for Adriatic region.

Keywords: forest fire prevention, holistic approach, IPA Adriatic

Research Projects on Fires

Poster Contributions

PRJ.P.01 - SPANISH THEMATIC NETWORK FUEGORED "EFFECTS OF FOREST FIRES ON SOILS"

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The Spanish Thematic Network FUEGORED "Effects of Forest Fires on Soils" was founded in 2007 because of the interest of Spanish researchers interested in the improvement of strategies and scientific links. The network was funded by the Ministry of Science and Innovation but nowadays, the activity continues with no official funds. The main objective of the network is to promote the dissemination of results of scientific research and provide technical and management information enabling them to improve forest management. Concretely, we consider as a basic goal the soil protection and conservation, mainly in fire-prone areas, such as the Mediterranean Basin. The impact of forest fires on soil causes damage which may be irreversible, such as post-fire erosion, alteration of water resources, encouragement and induction of flooding water pollution. In this long-term project, we pretend to develop and review scientific knowledge to date, to discuss and propose future tools based on scientific research to prevent negative effects of wildfires on soils. Currently, the network includes more than 350 members, researchers from over 30 universities and research centers throughout the Spanish State. To improve the national network, we count on the experience of decades of scientific and technical work in areas affected by forest fires from outstanding foreign researchers collaborating as FuegoRed Members, from countries such as Australia, USA, Portugal, Australia, Lithuania, the UK and others. Among members, we also count on managers and forestry engineers from various institutions and stakeholders. The research group consists of the leading names of Spanish science in the topic but also young talents, which are currently developing the most innovative lines of research, as well as some of the most prestigious international researchers in the area. Several international congresses, publication of books, online forum including news, job offers and others (syntethyzed in a bimonthly bulletin), in addition to a journal (FLAMMA) are initiatives that have led to an increase in the exchange of information, ideas and people between research and. We also promote interaction between scientists and forest management staff and decision makers. The official webpage (http://fuegored.weebly.com/), facebook page (https://es-es.facebook.com/pages/FuegoRED/162866617071769) and twitter account (@FuegoRed) provide information about activities, publications, meetings, pictures, members and other available resources.

Keywords: soil protection, scientific knowledge, post-fire restoration and rehabilitation, forest and landscape resilience, knowledge transfer

PRJ.P.02 - FIRE DRIVERS AND FIRE DYNAMICS UNDER FUTURE CLIMATE CHANGE: THE CONTRIBUTION OF CMCC TO THE FUME PROJECT

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Fire is by far the most frequent and widespread disturbance to vegetation in Mediterranean ecosystems. Every year about 45000 forest fires occur in Southern Europe, burning approximately 0.5 million hectares of forests and other rural lands (Camia et al., 2008). According to a number of authors, the primary drivers determining and shaping fire regime (climate, topography, fuel, and land use-land cover) were not stable during the last decades. As reported by IPCC (2014), changes in climate and socioeconomics are projected to continue, thus increasing fire danger and exposing assets, values, and ecosystems to greater fire risk. However, our understanding of how the fire driver changes affected fire regime in the past is limited. The FUME project (Forest fires under climate, social and economic changes in Europe, the Mediterranean and other fire-affected areas of the world) highlighted how the understanding of fire controlling factors, and their dynamics, is of utmost importance for anticipating future fire risks. With the aim to learn from the past so as to understand future fire impacts, the FUME project had four main objectives: (i) the investigation and disentangling of the relationships between socioeconomic, landscape and climate factors, and fires across various scales and countries during the last decades; (ii) the translation of climate, land use and socio-economic change scenarios into projections of modified fire potential and risk; (iii) the evaluation of the capacity to cope with future forest fires and reduce the risk through preventive or reactive measures; and (iv) appraisal of the related economic costs and policies at the European level. In this paper, we present and summarize the most important achievements reached by the Euro-Mediterranean Center on Climate Change (CMCC), a core partner of the project. The main scientific findings are that: (1) fire activity has significantly changed, also thanks to fire management improvements; (2) future land use distribution, if not regulated, could contribute to increased fire risk; (3) such increase could be counterbalanced by projected reduction in wind speed, leading to a lower wildfire rates of spread and size; (4) the projected average yearly damage induced by Mediterranean forest fires in the 2020-2070 period ranges from $ 5286 to $ 7587 million. Furthermore, in association with these main results, this paper also discusses the most important management implications, along with major open challenges that still need to be addressed.

Keywords: FUME project, fire regime, climate change, land use change, carbon losses

PRJ.P.03 - BRINGING EDUCATION AND KNOWLEDGE ON WILDFIRE ISSUE: THE EXPERIENCE OF THE PIROS MASTER PROGRAM

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The complex problem of wildfires in the Euro-Mediterranean region is raising more and more interest in the scientific community as well as in the population and in the media, due to the deep impacts of wildfires on economy, environment, landscape and people. Education and training play a key role in the process, since they represent a fundamental link between scientific research and practical applications to manage, prevent and mitigate wildfire issues. The International Master "PIROS - Wildfire Planning, Prevention and Fighting in Mediterranean Areas", organized by University of Sassari, Department of Science for Nature and Environmental Resources (DIPNET) and by the Assessorato al Lavoro of the Sardinia Region, was planned with the aim to give a high academic and specialization level on fire behaviour and propagation, fire planning and management, fire prevention, fire risk mitigation techniques, impacts evaluation and post fire recovery. The Master PIROS was held in Sassari, Sardinia (Italy), from November 2012 to June 2014, and was offered to 25 Sardinian graduated students. Donatella Spano, full Professor at the University of Sassari, directed the Master. Michele Salis and Valentina Bacciu, researchers at the University of Sassari and at the Euro-Mediterranean Center on Climate Change, composed the Organizing Direction of the Master. Dr. Silvia Gaias covered the tutor activity. The PIROS activities were monitored, coordinated and supported by an International Scientific Committee and an International Teaching Committee. The first aimed to guide the Course and to define guidelines and profiles for the didactics; the second focused on coordinating didactics, organizing the thematic modules, and defining the rules to select the students. The Master (overall 1,500 hours) was structured in 9 thematic modules with lectures, workshops, seminars, practical activities, final dissertation and individual study. A crucial experience was the Internship program, which was held by the students in relevant national and international institutions, universities and companies. Overall, 61 lecturers contributed to the didactics of the Course: Italian lecturers covered about 60% of the hours of the Master, while experts and researchers from the United States, France, Spain, Portugal, and Greece covered the remaining 40%.

PRJ.P.04 - EXTREME PROJECT, A MODELLING CHAIN TO SUPPORT THE PREVENTION AND MANAGEMENT OF EXTREME WILDFIRES IN SARDINIA

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Wildfire regime in Sardinia has been historically affected by the socio-economic conditions and their relationships with meteo-climatic conditions. A recent abrupt change on fire regime was observed at the end of 1970s, when socio-economic variations, mainly land abandonment and land use changes, were responsible of an increase in fire occurrence and in large catastrophic wildfires. This caused serious damages to forestry, agricultural and anthropic values, but in particular losses of human lives. The analysis of fire time series showed a large inter-annual variability of the burned areas and, as in other countries of the Mediterranean basin. Such variability is mainly due to the occurrence of wildfires with extreme behaviour concentrated in a limited number of days. These days are typically characterised by the advection of warm and dry air masses from North Africa. The aim of this project is (1) to study the synoptic patterns associated with extreme wildfire behaviour, (2) to propose a set of tools for the prediction of wildfire behaviour considering different weather scenarios, (3) to estimate the economic costs potentially associated with large wildfires, and (4) to characterize wildfire exposure and risk at regional and local scale. In order to provide the tools to predict fire behaviour some experimental activities were devoted to the comparison of different methods to obtain the simulation of wind field using both a mass-consistent model and a computational fluid dynamics models from the initial conditions provided by mesoscale meteorological models with different schemes of nesting and resolutions.

Remote Sensing Applications

Oral Presentations

RSA.01 - ROBUST SATELLITE TECHNIQUE (RST-FIRES) FOR TIMELY DETECTION OF FOREST FIRES BY SEVIRI DATA

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Satellite-based methods for fire detection have been originally applied only to polar-orbiting sensors. Recently, the usefulness of geostationary satellite sensors in fire detection and monitoring has been highlighted thanks to their unique characteristic of having a very high time repetition rate which in principle, may give more chance to detect short-lived fires, starting fires or fires with activity which has a strong diurnal cycle. Mediterranean Countries, strongly affected by disastrous fires, which each year burn hundreds of thousands of hectares of forests, may really benefit of the European geostationary satellite sensor MSG-SEVIRI (Meteosat Second Generation – Spinning Enhanced Visible and Infrared Imager). Despite its coarse spatial resolution (3x3 km^2 at 0° lat, 0° long), it offers a temporal resolution from 15 to 5 (in case of MSG Rapid Scanning System) minutes so that SEVIRI-based products may give an actual support to ground surveillance systems and help Civil Protection Services in timely detecting events for rapidly intervening before fire spreading as well as in monitoring ongoing events for optimizing ground and aerial resources. However, to fully exploit such a potential, refined data analysis algorithms are required. In the last years, many algorithms of fire detection have been adapted to MSG-SEVIRI starting from other polar (like NOAA-AVHRR or EOS-MODIS) or geostationary sensors (e.g. GOES) or, more recently, have been specifically designed for it. They are generally based on fixed thresholds (single/multiple channels or contextual methods) so that they are often a source of false alarms or show a low sensitivity in detecting small/starting fires. In this work, results of RST-FIRES (Robust Satellite Techniques for Fire detection) implemented to MSG-SEVIRI data are shown. Validation of RST-FIRES performances have been evaluated by means of a Total Validation Approach (TVA), based on a systematic check of detected hot spots through a direct ground observation of dedicated light aircrafts or ground voluntary brigades. RST-FIRES performances are presented and discussed also in comparison with other SEVIRI-based fire products such as FIR (Active Fire Monitoring), FD&M (Fire Detection and Monitoring) and SFIDE (System for FIre Detection).

Keywords: robust satellite techniques, SEVIRI, timely detection

RSA.02 - EVALUATING FIRE GROWTH SIMULATIONS USING SATELLITE ACTIVE FIRE DATA

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This study endeavored to quantitatively evaluate fire growth simulations for large wildfires against the spatio-temporal distribution of satellite active fires. Additionally, FARSITE simulations are reinitialized during the wildfire event using MODIS active fire data. Simulated fire growth is consistently delayed, pointing to further research on the sources of errors, by aiding calibration processes and improving data inputs. However, different re-initialization procedures showed the potential to improve simulations performance. Overall, this approach has the potential to be generalized to a large number of wildfires, provides simple quantitative spatio-temporal error measures enables evaluation of the fire modeling system and its calibration based on real wildfires and, is likely to improve fire spread simulations. Thus, more reliable fire growth predictions are expected, aiding fire management decisions to reduce the impact of wildfires, where protection of lives and assets play a major role.

Keywords: fire spread simulations, performance, error, FARSITE, MODIS

RSA.03 - COMBINING DIFFERENT REMOTELY SENSED MEASUREMENTS AND MODELS TO IMPROVE THE DETECTION OF AND EMISSIONS ESTIMATES FROM SOUTHEAST ASIAN FIRES

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A pair of recent studies using remotely sensed data and inverse modelling (Cohen, 2014; Cohen and Wang, 2014) over Southeast Asia have concluded that the estimated emissions of Black Carbon (BC) from fires is strongly underestimated in Southeast Asia. In addition to just the annual values being underestimated, there is strong inter- and intra-annual variation, with the underestimation varying from a factor of 4 in high years, to a factor of 1.5 in low years. Further, the remote sensing products used (AOD and other aerosol properties) and the analytical technique employed are able to sense emissions from fires in both space and time that are not observed by hot-spot based techniques, leading to a new spatial/temporal mapping of the fires. These new emissions have been compared with measurements from both regional and global sources and are found to match much better than other commonly used emissions sources from this region. This has been done over a 12-year period by using a state-of-the art modelling system of the chemical and physical processing, transport, and removal of BC. The system simulates important aspects of BC in the atmosphere, including: enhanced absorption from internal mixing and urban-scale chemical and physical processing. Additionally, it has been found that these new emissions provide a much better explanation for known spikes in aerosol concentrations even at sites a few thousand kilometers downwind. However, the final results are still lacking when it comes to being able to predict higher order changes in time, especially at the scale of a few days to a week. New work currently in progress aims to address this issue by incorporating additional remotely sensed measurements from difference sources, including both gasses and additional aerosol properties. The finer spatial and temporal resolution results are largely similar on the large-scale, but seem to capture the high variability fires better. It will be shown that this new combination of measurements is able to reproduce the large-scale field as well as the previous works, while also doing a better job yet when compared with local and regional scale daily measurements. These results lead to an improvement in our understanding of fires and emissions in cloud-covered tropical regions, as well as the impacts that these fires have on both the large-scale climate system and regional-scale extreme events. Further, comparisons are made between the end results and various measurements of precipitation and dynamics at these new spatial and temporal frequencies. The main hypothesis here is to examine the generally concept that El-Nino and the Monsoon exclusively control these regions of fires in Southeast Asia. And the results show that while they are both important, that there are other aspects that also dominate the initiation of and emissions from these fires, especially those that are more intense and variable in space and time. This will hopefully provide further information for others interested in better understanding these complex relationships.

Keywords: remote sensing, black carbon, multiple data sets, data assimilation, climate variability

RSA.04 - MONITORING FIRE EFFECTS ON THE MEDITERRANEAN VEGETATION WITH COSMO-SKYMED REMOTE SENSING DATA

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Monitoring fire effects in the Mediterranean region is critical, due to increasing fire events resulting from human disturbance and climate change. Assessments should inform on burnt area extent, fire severity, and vegetation regrowth, for identification of post-fire management options. The Italian Forest Services usually carries out field assessment campaigns. To detect burnt area extent, optical and SAR sensors have been used in a number of research efforts, with a spatial resolution which is not optimal in the fragmented Mediterranean landscape (Gitas et al. 2012; Minchella et al. 2009; Tanase et al. 2011). We present 18 months of results of an on-going investigation in Capo Figari protected area in Sardinia, Italy, affected by a large fire (June 25th, 2013). We test a set of different optical (Landsat) and SAR (CosmoSkyMed and Radarsat2) derived indices for estimation of fire impacts and vegetation regrowth. Field data allowed to calibrate and validate remote sensing data and to analyze ecological dynamics. Capo Figari is composed of a combination of evergreen woody shrubs 0.5-5m tall, with sclerophyllous leaves, low to dense cover interspersed by bare soil and rocks. Elevation ranges from 0 to 340m and slopes between 0° and 35°. First results came from Landsat and CosmoSkyMed (CSK) used for burnt area extent assessment. Stripmap data from CSK MapItaly campaign (descending pass, HH polarization, 5m spatial resolution, 25° incidence angle) were as good as Landsat data in the identification of the burnt area. A Ping Pong HH-HV multitemporal series (both ascending and descending, incidence angles between 43° and 49°) was useful to study the relationship between SAR signal and vegetation regrowth. Prior to analysis, the study area was stratified into six classes according to vegetation types, slope and aspect, using high resolution satellite and airborne data (Ikonos and orthophotos), land cover (Corine LC2006) information, and a Digital Terrain Model. We obtained two sparse vegetation classes, one maquis class, and three garrigue classes. The Burnt Maquis (BM) class, together with an Unburnt Maquis (UM) control area, was selected to test Ping Pong response with respect to vegetation regrowth. The HV/HH ratio was significantly related to field vegetation growth values. Being a preliminary research we related SAR data with field growth value from three different dates, and are collecting additional field data for further validation. The HH/HV ratio was also influenced by soil moisture and incidence angle. Values were positive and almost constant for both classes, with the BM area showing an increase of +0.8%/day, and UM area of +0.2%/day. The slope of the HV/HH time-series was selected as regrowth monitoring parameter, and a map of the area in regrowth was derived from the timeseries: inside the burnt perimeter vegetation regrowth was 3 times larger than in the unburnt area. Our results show that dense SAR timeseries can improve the relationship SAR-field data. Overall, CosmoSkyMed can be considered a suitable tool for both burnt area mapping and post-fire vegetation monitoring. Vegetation regrowth dynamics for different vegetation types are also presented.

Keywords: forest, fire, remote sensing, cosmoskymed, regrowth dynamics

RSA.05 - MAPPING FOREST FIRE SUSCEPTIBILITY IN TEMPERATE MOUNTAIN AREAS. A RESEARCH PROJECT FOCUSED ON ROMANIAN CARPATHIANS. CASE STUDIES AND LESSONS LEARNED

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Forest fires in Romanian Carpathians became a frequent phenomenon during the last decade, although local climate and other environmental features did not create typical conditions. From 2004, forest fires affect in Romania more than 1000 hectares/year of different forest types (mainly coniferous). Forest fires feature the summer dry periods but there are dry autumns and early winter periods with events of different magnitudes. Their magnitude and frequency are not well known, since a historical forest fire inventory does not exist (only press papers and local witness for some selected events). Only recent reports from the ISU local bodies (Emergency Situation Inspectorate) and field mapping and monitoring provide data about forest fires in the context of fire management missions. SIAFIM – Satellite Images Analysis for Forest Fire Management project (started 2012) proposes a methodology for Romanian forested regions starting from existing data. The GIS analysis integrates all the environmental data coverage for Romanian territory, focusing on the identification of the differences between forest stands (fuel modeling). This integrates data derived from processed remote sensing imagery produced by European sensors (SPOT 5,6 and Pleiades). The case studies focused on complementary areas for wildfire susceptibility conditions (Mehedinti Mountains, Iezer Mountains and Ceahlau Mountains). The geomatic product will be adapted to practical needs from different users, from emergency response services to forestry authorities, transport infrastructure managers (ex. power lines network managers), natural and national parks authorities. After validation, the data layers will be integrated in a webGIS interface, to be developed from pilot areas to the whole national territory. The application is connected with dynamic data layers in real time configuration (wind, temperature, precipitation, wildfire points and area occurrence). This will be a decision-making tool for environmental and infrastructure management. The project confirmed that wildfire occurrence in temperate forests became a frequent during the last decade. A special attention must be paid to wildfire in coniferous forests with a higher economic and environmental value, situated in low accessibility areas (this introduce real fire management difficulties). Although different approaches were done in Mediterranean areas, our project identified an increasing role of the soil cover features.

Keywords: Romanian Carpathians, SIAFIM project, wildfire susceptibility, geomatic product

Remote Sensing Applications

Poster Contributions

RSA.P.01 - THE FIRE DANGER RATING INDEX FMA AS CONTROL OF REMOTE SENSORING SYSTEM

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The efficiency on forest fire control is directly related to the rapidness on the event detection and localization, what significantly minimizes the potential damages. Recent remote monitoring surveys of smoke produced by burning and forest fires using weather radar equipment showed excellent preliminary results, but their progress is hindered due to the high operating cost of radar systems. The fire danger rating index is a good indicator of the event occurrence probability, what contributes to the monitoring areas and adds value to the alert degree information. The application of FMA fire danger index "Formula de Monte Alegre" for areas in radar coverage radius of the S-band weather radar operated by the Meteorological Research Institute, IPMet, São Paulo State University, UNESP, located in Bauru, central region of the state of São Paulo, Brazil, efficiently optimize the use of the radar equipment, significantly reducing operational costs and enabling new research and promising results have already reducing the average response time between ignition and detection for less than 5 minutes, which reduces by more than 50% response time considered optimal for conventional detection systems. Highly sensitive tasks that possible to detect targets with low reflectivity, such as smoke produced by burning and forest fires are set up on the radar, and interest areas are monitored only when the values of the fire danger rating index "FMA" are High and Very High. The weather radar systems are designed to detect events related to rain, and when your coverage area is in the dry season, with little rainfall, its operation is reduced to a minimum, performing a single task, order duration of one minute every hour. This normal operating mode reduces cost, preserving the equipment, but the leaves idle. The equipment of continuous operation significantly increases operational costs and exposes the possible physical stress. Thus, the "FMA" values act as a trigger (on-off) in the remote monitoring system of forest fires, optimizing its use at low cost, avoiding the possible stress of equipment and enabling the advance of research monitoring and detection of burnings and forest fires using weather radar.

Keywords: fire danger index, remote sensing, fire detection, weather radar

Socio-Economics and Cultural Issues

Oral Presentations

SEC.01 - DRIVERS OF FIRE RISK PERCEPTION AND PREPAREDNESS

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Households' fire prevention and mitigation actions may have major impacts on the actual consequences of wildfires on life and properties. Yet research shows that communities and individuals are often ill-prepared to confront fire events even in fire prone areas. This paper illustrates a study undertaken in Sardinia to understand what factors affect individual behaviour before fire occurrence. Specifically, we investigate the link between risk perception, attitudes regarding responsibility, individual and community socio-economic characteristics, and fire preparedness (i.e. actions undertaken by household prior to the occurrence of fire). Data were collected through a questionnaire that was circulated to a sample of Sardinian communities between 2014 and 2015. A preliminary analysis of the data indicates that respondents perceive fire risk as affecting mostly rural and natural landscapes rather than the urban environment. Hence they rely mostly on public agencies for firefighting and prevention. Some private actions are carried out but others such as insurance and joining a local voluntary firefighting group are regarded as of little effect on fire prevention and mitigation. Fire risk perception seems weakly correlated with preparedness. Building on these preliminary results, the paper will investigate the issue of what drives preparedness in order to improve the design of wildfire mitigation plans.

Keywords: risk perception, preparedness, fire prevention, policy making

SEC.02 - MODELING FIRE OCCURRENCE IN A LARGE RURAL AREA IN CENTRAL SPAIN BASED ON SPATIALLY AND TEMPORALLY DYNAMIC BIOPHYSICAL AND SOCIOECONOMIC FACTORS

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During last decades, fire activity has been changing in several countries bordering the Mediterranean Basin. Changes in climate and in the socioeconomic factors that affect landscapes and ignitions may have played a role. However, understanding the role of the various drivers of change on fire activity is challenging due to the varying rates of change in time and space of the factors involved. Here, we assessed, in a spatially and temporally explicit way, the role of climate, landscape features and socio-economic factors on daily fire frequency in a large (56,000 Km^2) rural area located in West-Central Spain from 1974 to 2008. The dataset covered 443 10x10 Km cells over a 35-yr period (n=15,505), in which a total of 28,467 fires occurred. Multilevel Zero-Inflated Negative Binomial (ZINB) models were used to dynamically model the excess of zeros (absences) and the number of fires (counts), handling the lack of independence of the repeated measures taken in each unit area over time. Multilevel ZINB models showed that fire occurrence was spatially more extensive (there were less absences) and more intense (there was higher number of fires per unit area) over time. During the study period, the number of fires increased by nearly 20%. In relation to climate, high total spring rainfall and high maximum temperature during the summer period increased fire occurrence (less absences). During this period, the role of spring rainfall was increasing, while that of maximum summer temperature remained nearly stable. In regard to landscape features, high occupation of stable hazardous land-cover types and high proportion of wildland interfaces increased, on average, fire occurrence. The role of the stability of hazardous land-cover-types on fire frequency (counts) decreased over time, whereas its role on explaining fire absences increased. Accordingly, as time went by, increases in hazardous land-cover types reduced significantly more the fire absences than at the beginning of the study period. In addition, high fire occurrence was found in areas with high road density and high topographic complexity. With regard to socio-economic factors, areas with high proportion of people employed in the agrarian sector, and over 55 year-old, with small farms and with high illiterate ratio, increased, on averaged, fire occurrence (less absences). This was also so in areas with high proportion of employees in construction and with high unemployment rate. The role of farm size and illiterate ratio decreased over time; by contrary, the role of the composition of labor forces increased until the year 2000, but remained stable thereafter; and, the effect of aged people continued increasing during the study period. This implies that accessible and unmanaged areas, with hazardous land-cover types, and inhabited by people employed in the agrarian sector, or decoupled from traditional agrarian practices, are more vulnerable to increasing fire risk.

Keywords: fire risk, non-stationary, global change, multilevel

SEC.03 - ANALYSING FIRES AND THEIR SOCIOECONOMIC FACTORS IN SARDINIA

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Forest fires are one of the main environmental problems in the Mediterranean basin causing enormous economic and ecological damages. They destroy biodiversity, increase desertification, and affect air quality, greenhouse gases balance and water resources. Furthermore, wildfires can have negative effects on human life and health, human property and wellbeing, cultural and natural heritage, employment, recreation, infrastructures, economic and social activities. In recent years, the increasing extension of urban areas, interfering with rural and/or forest land is making this impact even greater. Our objective is to analyse and model the phenomenon of burned areas in Sardinia and, in particular, to study the role played by socioeconomic factors. We analyse the occurrence of wildfires in Sardinia between 1995 and 2009. The database includes information on ignition dates, area of ignition (coordinates, slope, temperature, wind, etc.), socioeconomic variables and spatial covariates. Within the study period, we analyse all events occurred from June to September as fires ignited after September and until June are relatively few in number and very small in size. In this work we consider the burned area as our variable of interest. Burnt area is a very important topic to be analysed. Previous works have presented the analysis of wildfires using the burned area rather than the main characteristic under study. There are many reasons, however, for looking not only at the position of the fire but also at the number of hectares burned. For our proposal we describe and take advantage of the Bayesian methodology including Integrated Nested Laplace Approximation (INLA) and Stochastic Partial Differential Equation (SPDE). The results of our analysis show that the size of the burned area increases at weekends. In addition, areas away from roads and urban areas are more likely to be burned by large fires. Furthermore, temperature and population density seem to be positively correlated with burned areas size. In addition, an important spatial dependence as well as heterogeneity has been detected. The methodology used allows us to identify those areas most likely to suffer from damage caused by wildfires. In addition we find evidence of space dependence and socioeconomic factors as covariates driving the size of the burned areas. In conclusion, this model is able to improve the fire risk predictions and may contribute to the prevention and management of wildfires.

Keywords: burned area, socioeconomic variables, spatial models, SPDE, INLA

SEC.04 - EDUCATIONAL PROGRAM FOR FIRE RISK PREVENTION

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The low social awareness regarding the exposure to fire risk combined with the reduced individual capacity to prevent and face emergencies increase both social vulnerability and the cost of civil protection actions. A communication toolkit for the capacity building of citizens and communities towards wildfire risk prevention, adapted to Scholars, youths and their teachers, which aims at enhancing the resilience of citizens to wildfires in interface areas from the Mediterranean region, through effectively promoting and increasing awareness and participation on the culture of risk with updated knowledge and best practices. Development of innovative teaching programmes as well as didactic materials for children, young people and their teachers, is the main result. They will effectively contribute to unlock the huge potential of children and teens, who are really open to learning and are the most affected by changing environments, and will make a real contribution to the improvement of fire prevention, both in peri-urban areas where fires are a recent phenomenon, and in contexts where fire is still used as an environmental management tool. These two situations will be treated differently. Children are highly vulnerable to disasters, partially due to their particular stage of physiological and social development. Powerful forces of nature such as wildfires can have serious immediate and long-term impacts on human health, properties and livelihoods, which can have devastating consequences for children and their futures. In fact, children, and especially the youngest, are less prepared to deal with deprivation and stress due to their particular physical, social and psychological characteristics. However, children and young people can strongly contribute to the adaptation, enhanced resistance and resilience of Mediterranean landscapes and of the human societies inhabiting them. This project will prepare youth to better adapt to their quickly changing environment, relying on their strong capacity to contribute to changing attitudes, which has been largely overlooked. It will provide children with a better understanding of the risks they face from forest fires and the measures that can be taken at the community level to minimize those risks. Participatory policy and programming where children are actively engaged in decision-making, planning and accountability processes for prevention will be to be actively promoted.

Keywords: prevention, resilience, teaching programmes, interface

SEC.05 - COMMUNITY WILDFIRE PROTECTION PLAN: A CASE STUDY FROM EASTERN SARDINIA (ITALY)

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Every year, Mediterranean countries are threaten by wildfires, which affect values, forests and communities, put people and firefighters at risk, and cause huge economic losses and sometimes the loss of human lives. Worldwide, significant budgets are allocated to fire suppression efforts. Recently a number of studies reported that such high costs of suppression could be no longer sustainable. Moreover, large wildfires are becoming more frequent in Mediterranean–type ecosystems due to a set of complex and interacting driving factors (e.g., land abandonment, lack of fuel management and consequent fuel accumulation, climate and land cover changes, increase in the amount of wildland-urban interface, and ageing rural population. For these reasons, it is crucial to improve our fire prevention and planning in collaboration with local communities and institutions, as well as to identify hot-spot areas by coupling empirical and fire modeling approaches, with the goal of mitigating fire risk. In past years, Sardinia Forest Service (CFVA) was actively involved in increasing local awareness of the wildfire issue and in promoting community and homeowner involvement in planning and implementing pre-fire activities to mitigate wildfire risk. In this presentation, we will discuss the community wildfire protection plan promoted by CFVA and the municipality of Tortolì for a study area of about 1,000 ha located on the central eastern coast of Sardinia. Historically, the study area is a fire-prone area mainly covered by Mediterranean maquis and artificial plantations of Eucalyptus spp., and is characterized by significant tourist and anthropic pressure. The plan identifies a number of actions and activities, ranging from fire prevention education for residents and tourists, guidelines for fuel management adjacent to houses and buildings, identification of safe areas and defensible space, increasing awareness of fire risk among younger generations, and coupling empirical perceptions and knowledge of fire risk with fire modeling methodologies.

Keywords: community wildfire protection plan, wildland urban interface, fire prepared communities, wildfire risk evaluation, wildfire threat reduction

Socio-Economics and Cultural Issues

Poster Contributions

SEC.P.01 - SOCIO-ECONOMIC IMPACTS ON FIRE REGIME IN A MEDITERRANEAN AREA: THE CASE OF SARDINIA (ITALY) DURING THE LAST FOUR DECADES

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Despite wildfire always occurred in the Mediterranean Basin, several authors recently suggested that this phenomenon changed in its main features from the 70s, mainly due to sharp modifications in the relationships between man and the environment. Although it is well known that weather and climate strongly influence and shape fire activity and regime (just think about the effects of dry spell periods, heat waves and strong winds), it has been widely argued that the reduction or the increase of human pressure due to the marked industrialization and the related rural exodus, the variations in fuel build-up as a result of land abandonment, as well as fire suppression enhancement are significant leading factors altering fire regime. Italy was not immune to such social changes and, as explained by Bovio et al. (2007), at the beginning of the 70s the wildfire issue acquired greater importance, while previously it had gained only limited attention. From that time onward, the Italian fire regime experienced additional changes, at both national and regional scale. Nevertheless, the study of historical fire regime in Italy is still a challenge. Few studies were conducted, mainly at local level and for short periods, focusing on descriptive or modeling approaches, but fewer focused on the relationships between socio-economic factors and fire, and certainly not for long periods. This work is intended to be a first step in this direction, contributing to the understanding of the socio-economic impacts on fire regime through the investigation of a number of factors having, directly and indirectly, a decisive role on the fire regime evolution and dynamics in Sardinia (Italy), one of the most fire affected Italian regions. In the first part of the work, we collected and homogenized fire data and socio-economic variables concerning the demographic and productive scenario from 1971 to 2010. Then we analyse the trends and the changing points of fire occurrence and extension, comparing their dynamics with the evolution of socio-economic variables. Our analysis confirmed the general decrease in fire activity observed in other areas of Southern Europe, and several changing points were observed in relation with different socio-economic factors. Overall, rural abandonment, expressed by the reduction of farms and of used agricultural areas, and the increase of grazing pressure seemed to strongly influence burned area trends until the 90s. Since then, the enhancement and strengthening of fire-fighting entities appeared fundamental to contain the burned area levels. On the other hand, our analysis revealed that such measures have not been sufficient to reduce fire severity during extreme weather conditions, such as those observed during 1993, 2007, and 2009.

Keywords: fire regime, socio-economic variables, changing points

SEC.P.02 - HOW WILDLAND FIREFIGHTERS VIEW PUBLIC PERCEPTION OF THEIR WORK AND RISKS. A VISION IN SPAIN

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Environmental and forest fire prevention policies have a social participation chapter concerning to involve citizens, owners and residents especially in those areas with forest realities and people living there. At the same time these policies include accompanying measures focusing on urban people as present and future users in forested areas. Most of fire prevention and firefighting plans give importance on material resources and human resources at different levels. It is clear that human resources, firefighters at all professional levels, are a very important part in prevention and firefighting tasks. However, in many cases there is a risk to this human capital to not to be taken into account in a proper way from non firefighters viewers. Dozers in prevention tasks and helicopters and aircrafts in firefighting tasks seem to be the only effective means for an important part of the public. It has been shown as a spectacle, especially in fire season, and media have contributed to extend this vision. In spite of this, many groups of wildland firefighters in different parts of Spain have joined efforts to show to the public the reality of their work helped by networking and video-sharing tools. All these firefighters highlight the need to have public recognition as a way to improve an important public service but they feel that public is not well informed about prevention and firefighting tasks. It could be useful to improve and increase the wildland fire and prevention management capacity. This work explores how urban, owners and residents view firefighters and their work from the firefighters' vision based in present and past working experiences. It is expected to extend the study to other Fire Services out of Spain in order to compare own realities and share a situation that seems not to be so different.

Keywords: human resources, public information & recognition, reducing fire risk, socio-economic policies, professional wildland firefighting

Fires at WUI

Oral Presentations

WUI.01 - MODEL AND TOOL FOR ANTHROPOGENIC STAKES VULNERABILITIES ASSESSMENT AT WUI

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Forest fire hazard, defined as the likelihood of occurrence of a disaster, is nowadays better and better known. Many spatial models exist, and are currently used to produce hazard maps validated at different spatial and temporal scales (Haight et al. 2004). On the other hand, the other main component of forest fire risk, that is vulnerability, is usually simply empirically estimated. The estimation is usually based on the quantity of human stakes (persons and goods, in particular dwelling houses), which are considered over-decisive. However, the assessment of houses actual vulnerability is a key element for land management decision support and risk mitigation, especially in Wildland Urban Interface (WUI). We developed a shared (web) tool dedicated to vulnerability local assessment, based on a validated vulnerability model. The specification of this last was based on the cross of two main approaches: i) an expert-opinion based approach, and ii) a physical exposure analysis. The first one uses a multi-criteria analysis, in order to produce a formal model for vulnerability assessment from a collection of expert opinions. Criteria concern local equipments, topography, vegetation, building density, buildings materials and human factors (Pugnet & Maillé, 2013). The second one uses a physical exposure model in order to correlate damages observed on real cases and the physical exposure to fires, and finally to assess the reliability of the vulnerability experts opinion based model. The model was then applied to real case study interfaces where a fire occurred. For validation, the fire was simulated "in silico", with the Australian PHOENIX wildfire simulator (Tolhurst et al., 2008). This simulation gave us the main instantaneous and cumulated parameters of the fire that had threatened dwelling houses. Then, a physical exposure model (Blanchi & al., 2011) was used to assess the total quantity of energy theoretically received by the building. This allowed interpreting the good correlation between the observed damages, the exposure level to heat and the vulnerability index produced by the multi-criteria model. The developed web-shared tool is addressed to residents in Wildland-Urban Interface. It is aimed at producing a self-diagnosis of the vulnerability of dwelling houses, and some recommendations to improve the situation. A typical use case is the following: the end user locates his house on an interactive map; a GIS database is requested in order to inform some of the general criteria of vulnerability available (slope, aspect, dominant wind, interface type, etc.). The user completes the entry of the remaining criteria not available in the database, and launches the vulnerability index calculation. As the result, he gets a global vulnerability index, but also a list of criteria ordered according to their vulnerability score. A set of recommendations and possible actions is then provided to limit the vulnerability of the house.

Keywords: anthropogenic vulnerability, multicriteria analysis, exposure model, web-shared tool, damages

WUI.02 - MANAGEMENT OF MULTI HAZARD EVENTS INVOLVING WILDLAND URBAN INTERFACE FIRES

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This study is a part of a pilot that involves the integrated crisis management system (ICMS) being developed in the European Project CRISMA (www.crismaproject.eu/). An example of the integrated use of several tools aiming to support decisions at short and long term planning to manage a crisis event involving a wildfire triggered by an earthquake is hereby presented. A scenario where an earthquake causes an electrical disruption triggering a wildfire is the base of this study. Abstractly the fire front spreads in the direction of a village threatening people both by the flames and smoke. The decision to evacuate the village or to shelter the people in a refugee area is the object of decision. Both options have pros and cons and the impacts in terms of costs and losses must be evaluated. This multi hazard event has some characteristics that require different procedures that are different from those of each of the hazard events occurring separately. If the home sheltering of people can be a good solution in an isolated wildfire event, after the occurrence of an earthquake with the possibility of replicas (swarms) it is out of question in this multi-hazard scenario. On the other side the allocation of resources changes as other interventions may take precedence over firefighting. Two possibilities of decision situations are analysed: 1) people are being threatened by the wildfire triggered by the earthquake and response decisions must be taken, and 2) the earthquake has occurred and the probability of having an electric disruption causing a wild fire as a cascade effect mechanism is analysed for preventive and preparedness reasons. In both situations the decision to evacuate or to shelter and protect the people from the fire is affected by several considerations reflected in the following questions.

- What is the probability of occurrence of a wild fire triggered by an earthquake?
- What is the most probable place to occur a triggered fire ignition?
- What would be the fire front spread and smoke release and dispersion after the fire ignition?
- How many people should be evacuated or sheltered at the date of the event?
- Where could people be sheltered and what would be the impacts of this decision?
- What would be the impact of evacuating the village?
- Which are the serviceable roads after the earthquake?
- What would be the fastest available evacuation route to be used?
- May the evacuation column be reached by the flames or by the smoke plume?
- What is the best option to be taken using a set parameters of decision?

The existence of tools that support the decision maker answering the previous questions would be of great relevance to take the best option. In this example, the ICMS articulates earthquake models, fire behavior models, cascade effect model, evacuation model, social model and decision support model to provide information in order to support the decision maker to face such a hazard crisis situation.

Keywords: multi risk assessment, multi hazards, cascading effects, crisis management, wildland urban interface fires

WUI.03 - RURAL-URBAN INTERFACES AND THE IMPROVEMENT OF FOREST FIRE PREVENTION

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This paper presents experiences, which contribute to improve the Rural Urban Interface (RUI) knowledge for the wildland fire prevention and planning. These works are based on two study cases in Sardinia, in different contexts located near Cagliari, chosen for the availability of numerous data. Both areas are threatened by wildfires and show different RUI aspects that are to be taken into account for planning and fire prevention. Data collection was performed using public database of Sardinia and report from civil protection and park management. The Ruimap method and software developed by Irstea was used for interface mapping.

Mimose village, Sinnai community
The first study zone is located NE of Cagliari, between the villages of Sinnai and Maracalagonis. This area was converted from agricultural to a residential area three decades ago creating a new interface zone sensible to wildfires. The mapping of urban-forest interfaces is one of the key elements to assess fire-risk. In fact, it is a method to identify critical points in a territory such as dwellings and in case of fire, to protect the presence of people and their assets. The study case takes into account the August 2013 fire for comparing with others RUI data. The main interesting points of the RUI cartography give a better knowledge of the interface areas, a better understanding of the dynamics and enable us to identify the most immediate areas at risk. In the phase of fire prevention it is possible to give priority to the areas which need to be cleared and assess the fire fighting strategy.

Molentargius Regional Park
The Molentargius regional park is an area of 1600 ha in the vicinity of Cagliari. The park stretches on wetland, lagoon (Ramsar convention), abandoned salt flats frequented by numerous bird species and different terrestrial ecosystems with a patchwork of various vegetation interconnected with a man-made system of dwellings. Wildfires often start and threaten high value belongings inside or in the vicinity of the park. An analysis including information on ecosystems and land use was performed and used on the territory of the Molentargius regional park and completed with an interface analysis by using RUI mapping method. The results obtained show weaknesses that can be used to improve the management of the territory of the park.

The main conclusion of these study cases highlight the necessity of integrating a multidisciplinary approach of the RUI, based on mapping and on analysis of the area. Some priorities could set up a plan with organized actions, useful to connect management and prevention in the area. The results show that RUIs are a complex system with multiple shapes and functions. Each situation is unique and different experiences with different points of view improve the RUI knowledge and confirm the key

role of land management to lessen fire risk in RUI.

Keywords: rural-urban interfaces, fire prevention, planning policies, spatial analysis, mapping

WUI.04 - LAND USE CHANGES AND TEMPORAL PATTERNS OF WILDFIRE PROBABILITY AND INTENSITY IN NORTHERN SARDINIA, ITALY

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Wildfire spread and behaviour are affected by complex and non-linear relationships among many factors including weather, fuels, topography, and ignition patterns. During the last decades, Mediterranean areas have been affected by relevant modifications in the economic and social systems that have often produced transformations of the original landscape due to anthropization processes and land use changes. Socio-economic changes have led to an increase of the anthropic pressure in urban and coastal areas and to a progressive abandonment of farming and agro-forestry activities. This has favored substantial increases in fuel loading and continuity, especially where agricultural areas and pastures have been converted to shrublands and woodlands. Throughout most of Mediterranean coastal areas, potential fire risk for villages, tourist resorts, other human activities and people is really high, particularly in summer when human presence increases, extreme weather conditions can occur, and vegetation is highly flammable. Therefore, developing planning policies is essential for implementing strategies to prevent and reduce wildfire risk in these areas. Recently, several authors showed that the analysis of trends in both anthropization processes and land use changes and the evaluation on their impacts on fire occurrence and behavior are crucial for reducing and preventing fire risk and making decisions on future land use planning. Tracking past and recent land use change trends allows to minimize their impact and to provide information for long-term land use planning and natural resource management. The prediction of burn probability and intensity by the use of wildfire simulators is a valuable method to capture the large variability of fire spread and behavior produced by weather and fuel conditions, especially when extreme weather conditions, and their effects on fuel characteristics, leads to large fires. In this study, we focus on analyzing and evaluating the temporal evolution, over the period 1954-2000, of land use and urban areas in two coastal regions located in North Sardinia, Italy, both characterized by large tourism development during the last fifty years. We used wildfire simulation to examine how different level of urbanization, land use and fuel type changes, can affect fire likelihood and intensity. In particular, simulations were conducted using the landscape characteristics existing in the year 1954, 1977 and 2000. The experimental data showed that the land use change observed throughout the study period (from 1954 to 2000) determined a reduction of burn probability in the last time step (2000), while limited differences were observed from 1954 to 1977.

Keywords: Mediterranean coastal areas, WUI expansion trends, fire prevention planning

WUI.05 - SPATIO-TEMPORAL DYNAMICS OF WILDLAND-URBAN INTERFACES IN BALAGNE (CORSICA) FOR WILDFIRE RISK PREVENTION

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In the Mediterranean region, wildland-urban interfaces (WUI) – corresponding to areas where urban settlements meet and interact with rural lands (forest, agriculture) – increase and are a matter of concern for the wildfire risk management. Most fire ignitions are human-caused in the interfaces (90%) and the vulnerability of these areas is high (damage on goods and people) when a wildfire occurs. The aim of this work was to identify WUI spatio-temporal dynamics in order to improve future land settlement development taking into account wildfire risk. The analysis of the WUI dynamics was performed on the Balagne region located in Northern Corsica. This region is composed of three administrative territories for a total surface area of 96 000 hectares and is characterized by a high urban pressure strongly emphasised by the tourist activity. Wildland-urban interfaces – defined by an environment of 100 metres around dwellings – were characterized by 12 types resulting from the combination of spatial criteria quantifying both (i) the horizontal structure of forest and agricultural vegetation (forest area in 3 classes: none, discontinuous and continuous) and (ii) the dwelling density (in 3 classes: low density, moderate density and high density). Dynamics were studied on a ten year- period for land cover characteristics (from 1999 to 2009) and on five year-period for WUI area and dwelling density (from 2002 to 2007). The analysis of WUI dynamics tried to outline the evolution of the forest area (in term of horizontal structure), dwelling density, interfaces types. The region of Balagne showed important disparity in terms of WUI distribution from 9% (Cavi-Balagne and E Cinque Pieve di Balagna) to 47% (Ile Rousse). The WUI increase on a five year-period was more than 7% (up to 9% in Ile Rousse and E Cinque Pieve di Balagne) on the entire region which was very high compared to the average of the region (5%). This type of analysis allowed the identification, characterization and mapping of changes in space and time identifying areas where wildfire risk and dynamics are the highest in order to plan where and what prevention actions such as land settlement planning, brush clearing and urban spread assessment or communication and awareness campaigns to decision-makers and population, have to be set up first.

Keywords: wildland fire, wildfire risk, wildland-urban-interface, spatio-temporal dynamics

WUI.06 - TEMPORAL CHANGES IN WILDLAND URBAN INTERFACE CHARACTERISTICS, SUMMER WEATHER AND FIRE OCCURRENCE IN SOUTH-EAST FRANCE, 1993-2013

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Due to its climatic, historic and landscape attributes, the Euro-Mediterranean region is one of the most attractive migration areas in the world. It has also been identified as a global climate change hotspot in the latest Intergovernmental Panel on Climate Change (IPCC) report. Forest fire risk is expected to increase in Mediterranean regions as Wildland Urban Interface (WUI) area increases and summer temperatures continue to warm. The main focus of public policies to mitigate fire risk in France is on increasing WUI housing density. This reduces overall fire risk (ignition and propagation) and facilitates the protection of people and property in the case of a wildfire. The objective of this study is to evaluate the temporal trends in WUI characteristics and summer weather (Fire Weather Index or FWI) on fire occurrence between 1993 and 2013. Number of fires and burned area for fires > 1 ha in the Alpes-Maritimes WUI during 1993-2013 were acquired from the Prométhée database. Two representative study zones with a total area of 428 km² were selected to estimate the evolution in WUI characteristics. Building layers for 1990, 1999, and 2009 were created by superimposing the IGN BD-TOPO data base on ortho-rectified air photos and deleting or digitizing buildings for each date. WUI areas were then classified into four categories using WUIMap (Lampin-Maillet et al., 2010): Isolated, Scattered, Dense and Very Dense housing. Vegetation characteristics (Sparse, Discontinuous, and Continuous) were derived from 2009 infrared ortho-rectified air photos. A fire risk index was calculated for each WUI category according to Fox et al. (2015). FWI was calculated using Carrega (1988) based on daily soil water content (estimated from daily temperature and rainfall), wind speed and relative humidity for two weather stations. In all, 82 fires ranging from 1 ha to 1,595 ha (mean 47.6 ha: median 4.8 ha) were identified in the 21 year fire record. The five largest fires occurred in 2003 (1595 ha, 418 ha, and 235 ha) and 1994 (536 ha and 148 ha). The building layer for 1990 is currently being digitized (to be terminated in February) so WUI results are restricted for the moment to 1999 and 2009. The number of buildings increased from 49,953 in 1999 to 55,966 in 2009 (+12 %) and built area increased from 925 ha to 1,025 ha (+10.8 %), but WUI fire risk remained constant as housing density increased: isolated, scattered, and dense housing decreased by 8.6 %, 2.5 %, and 9.9 %, respectively while very dense housing area increased by 14.0 %. FWI, fire occurrence and burned area were all greater in August than July, and number of fires and burned area were strongly associated with FWI showing strong increases beyond a threshold FWI value of 18/20. Contrary to most predictions, WUI risk decreased slightly over time while FWI and summer fires showed no consistent temporal trends.

Keywords: fire risk, wildland urban interface, Fire Weather Index, risk management

WUI.07 - WILDFIRE RISK IN WILDLAND-URBAN INTERFACES IN NORTH WEST SPAIN

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The contact zone between human infrastructure and wildland vegetation is known as the wildland-urban interface (WUI). These areas are of particular concern in forest fire risk management because the presence of population living in contact with forestlands increases the likelihood of a fire starting as a consequence of human activities, and it increases also the probability of severe consequences of fires on human lives, properties and land-use activities. For this reason, to better understand the cause and conditions associated with the risk of fire in these areas is of great importance to develop plans for protection of human life, infrastructures and economic activities. We analyzed a total of 26,839 fire events occurred in five years (2006-2011) in Galicia, NW Spain. Data on the location of the ignition points of these fires as well on their causes, motivations and total area burned were obtained from forest fire reports. We delimitated WUI areas as the intersection of the forest area and/or forest influence areas (up to 400 m from forestland) with the buffer of 50 m around buildings, where bush clearing is compulsory by law. The characteristics of the vegetation and topography of the ignition points of all fires studied (N = 26,839) was identified, using information from the Fourth National Forest Inventory (IFN4). In addition, we randomly selected 26,839 locations where the vegetation and topography were also characterized using the same source, in order to compare the patterns of fire distribution among vegetation types and topography with a random model, using randomization tests. Most fires were deliberate (75%), while negligences and accidents caused 5.9% and 1.5% respectively. Natural fires accounted for just 1.5% of fires and 4.3% corresponded to rekindled fires. The risk of fires related to accidents or negligent behaviour was higher in WUI areas, whereas the risk of deliberate fires was higher in non-WUI areas. The motivations behind deliberate fires were more frequently related with vandalism, conflicts and interests in non-WUI areas, whereas in WUI areas they were more frequently related to mentally ill people, people seeking excitement, extremists or related to crime concealment. The risk of deliberate fires was higher than expected in holidays compared to working days. Total burned area per wildfire differed significantly among land use classes, with shrublands having the largest fires, followed by forests and tree plantations and by farmlands, whereas fires in meadows were smaller. Among forested areas, fires in eucalypt plantations or areas dominated by eucalypts are the largest, followed by mixed formations dominated by eucalypts and pines, pine plantations, with broadleaved native forests or mixed forests dominated by these species having smaller fires (up to 5 times smaller). We did not find any apparent pattern of fire risk in relation with topography.

Keywords: wildland-urban interface, land-uses, causes, Spain

WUI.08 - A METHOD FOR EVALUATING THE EFFECTIVENESS OF FUEL REMOVALS IN WILDLAND-URBAN INTERFACES THREATENED BY WILDFIRES IN SOUTHERN ITALY

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One of the most important issues in Europe is the expansion of wildland-urban interfaces (WUIs) and how this trend may affect the occurrence of wildfires. Land use changes, the abandonment of farmland, and reduced grazing have led to an increase in forested areas with an accumulation and continuity of dense surface fuels available for combustion. Policies based exclusively on extensive fire suppression have become ineffective in different parts of Europe. To reduce the threat of damaging and costly wildfires, European countries must develop integrated fuel management programs. This approach has proven to be one of the most cost-effective for preventing wildfires and reducing economic loss. To this end, we have conducted a cost-benefit analysis explaining the trade-off between benefits arising from protected urban areas and the cost of fuel removals required to reduce wildfire severity in WUI landscapes in the province of Taranto (Apulia region) in southern Italy. The cost-benefit analysis was conducted in three stages: 1) simulation of fire behavior, in terms of fireline intensity, at different fuel reduction and wind direction scenarios across WUI landscapes; 2) estimation of urban areas affected by wildfire across different scenarios; and 3) a cost-benefit ratio to determine fuel removals with the lowest cost per hectare of protected urban area. Our results highlight the need to provide a cost-benefit analysis of fuel removals in WUIs in order to efficiently prevent wildfires in the increasing number of WUIs of the Mediterranean landscape. Optimizing cost-benefit analysis of fuel removals offers the basis for appropriately assessing wildfire prevention and budgeting financial resources across the globe. Further, this method may be easily applied toward allocating any type of intervention in landscape management.

Keywords: fuel management, fireline intensity, wildland-urban interface, fuel removal effectiveness

WUI.09 - RESIDENTS PERCEPTION OF FOREST FIRE RISK AT WUI. STUDY CASES IN NORTHWESTERN ANDALUSIA (SPAIN)

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The firewise concept is still a challenge in many fire prone communities along the municipality of Córdoba province in northwestern Andalusia (Spain). This municipality has a very high number of fires during summer and is it is in the higher positions in national fire statistics data. Recent regional forest and civil protection laws require protective plans to owners and residents in forest influence areas. In recent years, regional and local governments have made an effort to transfer to citizens the importance of a self protective culture in fire prone areas. However the progress of these actions has had until now rather slow but positive results or non results. We have followed the situation in several fire prone communities and small towns of Córdoba municipality during last years. The methodology used consisted of three main parts: 1) an historical and territorial analysis of the changes affecting to the growth of these communities into the municipality context based on the quantitative best available information, 2) a legislation analysis concerning to fire at national, regional and local levels and 3) an analysis of changing human perception of fire risk through a number of personal surveys to communities owners and residents.

Keywords: Firewise, risk perception, fire prone communities, Córdoba

WUI.10 - WILDFIRE EVACUATION TRIGGER BUFFERS FOR SENSITIVE AREAS IN SARDINIA - EVITA PROJECTS OUTCOMES

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EVITA is a European Project that during 2013 and 2014 involved National Technical University of Athens, as a coordinating beneficiary, General Secretariat for Civil Protection of Greece, Prodigy Consultores (Spain – Mallorca) and Sardinia Region, as associated beneficiaries. Project developed a new methodology related to areas with high tourism intensity and high fire risk aimed to improve risk prevention and evacuation procedures, in reference to potentially dangerous fire events for the population and territory. In Sardinia Evita software, which was developed by National Technical University of Athens, was tested in some case studies, as a support to answer a key question, in case of a wildfire is approaching a sensitive site: "Should I initiate an evacuation and how long do I have to evacuate safely?" The Evita software was tested on several wide wildland fires occurred in various municipalities. Project permitted to promote understanding and awareness of fire risk particularly among tourists and was a support for improvement of operations related to prevention, fire risk management and evacuation in case of wildfires. Main actions were carried out in the Municipality of Loiri Porto San Paolo case study. In order to promote understanding and awareness of fire risk particularly among tourists was identified a participatory process, which allowed to take into account the subjective dimension and to strengthen the relationship between knowledge of experts and local knowledge. Specific meetings with stakeholders have been arranged in Evita case study. The participatory process was aimed to develop and improve, particularly among tourists, information, awareness, sharing, and action capability. An internal focus group was arranged to define strategy, while focus group in Loiri Porto San Paolo which involved local stakeholders were arranged in May and June 2014. The first focus group aimed to evaluate knowledge and perception of fire risk, to discover important local elements of risk, to evaluate assessing awareness of behaviour rules both for Prevention and Emergency management. The second focus group aimed to develop a suitable communication model for risk prevention and emergency management for tourist accommodation and more generally for tourist sensitive areas, shared by institutions and stakeholders. The adopted recommendations within the focus group helped to create an infographic by means of which we started testing the communication model in Loiri Porto San Paolo. With specific regard to monitoring action, a sample of 49 tourists was interviewed in August in the Loiri Porto San Paolo municipality. Results showed the importance of Evita software as a tool for safety evacuation measures in case of approaching wildfires, the perception of risk of fire compared with other risks (floods, earthquake, etc.), the perceptions of causes of wild fires, suggested actions to prevent fires and specific behaviour to be adopted in case of fire for the people's safety. Achieved results were important also as a basis for an appropriate communication campaign concerning safety against wildfires, and to increase the sense of security in tourists.

Keywords: safety evacuation, focus group, participatory process, communication campaign

Fires at WUI

Poster Contributions

WUI.P.1 - FIRE EXPOSURE AND VULNERABILITY ANALYSIS IN A WILDLAND URBAN INTERFACE OF NORTHERN SARDINIA, ITALY

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The goal of this study is to analyze fire probability and vulnerability of urban settings in a study area of about 46,000 ha located in a coastal area of North-East Sardinia. The study was carried out in a fire-prone area characterized by predominant and dense shrubland vegetation, by extensive rural-urban interfaces and by a relevant touristic pressure in the summer season. The analysis was performed using both the characterization and mapping of housing units, and the modeling of fire behavior by a probabilistic approach. The first part of the work was based on the analysis of the aerial photographs and field surveys. With this approach, we evaluated the vulnerability to fire of about 13,000 housing units through the evaluation and characterization of five factors: type of vegetation, percentage of the housing units in contact with the vegetation within a buffer area of 10 meters, presence of flammable structures, distance of flammable structures from the houses, and percentage of the flammable structures in contact with the vegetation, within a buffer area of 10 meters. The results highlighted that about 58% of the housing units were located in urban settings, while the remaining 42% were classified as rural-urban interfaces. About the latter, only 25% of units showed a reasonable distance from the surrounding vegetation, and 30% of units presented more than half of their perimeters in contact with the vegetation; in addition, 7% of units were close to highly burnable structures. Afterwards, we used simulation modeling based on the MTT algorithm of FlamMap in order to estimate the spatial variation of the main fire probability and severity indicators. Then we selected 32 different scenarios able to represent the most common and critical conditions for fire occurrence and spread in the study area. In more details, we combined two wind directions (210° and 290°), two wind speeds (32 and 20 km h^{-1}), two fuel moisture conditions (arid and extreme), two ignition patterns (historically based and random), and two active fire spread durations (1 and 3 hours). For each scenario, we simulated 10,000 fires. Overall, the analysis of the fire simulations showed that fuel moisture and ignition patterns were the main factors affecting burn probability. Furthermore, the combination of extreme fuel moisture and strong wind speed represented the most critical scenario. The maps of conditional flame length were strongly affected by vegetation types and topography, particularly in some specific areas and nearby the coastline. Also the fire size maps highlighted hot-spot areas able to originate very large fires, particularly when wind direction and slope effects were compounded. We finally combined the results of the WUI mapping and characterization with the fire simulations, and we identified and quantified the level of exposure and risk of the housing units. As expected, the houses surrounded by shrublands and complex topography, particularly if isolated, showed very high fire exposure profiles, while the lowest exposure was observed in compact villages and towns.

Keywords: fire exposure, Mediterranean areas, wildland-urban interface, burn probability, vulnerability assessment

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