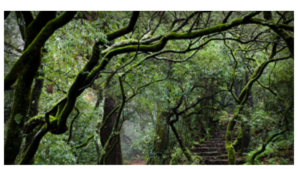
Book of Abstracts



Optimization and Wildfire Conference

Luso, Portugal
October 1 - 4, 2024

https://ow.dps.uminho.pt/

Optimization and Wildfire Conference

Book of Abstracts

Contents

Welcome

Dear participants,

In behalf of the Organizing and Scientific Committees, we are pleased to welcome you to the Optimization and Wildfire (O&W) Conference! Thank you for your presence and for sharing your knowledge.

As the impacts of wildfires grow - in the human life, environment, economies, and ecosystems - only multi-disciplinary approaches are suitable to address such complex and uncertain systems. With the organization of the O&W Conference, we intend to provide a forum to explore how Optimization, or more in general Operational Research and related disciplines, can contribute to those multi-disciplinary approaches. Although the first works on O&W can be traced back to the 1950s and much relevant work has been done since then, we strongly believe that much more can be achieved.

Being the first O&W Conference, we cannot help to share the satisfaction of having 46 accepted abstracts and 58 participants from 14 different countries. During the three keynote sessions, the 10 plenary sessions, the breaks, and social programme, there will be several opportunities to exchange knowledge, experiences, insights into the state-of-the-art and emerging topics.

We are grateful and honoured to have as keynote speakers: David Martell, one of the few most relevant contributors to the field for decades; Yu Wei, who has much expertise on linking models and practise; and José C. Borges, who has significant contributions in forestry.

We deeply appreciate the presence in the opening session of the O&W Conference of Tiago Oliveira, President of the Agency for the Integrated Management of Rural Fires (AGIF), and Pedro Arezes, Dean of the Engineering School of the University of Minho.

We acknowledge the support of IUFRO (International Union of Forest Research Organizations) and APDIO (Portuguese Association of Operational Research) in the dissemination of the

Conference. We also acknowledge the support of the Portuguese Foundation for Science and Technology through Project “O3F - An Optimization Framework to Reduce Forest Fire”, involving the University of Minho, the University of Aveiro and the School of Agriculture of the University of Lisbon. Lastly, we acknowledge the support of the Research Centers: Algoritmi, School of Engineering, University of Minho, CIDMA - Center for Research and Development in Mathematics and Applications, University of Aveiro, and CMAFcIO - Center of Mathematics, Fundamental Applications and Operations Research, University of Lisbon.

A final note to mention the location of the conference, which is held next to “Mata do Bussaco”, a managed forest since the 17th century.

The Portuguese Nobel Prize of Literature, José Saramago, in his book “Viagem a Portugal” (Journey to Portugal) wrote about Bussaco:

“The traveler strolls through, surrendering unconditionally, and is unable to express anything more than silent astonishment at the explosion of trunks, various leaves, stems, spongy mosses, which cling to the rocks or climb up the trunks and when he follows them with his eyes he finds the tangle of high branches so dense that it is difficult to know where this one ends and that one begins. The forest of Bussaco requires all the words, and having said them, it shows how everything has been left unsaid.”

We wish you a pleasant and scientifically fruitful Conference!

Filipe Alvelos, chair

Isabel Martins, co-chair

Ana Rocha, co-chair

Committees

Program Committee

Abílio Pereira Pacheco, University of Porto / ForestWise Lab, Portugal.

Ana Maria Rocha, University of Minho, Portugal.

André Mendes, University of São Paulo, Brazil.

Andrea Trucchia, CIMA Foundation, Italy.

Babak Abassi, RMIT University, Australia.

Begoña Vitoriano, Universidad Complutense de Madrid, Spain.

Fabricio Oliveira, Aalto University, Finland.

Filipe Alvelos (chair), University of Minho, Portugal.

Günther Raidl, TU Wien, Austria.

Isabel Martins (co-chair), University of Lisbon, Portugal.

Jaime Carrasco Barra, Universidad Tecnológica Metropolitana, Chile.

José Ramón González Olabarria, Forest Sciences Centre of Catalonia, Spain.

Mahdi Bashiri, Coventry University, UK.

Michael A. Forbes, University of Queensland, Australia.

Miguel Constantino, University of Lisbon, Portugal.

Mostafa Rezaei, ESCP Businness School, France.

Peng Wu, Fuzhou University, China.

Sándor F. Tóth, University of Washington, USA.

Susete Marques, University of Lisbon, Portugal.

Woodam Chung, Oregon State University, USA.

Organizing Committee

Ana Maria Rocha (co-chair), University of Minho, Portugal.

Ana Raquel Xambre, University of Aveiro, Portugal.

António Bento Gonçalves, University of Minho, Portugal.

Filipe Alvelos (chair), University of Minho, Portugal.

Helena Alvelos, University of Aveiro, Portugal.

Isabel Martins, University of Lisbon, Portugal.

Lino Costa, University of Minho, Portugal.

Marco Marto, University of Minho, Portugal.

Senhorinha Teixeira, University of Minho, Portugal.

Program Overview

	Tuesday October 1st	Wednesday October 2nd	Thursday October 3rd	Friday October 4th
09:00		Opening session	Keynote session Yu Wei	Keynote session José Borges
09:30		Keynote session David Martell		
10:00			Tm1	Fm1
10:30		Coffee break		
11:00		Wm1	Coffee break	Coffee break
11:30			Tm2	Fm2
12:00		Wm2		
13:00		Lunch	Lunch	Closing session
13:30				Lunch
14:30		Wa1	Ta1	
15:00				
16:00		Wa2	Coffee break	
16:30	Get together Mata do Bussaco - Portas de Coimbra	Coffee break	Ta2	
17:00		Guided tour Mata do Bussaco (start: Wellington's olive)		
17:30				
18:00				
19:00			Conference dinner Curia Palace Hotel	
19:30				

Keynote Lectures

Keynote I | Wildfire Management: An Operational Research Perspective

DAVID MARTELL

Department of Industrial Engineering, University of Toronto.

Climate change, changes in land use patterns and growing recognition of the impact of fire on terrestrial ecosystems have forced many wildfire management agencies to re-think how they plan for and respond to wildfires and how to do so in the future. I will describe some of the research my colleagues and I have carried out in Canada and identify what I consider to be important open problems to which I believe operational researchers can make important contributions, and I will suggest some ways in which I think they might do so.

DAVID MARTELL is a Professor Emeritus in the Institute of Forestry and Conservation at the University of Toronto. He completed his B.A.Sc., M.A.Sc. and Ph.D. in the Department of Industrial Engineering at the University of Toronto where he studied Management Science and Operational Research and their application to forest fire management. He was assigned to one of the Province of Ontario's fire incident management teams as research scientist for several years. He is a past president of the Canadian Operational Research Society, the 2009 recipient of its Award of Merit, and the 2020 recipient of the International Association of Wildland Fire Ember Award for Excellence in Wildland Fire Science. His current research interests include the management of aerial detection and initial attack systems and inter-provincial and international fire management resource sharing.

Chair | Abílio Pereira Pacheco

Keynote II | Enhancing Wildland Fire Decision Support through Spatially Explicit Modeling and Uncertainty Management

YU WEI

Department of Forest and Rangeland Stewardship, Colorado State University.

My presentation demonstrates two aspects of developing operations research models for wildland fire decision support: spatially explicit modeling and managing uncertainty. Fire management decisions, such as fuel treatment and suppression, often need to be made at precise locations, along specific line features, or within defined polygons. To facilitate this, we can overlay various spatial layers to break down a landscape into actionable decision elements like fuel break segments, firelines, fuel treatment areas, or aerial drop sites. Additional spatial layers, such as those showing valuable resources, assets at risk, and fire intensity, help define performance measures-costs or losses-that incentivize effective fire management. Addressing uncertainty is another major challenge in wildland fire management. To tackle this, we can use both samples and probabilities in wildland fire optimization models. Samples, whether simulated or empirical, can be aggregated into probability surfaces, supporting simpler model formulations while acknowledging some potential loss of detail from individual fire samples. My research has focused on building stochastic programming models that use both types of data for spatially explicit decision support. Looking ahead, I believe the future of operations research in wildland fire management will hinge on leveraging large datasets. Integrating operations research models with machine learning, and supported by extensive data resources, will be crucial for developing and implementing robust and effective wildland fire decision support systems.

YU WEI earned his bachelor's degree in Forest Economics and Management from Hebei Agriculture University, followed by a master's degree in the same field from Beijing Forestry University. Additionally, he holds an MS degree in Computer and Information Science and completed his Ph.D. in Natural Resource Management at the University of Minnesota. Joining Colorado State University as a professor in 2005, Yu Wei has been dedicated to applying techniques in operations research (OR) and management science to the fields of wildland fire and forest management, with a research focus on spatially explicit optimization, machine learning, and stochastic programming. Currently, Yu Wei teaches classes in quantitative analysis in forest management, GIS application, and wildfire economics and management. He served as the chair for the Symposium of Systems Analysis on Forest Research (SSAFR) and currently serves as an associate editor for the Canadian Journal of Forest Research.

Chair | Filipe Alvelos

Keynote III | Addressing Wildfire Risk and Uncertainty by Adaptive Territorial Management

JOSÉ C. BORGES

School of Agriculture, University of Lisbon.

Wildfires pose a challenge to forest management planning. Traditionally, addressing wildfire risk has focused on simplistic and eventually unsuccessful approaches targeting total fire exclusion. Moreover, the response to fire threats has been mostly focused on fire suppression. Nevertheless, even the most modern and qualified suppression systems are challenged by the high intensity and spread features of extreme wildfire events (EWE) and fail to circumscribe burnt areas and fire impacts under such conditions. This talk will outline research targeting the integration of forest and fire management as well as the provision of a wide range of ecosystem services in contexts of global change that require often the conversion of forest types. The impacts of these management options on that provision are not immediate. They rather take place over extended temporal horizons and may thus be affected by the occurrence of wildfires. In this context, addressing the wildfire challenge requires models and methods that may design effectively both the forest management planning decision and criteria spaces. This will be influential to estimate the impact of management options on the provision of ecosystem services and to analyze the tradeoffs among the latter. This talk will also outline the FIRE-RES (https://fire-res.eu/) approach to extend this research in order to address the specificity of EWE. The emphasis will be on adaptive territorial management innovations that may encompass novel practices, namely fire management models and adaptive management strategies, to mitigate the impacts of EWE on forest ecosystems, and the provision of ecosystem services. In this context, the talk will focus on innovative actions to design pre-fire (prevention and preparedness) and post fire (adaptation and restoration) landscape mosaics that are less prone to the occurrence of EWE and that can facilitate detection and suppression when a EWE occurs. These actions address the innovation of a) data acquisition and information systems - namely by taking advantage of Earth observation data from the Copernicus Program, b) fire simulators, vegetation dynamics models and management options, c) guidelines to design both the urban and the rural components of the wildland-urban interface, d) methods to design and plan for resilient forested landscapes. The potential of innovative models, methods and tools to address wildfire risk and support adaptive forest management planning is illustrated by an application to a forested landscape extending over 14 thousand ha and involving multiple decision makers and stakeholders.

Ph.D. in Forest Sciences (U. Minnesota), associate professor at the School of Agriculture (ISA), ULisboa. Coordinator of IUFRO Unit 4.04.04 Sustainable forest management scheduling and of the Erasmus Mundus Joint Master Degree MEDFOR. Has 25+ years of higher education, research and outreach experience in forest management planning methods and decision support systems. Responsible for forest and natural resources management courses in ISA with participation in several international courses. Acted as PI or as coordinator of the participation of ISA in national and international projects targeting the development of forest management planning methods, of tools to analyse trade-offs between ecosystem services and of business models to attract payments for these services. Co-authored over 100 international peer-reviewed publications.

Chair | Isabel Martins

Contributed Presentations

Overview

Wednesday morning

Wm1 | 11:00-12:00	Chair | Alan Ager
	Optimizing Thinning Scheduling, Carbon Stocks, and Wood Supply in Mediterranean Pine Plantations under the Risk of Fire. By Mauricio Acuna
	Optimized Design of Wildfire Risk Mitigation Actions. By Nicolò Perello
	Fire2a's Tools to Mitigate the Effects of Wildfires. By Filipe de La Barra
	A Review of New Spatial Optimization Platforms for Prioritizing Investments in Wildfire Risk Reduction and Restoration. By Alan Ager
Wm2 | 12:00-13:00	Chair | Alan Murray
	Optimized Hourly Fuel Moisture Model for Enhanced Wildfire Danger Assessment. By Nicolò Perello
	Improving Fuel Characterization through Percentile-Based Canopy Base Height Models for Maritime Pine in Portugal. By Jean Magalhães
	Strategic Fire Hazard Mitigation Planning: a Case Study in the Lousã Region, Portugal, By Ana Sá
	Optimizing Wildland Fuels Treatment to Mitigate Wildfire Risk and Vulnerability. By Alan Murray

Wednesday afternoon

Wa1 | 14:30-15:30	Chair | Pete Bettinger
	Optimizing the Allocation of Fuel Management Investments for the Portuguese National Fire Plan. By Alan Ager
	Maximizing Opportunities for Co-Implementing Fuel Break Networks and Restoration Projects in the Umatilla National Forest, USA. By Bruno Aparício
	Optimization-Based Impacts of Forest Management Practices on Recreational and Aesthetic Services in Forested Landscapes. By Brigite Botequim
	A New Look at an Old Forest Harvest Scheduling and Wildfire Model. By Pete Bettinger
Wa2 | 15:30-16:30	Chair | José González-Olabarria
	Optimizing Residual Agro-Forestry Biomass Land Harvest while Considering Triple Bottom Line (TBL) and Wildfire Risk Factors. By Ruxanda Silva
	Sustainable Management Model for the Residual Agroforestry Biomass Supply Chain. By Saeed Hassanpour
	Exploring Mathematical Formulations for the Post-Fire Forest Planning Problem. By Miguel Gomes
	Allocation of Optimal Fuel Management Actions that Rely on Multi-Actor Prioritization Strategies. By José González-Olabarria

Thursday morning

Tm1 | 10:00-11:00

Chair | Mahdi Bashiri

An Integer Programming Formulation for Sensor Placement in LoRaWAN Networks. By Jessica Singer

Optimized Distributed Temperature Sensor for Forest Fire Detection Using Existing Telecommunications Fiber Networks. By Joana Vieira

Optimizing Autonomous Unmanned Aerial System Deployment Locations for Enhanced Wildfire Detection and Monitoring. By Sascha Zell

A Robust Approach for the Prepositioning of Resources for Wildfire Suppression. By Agostinho Agra

Tm2 | 11:30-12:45

Chair | Savvas Gkantonas

Advancements in Wildfire Detection: Integrating Wind Field Simulation and Gas Dispersion Modeling. By Md Khalid Mustafa

A Genetic Algorithm for Multiple Fires Suppression. By Marina Matos

Resource-Constrained Emergency Scheduling for Major Forest Fires: A Learning Driven Adaptive Artificial Bee Colony Approach. By Zilong Zhao

Optimal Off-Policy Evaluation in Finite Stochastic Partial Monitoring. By Mostafa Rezaei

A Physics-Based Optimisation Framework for the Management of Wildfire Risk and Emergencies. By Savvas Gkantonas

Thursday afernoon 1st

Ta1 | 14:30-15:15

Chair | André Mendes

Iterated Local Search for Firefighting Helicopter Planning. By Marta Barreiro

Covering and Network Design for Wildfire Preparedness. By Elsa Silva

Robust Optimisation for Dispatching Fire Suppression Resources. By André Mendes

Ta2 | 15:15-16:00

Chair | Kristy Butler

Constructive Heuristics to Solve the TOPVTW Applied to Wildfire Suppression. By Bibiana Granda-Chico

Intelligent Decision Making in Resource Management for Wildfire Suppression. By Mahdi Bashiri

Heuristics for Wildfire Suppressibility in Victoria, Australia. By Kristy Butler

Thursday afernoon 2nd

Ta3 | 16:30-17:15

Chair | Miguel Constantino

Data-Driven Approach for the Optimization Problem in Fire Suppression. By Mauro Barros

Leveraging Automatic Vehicle Location Data to Quantify Fireground Operations in Victoria, Australia. By Kristy Butler

Forest Road Network for Firefighter Access. By Miguel Constantino

Ta4 | 17:15-18:00

Chair | Marta Pascoal

The Graph Burning Problem under Constrained Diffusion. By Enrico Iurlano

A Dash Interface for the pyO3F Framework. By Marco Marto

The Wildfire Safety Paths Problem. By Marta Pascoal

Friday morning

Fm1 | 10:00-11:00

Chair | Helena Alvelos

The Use of a Cell-Based Forest Fire Growth Model to Support Strategic Landscape Management Planning in a Portuguese Landscape. By Susete Marques

A Surrogate-Model-Based Algorithm for Multi-objective Optimization. By Aboozar Mohammadi

Alleviating the Impact of Wildfires in Forest Management Planning and Supply Chain Activities. By Shuva Gautam

Modelling Wind Behaviour for the Development of Scenarios in the Context of Wildfire Spread. By Helena Alvelos

Fm2 | 11:30-12:45

Chair | Abílio Pereira Pacheco

Predicting Demand for Wildfire Suppression Resources. By Ilbin Lee

Experimental and Numerical Study of Biomass Thermal Conversion in a Small-Scale Reactor. By Senhorinha Teixeira

Comparing Post-Fire Mortality in Spanish Forests: Mixed Stands and Different Fire Strategies Exhibit Higher Damage. By Marina Peris-Llopis

Rethinking Milling Capacity Investments in Support of Fuel Reduction Thinning Programs in the Western United States. By Greg Latta

FyMIS Simulator: A Versatile Tool for the Economic Evaluation of Alternative (Re)Forestation Strategies. By Abílio Pereira Pacheco

Wm1 - 1 | Optimizing Thinning Scheduling, Carbon Stocks, and Wood Supply in Mediterranean Pine Plantations Under the Risk of Fire

Mauricio Acuna[1], Rafael Navarro-Cerrillo[2], María Angeles Varo-Martínez[3]

[1]Natural Resources Institute of Finland (Luke), Joensuu, Finland, mauricio.acuna@luke.fi

[2] University of Cordoba, Cordoba, Spain, rmnavarro@uco.es

[3]University of Cordoba, Cordoba, Spain, g72vamam@uco.es

Carbon pricing can be essential in promoting adaptive silviculture in Mediterranean pine forests. Commercial thinning in these forests can improve carbon sequestration and stocks, contributing to climate change. However, thinning scheduling decisions must also consider the risk of fire that affects these pine forests every year. Fires can critically impact the supply of timber products from these plantations and result in increased carbon emissions, offsetting the benefits associated with carbon sequestration. Thus, this scenario with increased uncertainty requires more robust planning approaches along the supply chain that can react and secure the delivery of products demanded by end customers. This paper presents a solution approach that combines stochastic programming and Monte Carlo simulation to optimize the stand's thinning schedule and maximize Net Present Value (NPV) over a 10-year planning period. In addition to harvesting and transport costs, the model included revenue from two sources: sawlogs and biomass extracted during the thinning and credits from carbon stocks at the end of the planning period. The study area is in Andalusia, southern Spain, totalling a forest area of nearly 30,000 ha. Airborne Lidar data and allometric biomass models were used to estimate above-ground forest biomass, including commercial timber and carbon stocks. Airborne Lidar and Satellite imagery were also used to develop fuel and fire risk models, which in turn, were used as input in the thinning scheduling and supply chain model. The analysis focused on the impact of carbon prices on NPV, optimal thinning schedules, flows of sawlogs and biomass products to customers, and carbon stocks at the end of the planning period. Carbon prices and fire risk also impacted the flow of sawlogs and biomass delivered to end customers. These results reveal that thinning schedules, wood supply, and NPV are very sensitive to carbon prices and damage by fire.

Keywords: Thinning Scheduling· Stochastic Programming· Carbon Stocks· Wood Supply· Pine Plantations

Wm1 - 2 | Optimized Design of Wildfire Risk Mitigation Actions

Nicolò Perello[1], Andrea Trucchia[2], Francesco Baghino[3], Mirko d'Andrea[4], Silvia degli Esposti[5], Paolo Fiorucci[6]

[1]University of Genoa, Genoa, Italy; CIMA Foundation, Savona, Italy, nicolo.perello@edu.unige.it

[2]CIMA Foundation, Savona, Italy, andrea.trucchia@cimafoundation.org

[3] University of Genoa, Genoa, Italy; CIMA Foundation, Savona, Italy, francesco.baghino@cimafoundation.org

[4]CIMA Foundation, Savona, Italy, mirko.dandrea@cimafoundation.org

[5] CIMA Foundation, Savona, Italy, silvia.degliesposti@cimafoundation.org

[6]CIMA Foundation, Savona, Italy, paolo.fiorucci@cimafoundation.org

Climate change, coupled with socio-economic changes over recent decades, is altering wildfire regimes and increasing the occurrence of extreme wildfires. This presents new challenges in wildfire management, particularly emphasizing the need for more careful land management and the implementation of mitigation actions such as prescribed fires or fuel treatments to modify expected behavior of future wildfires. Given the cost of these operations, both economically and in terms of implementation difficulty, it is crucial to optimize these interventions to achieve the desired effects, that is reducing wildfire risk through the territory. In this work, a methodology for optimizing mitigation actions using the wildfire simulation model PROPAGATOR is proposed. This methodology helps identify where to carry out these operations to reduce costs and maximize the effect on wildfire behavior. The methodology explores the search space by the use of the simulation model, considering the different scenarios and dynamically addressing the search. The proposed methodology translates into a decision-support tool for stakeholders, which can explore scenarios and optimally plan mitigation actions. The tool also allows the integration of local knowledge held by the stakeholder, combining it with the simulation tool to provide better support. The tool has been tested in some hypothetical case studies considering prescribed fires and fuel treatments, to test its capabilities.

Keywords: Fuel Management· Wildfire Simulation· Optimization

Wm1 - 3 | Fire2a's Tools to Mitigate the Effects of Wildfires

Felipe de la Barra[1], Fernando Badilla[2], Jaime Carrasco[3], Lucas Murray[4], Matías Vilches[5], Horacio Gilabert[6], Carolina Espinoza[7], David Palacios[8], Rodrigo Mahaluf[9], Felipe Ulloa[10], José Ramón González-Olabarria[11], Jordi Garcia-Gonzalo[12], Andrés Weintraub[13]

[1]Complex Engineering System Institute - ISCI, University of Chile, Industrial Engineering Department, Santiago, Chile, felipedelabarra@fire2a.com

[2]Complex Engineering System Institute - ISCI, University of Chile, Industrial Engineering Department, Santiago, Chile, fernandobadilla@gmail.com

[3]Complex Engineering System Institute - ISCI, Universidad Tecnológica Metropolitana, Santiago, Chile, jaimecarrasco@fire2a.com

[4]Complex Engineering System Institute - ISCI, University of Chile, Industrial Engineering Department, Santiago, Chile, lucasmurrayh@gmail.com

[5]Complex Engineering System Institute - ISCI, University of Chile, Industrial Engineering Department, Santiago, Chile, matias.vilches.a@gmail.com

[6]Pontificia Universidad Católica de Chile, Department of Ecosystems and Environment. Santiago, Chile, hgilab@uc.cl

[7]Complex Engineering System Institute - ISCI, University of Chile, Industrial Engineering Department, Santiago, Chile, carolina.einfante@gmail.com

[8]Complex Engineering System Institute - ISCI, University of Chile, Industrial Engineering Department, Santiago, Chile, davidpalacios@fire2a.com

[9]Complex Engineering System Institute - ISCI, University of Chile, Industrial Engineering Department, Santiago, Chile, rodrigomahaluf@fire2a.com

[10]Departamento de Ingeniera Industrial, Universidad de Talca, Chile, felipe.ulloa@utalca.cl

[11]Centre De Ciència i Tecnologia Forestal de Catalunya (CTFC), Solsona, Spain, jr.gonzalez@ctfc.cat

[12]Centre De Ciència i Tecnologia Forestal de Catalunya (CTFC), Solsona, Spain, j.garcia@ctfc.cat

[13]Complex Engineering System Institute - ISCI, University of Chile, Industrial Engineering Department, Santiago, Chile, aweintra@dii.uchile.cl

Fire2a is a team dedicated to finding solutions to mitigate the effects of wildfires. Our solutions involve the development of novel methodologies through the integration of various mathematical and technological tools. These tools include machine learning for fire ignition modelling, spatially explicit fire spread simulators, fire risk metrics, species distribution models, stochastic and multiobjective optimization, and simulation-based optimization. The goal is to do appropriate forest fuel management and effectively create fire-resilient landscapes while minimizing different values at risk. Much of our work is integrated in the Fire Analytics Processing-Toolbox plugin. It allows users to develop their own workflows, leveraging the power of QGIS's data-science pipeline environment. This Open Source Software is in active development providing several algorithms: A Forest Fire Simulator, which supports three fuel model behavior systems, including crown, spotting, breaching behavior; weather and topography effects. It delivers outputs as fire scars isochrones, fire propagation directed graphs, hit rate of spread, flame length, fireline intensity and crown scar for each simulation or as a summary of multiple simulations. It also includes Risk metrics such as Burn Probability and Down Stream Protection Value that integrates any user defined values. Finally, a decision support tool that allows placing firebreaks using mathematical programming or machine reinforcement learning algorithms.

Keywords: Wildfire Risk Simulation· Cell2fire· Fuel Management· QGIS· Fire Prevention

Wm1 - 4 | A Review of New Spatial Optimization Platforms for Prioritizing Investments in Wildfire Risk Reduction and Restoration

Alan Ager[1], Hugh Safford[2], Bruno A. Aparicio[3], Michelle Day[4], Cody Evers[5]

[1]Oregon State University, Corvallis OR USA, alan.ager@oregonstate.edu

[2]University of California, Davis CA USA, dsafford@ucdavis.edu

[3]University of Lisbon, Lisbon Portugal, bruno.a.aparicio@gmail.com

[4]SDA Forest Service, Missoula, MT USA, michelle.day@usda.gov

[5]Cody Evers, Portland State University, Portland OR USA, cevers@pdx.edu

Spatial optimization models have been incorporated into a wide range of landscape planning platforms to prioritize investments in wildfire risk reduction, ecological restoration, and biodiversity conservation. Newer spatial planning platforms are increasingly integrating a wide range of science and technology to facilitate their application, including geospatial interfaces, links to big data, cloud hosting, and scenario analyses tools. In this talk we review several new planning platforms with particular attention to fully integrated systems developed in the US to streamline planning for large scale forest and fuel management projects aimed at reducing wildfire risk. The models examined represent an array of planning systems with a common thread among the platforms is the use of spatial optimization to find efficient solutions in terms of minimizing the cost per unit of progress towards stated targets. We demonstrate a case study where one of the US platforms (ForSys) was used to spatially optimize fuel treatments within the 278 municipalities in Portugal. We conclude that uptake of these newer platforms and underlying science by public and private entities is not keeping pace with the rate of technology development, thus the bottleneck in application and realizing potential benefits rests with institutional capacity to absorb and implement these technologies rather than the design, development, and deployment of them.

Keywords: Spatial Planning· Optimization· Wildfire Risk· Restoration Prioritization

Wm2 - 1 | Optimized Hourly Fuel Moisture Model for Enhanced Wildfire Danger Assessment

Nicolò Perello[1], Andrea Trucchia[2], Francesco Baghino[3], Mirko d'Andrea[4], Silvia degli Esposti[5], Paolo Fiorucci[6]

[1]University of Genoa, Genoa, Italy; CIMA Foundation, Savona, Italy, nicolo.perello@edu.unige.it

[2]CIMA Foundation, Savona, Italy, andrea.trucchia@cimafoundation.org

[3] University of Genoa, Genoa, Italy; CIMA Foundation, Savona, Italy, francesco.baghino@cimafoundation.org

[4]CIMA Foundation, Savona, Italy, mirko.dandrea@cimafoundation.org

[5] CIMA Foundation, Savona, Italy, silvia.degliesposti@cimafoundation.org

[6]CIMA Foundation, Savona, Italy, paolo.fiorucci@cimafoundation.org

Changes in wildfire regimes have been observed in several regions around the world, posing significant challenges to wildfire risk management systems. Consequently, there has been a renewed interest in developing reliable Forest Fire Danger Rating (FFDR) systems to support preparedness and response phases. In the early 2000s, the Italian Civil Protection conducted a research program that led to the development of the FFDR system RISICO. This system is now used as a decision-support tool at both national and regional levels. One of the main dynamic components of RISICO is the Fine Fuel Moisture Content (FFMC) index, which is crucial because fuel moisture conditions influence both the ignition and behavior of wildfires. A new formulation of the FFMC model has been proposed to better discriminate severe wildfire danger conditions. The model simulates hourly fuel moisture dynamics, enabling the identification of rapid changes in danger conditions during the day. Also, it has been designed to include information about different fuel types, allowing it to simulate various fuel conditions within a given territory. The model has been calibrated and tested using hourly Fuel Stick moisture measurements, optimizing its parameters with the use of a meta-heuristic PSO-type algorithm. Finally, the FFMC model has been tested in Italy on past wildfires from 2007 and during the 2023 fire season to assess its performance in identifying high forest fire danger conditions.

Keywords: Wildfire Danger· Fuel Moisture· Optimization· Metaheuristic

Wm2 - 2 | Improving Fuel Characterization through Percentile-Based Canopy Base Height Models for Maritime Pine in Portugal

Jean Luiz Andrade Magalhães[1], Margarida Tomé[2]

[1]Centro de Estudos Florestais, Instituto Superior de Agronomia, Universidade de Lisboa, Portugal,

jeanmagalhaes@isa.ulisboa.pt

[2] Instituto Superior de Agronomia, Centro de Estudos Florestais, Universidade de Lisboa, Portugal,

magatome@isa.ulisboa.pt

Simulation of fire behavior in forest ecosystems is essential for effective management of critical fire-prone areas, especially in vulnerable regions of Portugal. Key variables in these simulations include Canopy Bulk Density (CBD), Canopy Base Height (CBH), and Canopy Fuel Load (CFL), each playing a crucial role in modeling fire behavior by influencing flame spread and fire intensity. CBH, particularly challenging to define, represents the minimum height above the ground where there is sufficient aerial fuel to propagate fire vertically through the canopy. Used to calculate the critical frontal intensity for the transition from surface fire to crown fire, CBH is critical in identifying different types of crown fires. This study proposes adjusting specific equations for various percentiles of CBH for the maritime pine species in Portugal, instead of relying on the average stand CBH commonly found in the literature. This approach allows forest managers to select the most appropriate percentile for specific analyses, providing a more precise and customized tool for fire simulation. By enhancing the accuracy of CBH percentile selection, we improve the ability to predict fire behavior and, consequently, the effectiveness of forest management strategies in critical fire-prone areas. Thus, this work significantly contributes to the protection and sustainable management of Portuguese forests, offering an enhanced method to assess and mitigate fire-related risks.

Keywords: Canopy Base Height· Fuel Characterization· Forest Modeling· Fire Behavior Variables

Wm2 - 3 | Strategic Fire Hazard Mitigation Planning: a Case Study in the Lousã Region, Portugal

Ana Sá[1], Brigite Botequim[2], Alexandra Marques[3], Rogério Rodrigues[4], Rui Pinto[5], Paulo Fernandes[6]

[1]CoLAB ForestWISE, Vila Real, Portugal, ana.sa@forestwise.pt

[2]CoLAB ForestWISE, Vila Real, Portugal, brigite.botequim@forestwise.pt

[3]CoLAB ForestWISE, Vila Real, Portugal, alexandra.marques@forestwise.pt

[4]CoLAB ForestWISE, Vila Real, Portugal, rodrigues.rogerio@forestwise.pt

[5]CoLAB ForestWISE, Vila Real, Portugal, pinto.rui@forestwise.pt

[6]CoLAB ForestWISE, Vila Real, Portugal, ana.sa@forestwise.pt, CITAB, UTAD, Vila Real, Portugal, pfern@utad.pt

Climate change has been modifying fire regime, resulting in larger, more frequent, and particularly impactful wildfires, especially in Mediterranean regions prone to dry-summer conditions. Mitigating the impacts of these wildfires requires strategic placement of fuel treatments consistent with landscape-level fire risk management. Preventive fire planning benefits from an integrated knowledge of fire spread and behaviour, under historical and extreme weather conditions. In this work we run fire spread and behaviour simulations to estimate fire hazard in a forested area in central Portugal that includes a Portuguese Living Lab. Different fire descriptors are estimated to strategically place fuel treatments based on the likelihood of fire intensity (combining burn probability and flame length) and simulated major fire paths. Results reveal the prior location of fuel treatments and their impact on reducing fire-hazard around targeted exposed values. Mapping those fire containment units can help preventive fire management decisions. Inter-municipal cooperation is crucial to mitigate the downstream impacts of fires. Moreover, the proposed framework can be used to foster collaboration among stakeholders and local communities for a proactive fire management and can be applied to support the Integrated Landscape Management Operations (OIGP).

Keywords: Fire Simulations· Fire Containment Units· Fire Prevention Planning

Wm2 - 4 | Optimizing Wildland Fuels Treatment to Mitigate Wildfire Risk and Vulnerability

Alan T Murray

Wildfire Resilience Initiative, University of California at Santa Barbara, USA, amurray@ucsb.edu

Over the past two decades, California has experienced an increase in scale, frequency and intensity of wildfires, posing a significant threat to communities across California. As a result, it has become increasingly vital to develop analytical tools, risk reduction strategies and operational plans to enhance wildfire resilience. One such wildfire resiliency approach is the use of vegetation treatment, which may involve prescribed burns, strategic fuel breaks, mastication and other measures. A challenge is selecting the best areas for vegetation treatment, where viable projects must be contiguous and manageable in size. Spatial optimization modeling has much potential for addressing this problem, enabling the formalization of the planning problem as well as offering approaches for identifying the best solutions possible. However, challenges remain as the underlying geographical detail and spatio-temporal characteristics are formidable. This paper highlights geographic analytics to support vegetation treatment planning, including the use of remote sensing, topography, climate, weather and fire behavior simulation, along with a location model that reflects the intent to identify the best project areas. Application results for US Forest Service lands as well as the Santa Barbara region are detailed, demonstrating the importance and challenges in address contiguity in project area identification.

Keywords: Contiguity· Land Acquisition· Thresholds

Wa1 - 1 | Optimizing the Allocation of Fuel Management Investments for the Portuguese National Fire Plan

Alan Ager[1], Bruno A. Aparício[2], José M. C. Pereira[3], Michelle Day[4]

[1]Oregon State University, Corvallis, OR USA, alan.ager@oregonstate.edu

[2]University of Lisbon, Lisbon Portugal, bruno.a.aparicio@gmail.com

[3]University of Lisbon, Lisbon Portugal, jmocpereira@gmail.com

[4]USDA Forest Service, Missoula, MT USA, michelle.day@usda.gov

The escalating wildland fire problem in Portugal motivated policymakers to develop a national plan to treat fuels on 250,000 ha over the next 10 years. The plan allocated funding to the 5 regions in the country, with finer scale investment among the 278 municipalities delegated to local fire management agencies to prioritize and implement treatments. We used the spatial optimization model ForSys to simulate national scale treatment scenarios for the three national priorities as specified in the plan. Data from prior fire simulation studies were used to generate maps of ignition density, building exposure, and fire size. Treatment scenarios used these metrics as optimization objectives to identify where treatments will be most effective at addressing one or more of the national goals. We then analysed the effect of pro-rating treatment area to all 278 municipalities proportional to their risk, versus treating areas with the highest risk without considering municipality boundaries. We identified sharp tradeoffs among the different fire management objectives for many, but not all municipalities. Pro-rating treatments to all municipalities based on management objective resulted in significant reduction in treatment efficiency. Our results provide a rare example of applying optimization models at national scales to translate policy priorities to local treatment units and examine the relative efficiency of alternative allocation strategies.

Keywords: Portugal Wildfire· Spatial Optimization· Wildland Fuel Management· Forsys

Wa1 - 2 | Maximizing Opportunities for Co-implementing Fuel Break Networks and Restoration Projects in the Umatilla National Forest, USA

Bruno A. Aparício[1], Alan Ager[2], Michelle Day[2], Rachel Houtman[3], Andrew Stinchfield[4]

[1] International Visiting Scholar, USDA Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Lab, Missoula, Montana, USA, bruno.a.aparicio@gmail.com

[2] USDA Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Lab, Missoula, Montana, USA, alan.ager@oregonstate.edu, michelle.day@usda.gov

[3] USDA Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Lab, Missoula, Montana, USA, Oregon State University, College of Forestry, Forest Ecosystems & Society, Corvallis, Oregon, USA, rachel.Houtman@usda.gov

[4]USDA Forest Service, Umatilla National Forest, Pendleton, Oregon, USA, andrew.stinchfield@usda.gov

Increasing impacts from wildfires are reshaping fire policies worldwide, with expanded investments in a wide range of fuel reduction strategies, namely fuel break networks (FBN) and landscape restoration. However, studies that combine these strategies and examine alternative co-prioritization strategies and potential synergies are largely non-existent. In this talk, we will present the advances in this field, using the Umatilla National Forest, a 0.5 million ha national forest in the western US as a case study. We will first show how the ForSys prioritization model was used to prioritize the proposed 3,538 km FBN, and explore tradeoffs between two implementation strategies: one that promotes long linear fuel breaks, and the other that promotes radial fuel breaks. Then, we used these results to map areas relevant for both landscape restoration and FBN projects, i.e., areas with high dual-benefits. We assumed that the two strategies are implemented at the same time, and that one follows the other. Hence, we created two scenarios: FBN-first, where a FBN project is created first and a restoration project is implemented close to it; and restoration-first, where a restoration project is created and a FBN project is implemented inside the restoration project. Restoration projects were created using ForSys with the objective of net revenue or resiliency. Our results highlight specific areas of Umatilla National Forest where dual-benefits can be obtained and synergies maximized.

Keywords: ForSys· Fuel Break Networks· Spatial Optimization· Restoration Planning

Wa1 - 3 | Optimization-Based Impacts of Forest Management Practices on Recreational and Aesthetic Services in Forested Landscapes

Brigite Botequim[1*], Dagm Abate[2*], Susete Marques[3], Constantino Lagoa[4], Juan Guerra-Hernández[5], Geerten Hengeveld[6], Marjanke Hoogstra-Klein[7], José C. Borges[8]

[*] These authors contributed equally to this work

[1]CoLAB ForestWISE - Collaborative Laboratory for Integrated Forest & Fire Management, Quinta de Prados, 5001-801 Vila Real, Portugal; Forest Research Centre, Associate Laboratory TERRA, School of Agriculture (ISA), University of Lisbon, Tapada da Ajuda, P-1349-017, Lisboa, Portugal, brigite.botequim@forestwise.pt

[2]Forest Research Centre, Associate Laboratory TERRA, School of Agriculture (ISA), University of Lisbon, Tapada da Ajuda, P-1349-017, Lisboa, Portugal, dagmabate@isa.ulisboa.pt

[3]Forest Research Centre, Associate Laboratory TERRA, School of Agriculture (ISA), University of Lisbon, Tapada da Ajuda, P-1349-017, Lisboa, Portugal, smarques@isa.ulisboa.pt

[4]The Pennsylvania State University, University Park, PA, United States,

[5]Forest Research Centre, Associate Laboratory TERRA, School of Agriculture (ISA), University of Lisbon, Tapada da Ajuda, P-1349-017, Lisboa, Portugal,

[6] Forest and Nature Conservation Policy group, Wageningen University, the Netherlands,

[7] Forest and Nature Conservation Policy group, Wageningen University, the Netherlands,

[8]Forest Research Centre, Associate Laboratory TERRA, School of Agriculture (ISA), University of Lisbon, Tapada da Ajuda, P-1349-017, Lisboa, Portugal, joseborges@isa.ulisboa.pt

Facing future challenges and societal demands, effective ecosystem management is critical for sustaining provisioning, regulating, supporting, and cultural services in forested landscapes. This study addresses concerns about cultural services in multi-ownership forest plantations by developing the Recreational and Aesthetic Value of Forested Landscape (RAFL) instrument to enhance assessment.

Introducing the Landscape Resource Capability Model (LRCM) and optimization-based linear programming (LP), the aim is to align timber production with cultural services through new forest management strategies (FMS) over a 50-year planning period (2022-2071). Field data from Northwestern Portugal ($\approx$ 14,400 ha) informed the study, where 1114 stands are dominated by $\approx$ 11,000 ha of Eucalyptus globulus Labill (current eucalypt FMS).

The potential of current (cFMS) and new (nFMS) FMS to enhance recreational and aesthetic services was assessed. Results reveal a robust correlation between forest attractiveness and measurable attributes. LP-RCM solutions facilitate the transition between cFMS and nFMS, supporting the simultaneous provision of a minimum baseline RAFL score while optimizing scenarios for timber revenue. The study also provides valuable implications for wildfire management by examining how maximizing cultural ecosystem services (RAFL score) can be achieved while simultaneously attaining different levels of wildfire resistance indicator.
This research improves cultural landscape planning by conducting spatial assessments of how forest management impacts recreational and aesthetic values at the landscape level over time.

Keywords: Recreational And Aesthetic Values· Alternative Management Strategies· Forested LandscapeMathematical Programming· Wildfire Resistance· Cultural Landscape-level Planning

Wa1 - 4 | A New Look at an Old Forest Harvest Scheduling and Wildfire Model

Pete Bettinger

University of Georgia, Athens, Georgia, USA, pbettinger@warnell.uga.edu

Methods for estimating the impact of potential wildfires on ecosystem service outcomes range from rather simple strata-based approaches that adjust aggregate forest conditions over time to spatial simulation approaches that model finer detail of forest conditions over time. A model [1] was proposed about 15 years ago to integrate a heuristic search process (tabu search) with a spatial wildfire simulator (FARSITE) to maximize wood produced from a model forest while adjusting forest conditions that change due to the severity of simulated wildfires. Feedback from fire effects prompts changes in forest conditions that are then used to re-schedule the harvest plan. The model uses both vector and raster GIS data and operates in a sequential manner much like binary search might, to account for changes in forest conditions over time. The main drawback of the modelling approach is the amount of time necessary to conduct all of the processes necessary to address the objective and constraints and to account for the changes in forest conditions due to wildfire. This presentation describes the mechanics of the processes employed.

Reference:

[1] Bettinger, P. (2009). A prototype method for integrating spatially-referenced wildfires into a tactical forest planning model. *Research Journal of Forestry*, 3(1), 8-22.

Keywords: Tabu Search· Combinatorial Optimization· Forest Landscape Planning

Wa2 - 1 | Optimizing Residual Agro-Forestry Biomass Land Harvest while Considering Triple Bottom Line (TBL) and Wildfire Risk Factors

Ruxanda Godina Silva[1], Carina Pimentel[2], Reinaldo Gomes[3], Ana Luísa Ramos[4]

[1]University of Aveiro, Aveiro, Portugal, ruxanda@ua.pt

[2]Algoritmi Research Center, University of Minho, Guimarães, Portugal, carina.pimentel@dps.uminho.pt

[3]INESC TEC-Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciência, Porto, Portugal, reinaldo.s.gomes@inesctec.pt

[4]GOVCOPP, DEGEIT, University of Aveiro, Aveiro, Portugal, aramos@ua.pt

Our research presents a multi-objective mixed integer linear programming (MILP) model aimed at optimizing the planning of agro-forestry residual biomass. Within a sustainable supply chain optimization framework, various triple bottom line (TBL) criteria are integrated, including considerations for wildfire risk. The model facilitates tactical decision-making, encompassing land harvest selection, residual biomass sourcing and allocation, harvest prioritization, and identification of potential intermediary points for storage. Environmental criteria are evaluated through total CO2 emissions, economic criteria via total profit, and social criteria via risk of accidents. To address wildfire risk, the model factors in the cost of wildfires. Multiple scenarios are devised to weigh each criterion differently. The efficacy of the model is illustrated through a case study focused on a biomass provider operating within the biomass-forest-to-bioenergy supply chain in Central Portugal. Lastly the results of sensitivity analysis are presented.

Keywords: Biomass· Optimization· Supply Chain· Triple Bottom Line (TBL)

Wa2 - 2 | Sustainable Management Model for the Residual Agroforestry Biomass Supply Chain

Saeed Tasouji Hassanpour[1], Reinaldo Gomes[2], Radu Godina[3], Carina Pimentel[4]

[1]DEGEIT, University of Aveiro, Portugal, stasoujihass@mun.ca

[2]INESC TEC-Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciência, Porto, Portugal, reinaldo.s.gomes@inesctec.pt

[3]UNIDEMI-Department of Mechanical and Industrial Engineering, NOVA School of Science and Technology, FCT NOVA, Universidade NOVA de Lisboa, 2829-516 Caparica, Portugal and Laboratório Associado de Sistemas Inteligentes, LASI, 4800-058 Guimarães, Portugal, r.godina@fct.unl.pt

[4]Production and Systems Department / ALGORITMI Research Centre / LASI, University of Minho, Braga, Portugal and GOVCOPP, University of Aveiro, carina.pimentel@dps.uminho.pt

In this talk, a Sustainable Biomass Supply Chain (SBSC) Model will be presented. The SBSC is engineered to optimize the intricate logistics of biomass production, processing, transportation, and consumption over multiple time periods. The model's primary objective is to develop a cost-effective and environmentally sustainable supply chain that minimizes total costsŮincluding transportation, treatment, and storage facility establishment-while mitigating the risk of biomass accumulation and wildfire hazards. This optimization involves the coordinated efforts of various stakeholders, such as producers, intermediaries, transporters, final consumers, and municipal entities, each playing distinct roles to ensure the efficient flow of biomass. This work presents the SBSC Model as a robust framework for achieving sustainability in biomass supply chains, balancing economic efficiency with environmental and risk management considerations. The SBSC Model integrates diverse generation nodes, encompassing fuel management as well as traditional agricultural and forestry activities, ensuring a consistent supply of residual biomass. Biomass can be temporarily stored at intermediary storages, temporary eco-points, and existing eco-points, each with specific capacities and functions. The model strategically manages the movement of raw and treated biomass through the supply chain, facilitating direct transport to customers or via intermediary stages for pre-treatment and storage.

Keywords: Biomass Supply Chain· Wildfire Risk· Mixed-Integer Linear Programming· Sustainability

Wa2 - 3 | Exploring Mathematical Formulations for the Post-Fire Forest Planning Problem

A. Miguel Gomes[1], Isabel Martins[2], Abílio Pereira Pacheco[3], Filipe Alvelos[4]

[1]INESC TEC, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal, agomes@fe.up.pt

[2]Centro de Matemática, Aplicações Fundamentais e Investigação Operacional, Instituto Superior de Agronomia, Lisboa, Portugal, isabelinha@isa.ulisboa.pt

[3]CoLAB ForestWISE, Faculdade de Engenharia, Universidade do Porto, INESC TEC, Porto, Portugal, abilio.p.pacheco@gmail.com

[4]ALGORITMI Research Centre/LASI, Universidade do Minho, Braga, Portugal, falvelos@dps.uminho.pt

In this study, we propose mathematical formulations for addressing the forest planning problem in a post-fire context. The forest is divided into hexagonal units, each with several alternative prescriptions. A prescription refers to a planned schedule of activities designed to achieve specific outcomes. The problem involves selecting one prescription for each cell to maximize the net present value, while maintaining certain levels of forestry species diversity across the forest.
We present two mathematical formulations for this problem: the first includes pairwise cell adjacency constraints, and the second is based on the bucket model for the harvest scheduling problem with clearcut area constraints. All models aim to balance two objectives: maximizing forestry species diversity and economic value, thereby exploring the trade-off between biodiversity and net present value in forest management.

Keywords: Spatial Forest Planning· Mixed-Integer Programming

Wa2 - 4 | Allocation of Optimal Fuel Management Actions That Rely on Multi-actor Prioritization Strategies

José Ramón González-Olabarria[1], F. Ulloa-Fierro[2], E. Álvarez-Miranda[3], G. Krsnik[4], J. Garcia-Gonzalo[5]

[1]Centre De Ciència i Tecnologia Forestal de Catalunya (CTFC), Solsona, Spain, jr.gonzalez@ctfc.cat

[2]School of Engineering, Universidad de Talca, Talca, Chile; Complex Engineering System Institute (ISCI), Santiago, Chile, felipe.ulloa@utalca.cl

[3]School of Engineering, Universidad de Talca, Talca, Chile; Complex Engineering System Institute (ISCI), Santiago, Chile, ealvarez@utalca.cl

[4]Centre De Ciència i Tecnologia Forestal de Catalunya (CTFC), Solsona, Spain, goran.krsnik@ctfc.cat

[5]Centre De Ciència i Tecnologia Forestal de Catalunya (CTFC), Solsona, Spain, j.garcia@ctfc.cat

Whenever a large-scale fuel management policy is to be planned and implemented on a territory, it is highly recommended to define a clear strategy based on prioritization before selecting actions on the territory. On this study we present a strategic assessment defining priority areas for fuel management aiming to prevent large fires. The prioritization method is based on the integration of multiple criteria and the involvement of multiple actors. On a second stage, using the strategic assessment and embedded rules as drivers, we proposed an optimization method to tactically allocate fuel management actions across a landscape. To face this comprehensive problem, that explicitly couples strategic and tactical phases of fuel management planning, we develop a combined framework of Multi-Attribute Utility Theory (MAUT) and Mixed Integer Programming (MIP) model to capture the consensus and obtain a cost-effective prioritization management plan.

Keywords: Spatially Explicit Optimization· Multi-criteria Prioritization Planning· MAUT· MIP

Tm1 - 1 | An Integer Programming Formulation for Sensor Placement in LoRaWAN Networks

Jessica Singer[1], Javier Marenco[2]

[1]Dto. de Computación, FCEyN, Universidad de Buenos Aires, Argentina, singer.jeess@gmail.com

[2]Escuela de Negocios, Universidad Torcuato Di Tella, Argentina, javier.marenco@utdt.edu

A promising approach for the early detection of fires in forests consists in placing ground-based sensors that communicate through a *LoRaWAN network* with certain *gateways*. LoRaWAN networks have received a lot of interest in recent years, especially with the rise of solutions based on *Internet of Things*. In this work we address the problem of sensor placement in LoRaWAN networks using integer programming techniques, taking into account the particular characteristics of these networks. We consider a set of *points of interest*, a set of potential locations for sensors, and a set of gateways. The problem consists in determining (a) a subset of potential locations in which sensors are to be installed, (b) a gateway and a spreading factor associated with each sensor, and (c) a channel associated with each gateway, in such a way that the number of sensors does not exceed a prespecified number (given by budget constraints) and minimizing a combination of (i) the number of uncovered points of interest and (ii) the network interference. We provide an integer programming formulation for this problem and we explore the capabilities of a state-of-the-art solver over this formulation applied to the "Pereyra Iraola" park in Buenos Aires, Argentina. We also present preliminary theoretical results on this formulation.

Keywords: Wildfire Detection· Sensor Placement· Integer Programming

Tm1 - 2 | Optimized Distributed Temperature Sensor for Forest Fire Detection Using Existing Telecommunications Fiber Networks

Joana Vieira[1], Miguel Coelho[2], Luís Santiago[3], Rodolfo Oliveira[4], António Navarro[5], Rogério N. Nogueira[6], Ana M. Rocha[7]

[1]Institute of Telecommunications and University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal, joana.saraiva.vieira@av.it.pt

[2]Institute of Telecommunications and University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal, miguel.calca@av.it.pt

[3]Institute of Telecommunications and University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal, luissantiago@ua.pt

[4]Institute of Telecommunications and University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal, rodolforeis@av.it.pt

[5]Institute of Telecommunications and University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal, navarro@av.it.pt

[6]Institute of Telecommunications and University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal, rnogueira@av.it.pt

[7]i3N & Physics Department, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal, amrocha@ua.pt

Forest fires pose significant threats to lives, infrastructure, and ecosystems. Some existing fire detection systems rely on pointwise sensors(Ramteke et al., 2021). Here, we propose an optimized Ramanbased distributed temperature sensor (DTS) for wildfire detection that allows continuous temperature monitoring along the fiber. This system will be integrated with an alert system that broadcasts alarm messages via FM radio near the fireaffected area. The DTS system will use the existing optical fiber networks in forests and along roads, avoiding new fiber deployment. Distributed sensors enable spatially continuous measurements along several kilometers of optical fiber with just one interrogation unit. To use the existing telecommunications fiber networks the coexistence of sensor and data signals must be assured. Recently this was demonstrated, but with reduced data transmission capacity in the C band (Wellbrock et al., 2020). Here, we use a pump source wavelength outside the telecommunications transmission window (1064 nm) to maintain the capacity.

The Raman-based DTS analyzes the backscattered Raman signals power ratio to pinpoint temperature variations along the fiber. If this is the case, the server locates the nearby main roads and, the FireTec Switch interrupts the live FM radio broadcasting, transmitting audio and text warning messages to the car drivers nearby (Coelho et al., 2023). We believe such a system could prevent road fatalities when evacuating fire areas.

Acknowledgements: This work is funded by FCT/MCTES through national funds and when applicable co-funded EU funds under the project FireTec, UIDB/50008/2020-UIDP/50008/2020 and UIDB/50025/2020-2023, and by FCT through Joana Vieira's grant 2023.03578.BD.

References:

Coelho, M., Santiago, L., Araujo, D., Navarro, A., & Carvalho, N. B. (2023). A Low-Cost Embedded System to Support Broadcasting Emergency Messages Through FM Radio Stations. *IEEE Embedded Systems Letters*, 1-4. https://doi.org/10.1109/LES.2023.3343641

Ramteke, A., Pochhi, P. R., & Dhuture, P. R. (2021). IoT Based Forest Fire Detection System Using Raspberry PI and GSM. *International Journal of Advanced Research in Science, Communication and Technology*, 5(2), 433-436. https://doi.org/10.48175/IJARSCT-1219

Wellbrock, G. A., Xia, T. J., Huang, M., Salemi, M., Li, Y., Ji, P. N., Ozharar, S., Chen, Y., Ding, Y., Tian, Y., Wang, T., & Aono, Y. (2020). Field Trial of Distributed Fiber Sensor Network Using Operational Telecom Fiber Cables as Sensing Media. 2020 European Conference on Optical Communications (ECOC).

Keywords: Distributed Temperature Sensor· Raman Backscatter· Forest Wildfire

Tm1 - 3 | Optimizing Autonomous Unmanned Aerial System Deployment Locations for Enhanced Wildfire Detection and Monitoring

Sascha Zell[1], Armin Fügenschuh[2]

[1]Brandenburg University of Technology, Cottbus, Germany, sascha.zell@b-tu.de

[2]Brandenburg University of Technology, Cottbus, Germany, fuegenschuh@b-tu.de

The increase in the frequency and severity of forest fires as a symptom of climate change requires innovative methods of fighting forest fires. For this reason, an autonomous Unmanned Aerial System (UAS), consisting of a heterogeneous fleet of Micro Air Vehicles (MAVs) and purpose-built hangars, will be stationed in a large, sparsely populated operational area in the South of Brandenburg, Germany. Once alerted, the MAV fleet will autonomously approach the fire area to monitor the spread of the fire and transmit a report to the local operations center. We introduce a Mixed-Integer Linear Program (MILP) that solves the location-allocation problem by selecting different hangar and MAV types, with the objective of approaching the sources of fire as quickly as possible while guaranteeing a certain monitoring time. We also apply a MILP by Schmidt and Fügenschuh (2023) to scan the area rapidly, taking into account the flight dynamics of the MAVs. Furthermore, we present a Discrete-Event Simulation (DES) approach that allows to quantify the reward for deploying more resources, e.g. larger hangars or higher-quality MAVs. MAV sensors and a YOLOv8 network automatically identify sources of fire and smoke.

References:

[1] Schmidt, J., & Fügenschuh, A. (2023). A two-time-level model for mission and flight planning of an inhomogeneous fleet of unmanned aerial vehicles. *Computational Optimization and Applications*, 85(1), 293-335.

Keywords: Mixed-Integer Linear Programming· Unmanned Aerial Systems· Micro Air Vehicles· Autonomous Wildfire Monitoring

Tm1 - 4 | A Robust Approach for the Prepositioning of Resources for Wildfire Suppression

Agostinho Agra[1], Helena Alvelos[2], Ana Raquel Xambre[3], Filipe Alvelos[4], Francisco Marques[5]

[1]Department of Mathematics / Center for Research and Development in Mathematics and Applications, University of Aveiro, Portugal, aagra@ua.pt

[2]Department of Economics, Management, Industrial Engineering and Turism/ Center for Research and Development in Mathematics and Applications, University of Aveiro, Portugal, Aveiro, helena.alvelos@ua.pt

[3]Department of Economics, Management, Industrial Engineering and Turism / Center for Research and Development in Mathematics and Applications, University of Aveiro, Portugal, Aveiro, raquelx@ua.pt

[4]Department of Production and Systems / ALGORITMI Research Center / LASI, University of Minho, Portugal, falvelos@dps.uminho.pt

[5]University of Aveiro, Portugal, franciscocmarques@ua.pt

We consider the problem of prepositioning a set of firefighting resources for wildfire suppression. As wildfires are highly affected by uncertainty we devise a two-stage robust model where the prepositioning of resources are the first-stage decisions and the movement of these resources after the fire ignitions are known are the second-stage decisions. To model uncertainty, we consider a discrete set of scenarios which represent different combinations of ignition locations, wind speed and directions. A robust mixed integer program is proposed to determine the optimal prepositioning of resources aiming to minimize the fire spread when the worst-case occurs. The fire spread in the landscape is modeled using the minimum travel time principle. As the size of the model grows considerably with the number of scenarios, a row and column generation algorithm is proposed. Computational experiments based on an actual landscape are reported showing the efficiency of the row and column algorithm.

Keywords: Fire Suppression· Robust Optimization· Decomposition Algorithm

Tm2 - 1 | Advancements in Wildfire Detection: Integrating Wind Field Simulation and Gas Dispersion Modeling

Md Khalid Mustafa[1], Prof. Dr.-Ing. Haresh Vaidya[2]

[1]Hochschule Ansbach, Energie Campus, Deutschland, mustafa19438@hs-ansbach.de

[2]Hochschule Ansbach, Energie Campus, Deutschland, haresh.vaidya@hs-ansbach.de

This study aims to integrate Wind Ninja, a high-resolution wind simulation tool, to enhance the understanding of gas dispersion over complex terrains. Utilising a high-resolution digital elevation model (DEM), Wind Ninja generates detailed wind fields over the study area of Energie Campus, Feuchtwangen which will be subsequently coupled with a gas dispersion model to follow the spread of gases, mainly the VOC's that are emitted during the pre-ignition and ignition phase of a fire. Preliminary wind flow simulations have demonstrated significant impacts of topography on local wind patterns, offering valuable insights into temporal and spatial variations of wind behaviour. These results have laid the groundwork for further inverse gas dispersion modelling, aiming to deliver precise gas emissions sources in complex environments. Building on the coupled results gained throughout this study an early wildfire detection system can be developed in the future. The research promises significant societal benefits and reduced emergency response times. Future work includes coupling the inverse gas modelling techniques and the wind flows generated through Wind Ninja to identify the gas emission sources and explore applications in early wildfire detection. This interdisciplinary approach advances our understanding of atmospheric gas dynamics and increases public safety.

Keywords: Wind Ninja· Inverse Gas Dispersion Modelling· Digital Elevation Model

Tm2 - 2 | A Genetic Algorithm for Multiple Fires Suppression

Marina A. Matos[1], Rui Gonçalves[2], Ana Maria A. C. Rocha[3], Lino A. Costa[4], Filipe Alvelos[5]

[1]ALGORITMI Research Centre / LASI, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal, mmatos@algoritmi.uminho.pt

[2]ALGORITMI Research Centre / LASI, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal, rgoncalves0320@gmail.com

[3]ALGORITMI Research Centre / LASI, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal, arocha@dps.uminho.pt

[4]ALGORITMI Research Centre / LASI, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal, lac@dps.uminho.pt

[5]ALGORITMI Research Centre / LASI, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal, falvelos@dps.uminho.pt

Forest fires are becoming an increasing concern around the world, as their frequency and severity have risen over the past few decades. Consequently, effective firefighting management is crucial to minimize the damage inflicted on human lives, the economy and ecosystems.
In this work, we consider the suppression of multiple fires. Given information on their locations and an estimate of their growth, the problem consists in allocating firefighting resources to fires through time. A major issue is that the quantity of water needed to suppress a fire increases with time. We consider that multiple resources can attack the same fire, each resource has a water capacity and water refills are possible. We use lexicographic optimization with the first objective of minimizing the number of escaped fires, the second objective minimizing the instant all fires are suppressed and as a third objective, to minimizing the cost associated with the resources used. We propose a genetic algorithm based on coding an individual as a set of permutations, one for each resource, and a decoding operator that returns a feasible solution. We present computational results in an actual landscape.

Keywords: Forest Fires· Fire Suppression· Firefighting Dispatch and Schedule Problem· Metaheuristics

Tm2 - 3 | Resource-Constrained Emergency Scheduling for Major Forest Fires: A Learning Driven Adaptive Artificial Bee Colony Approach

Zilong Zhao[1], Peng Wu[2]

[1]Fuzhou University, Fuzhou, China, zzl18822078576@163.com

[2]Fuzhou University, Fuzhou, China, wupeng88857@126.com

Major forest fires pose a significant threat to the natural environment as well as the safety of human life and property. This study addresses a substantial challenge in emergency scheduling for major forest fires, taking into account factors such as limited firefighting resources and a multitude of fire points with diverse spread speeds and varying geographic locations. To optimize the allocation and rescue sequence of fire points, we first relax the rescue priority constraint in existing research, and propose a novel mixed-integer linear programming (MILP) model with the goal of minimizing the overall fire spread area. Given the inherent strong NP-hardness of this problem, we develop an adaptive artificial bee colony algorithm enhanced with Q-Learning algorithm (AABC-QL), where Q-Learning leverages training information from the employed bee phase to guide neighborhood search operators selection in the onlooker bee phase, thereby enhancing the algorithm's global and local search capabilities. Experimental results on two real-life cases and numerous randomly generated simulation instances have demonstrated the benefits of relaxation rescue priority and the superiority of the proposed AABC-QL. Simultaneously, we derive some insightful management insights indicating that independently increasing the average driving speed of firefighting vehicles or the fire extinguishing speed of rescue teams contributes to the objective and helps in understanding their relative strengths.

Keywords: Major Forest Fires· Emergency Rescue Scheduling· Resource-Constrained· Mixed-Integer Linear Programming· Q-Learning· Adaptive Artificial Bee Colony Algorithm

Tm2 - 4 | Optimal Off-Policy Evaluation in Finite Stochastic Partial Monitoring

Mostafa Rezaei[1], Ilbin Lee[2], Csaba Szepesvari[3]

[1]ESCP Business School, Paris, France, mrezaei@escp.eu

[2]University of Alberta, Edmonton, Canada, ilbin@ualberta.ca

[3]University of Alberta, Edmonton, Canada, csaba.szepesvari@gmail.com

In finite stochastic partial monitoring (FSPM), a latent, finite-valued random variable (the outcome) and an action jointly determine an observation and a reward. A policy is a distribution over actions, and its value is the expected reward when actions are sampled from it. In off-policy evaluation, a learner estimates the value of a target policy given action-observation pairs generated by a logging policy. Although the learner knows the FSPM mechanism and the policies, they do not have access to the latent outcomes or their distribution and may not have direct access to the rewards. For instance, in wildfire management, a decision maker must decide the resources to allocate to a newly detected fire (action). The outcome, randomly determined by nature, is the minimum resources needed to contain the fire. If allocated resources exceed this level, the fire is contained; otherwise, it is not. The incurred loss is the excess resource cost compared to the minimum level, with the decision maker only observing if the fire was contained. We propose constructing unbiased estimators by controlling the variance under a worst-case outcome distribution. We demonstrate that optimal estimators can be computed efficiently through convex optimization. Experimental results with both contextual and non-contextual problems, using public and synthetic datasets, show that these optimal estimators significantly outperform several alternatives.

Keywords: Off-Policy Evaluation· Partial Monitoring· Wildfire Operations

Tm2 - 5 | A Physics-Based Optimisation Framework for the Management of Wildfire Risk and Emergencies

Savvas Gkantonas[1], Epaminondas Mastorakos[2], Kayman Krishnamohan[3], Diego Garcia Rios[3], Andrea Giusti[3]

[1]Spinthir Designs Limited, London, UK & Department of Engineering, University of Cambridge, Cambridge, UK, sg834@cam.ac.uk

[2] Department of Engineering, University of Cambridge, Cambridge, UK, em257@cam.ac.uk

[3]Department of Mechanical Engineering, Imperial College London, London, UK,

kayman.krishnamohan20@imperial.ac.uk, diego.garcia-rios20@imperial.ac.uk, a.giusti@imperial.ac.uk

A stochastic model for predicting fire spread in the wildland and the wildland-urban interface is coupled with Monte Carlo optimisation approaches to predict the risk of fire outbreaks and optimise the management of resources. The aim is to both prevent the occurrence of a fire and address an existing fire with minimal loss of land. The use of the model to predict fire risk is first discussed to highlight differences with approaches typically used in an operational context. Then, its use to address land management problems is presented, where partial or complete cleaning of the terrain and vegetation replacement are re-phrased in terms of rules and actions for the Monte-Carlo Tree Search (MCTS) algorithm, an optimisation model from game theory. Validation in reference test cases demonstrates that the combination of the spread model with MCTS enables solutions that outperform intuition. The same framework, but with different actions and rules is then applied to real-time management of fire extinction actions. The framework has been coupled with machine learning (ML) to assist the selection of the extinction action, to keep the space of actions limited. A methodology based on time-to-reach areas to be saved has been developed to train ML algorithms, including random forest, convolutional neural networks, and deep learning methods. These are evaluated and compared to develop a robust selection function. This function is then integrated with MCTS and used in test cases to allocate a limited number of extinction actions.

Keywords: Stochastic Spread Model· Monte Carlo Optimisation Actions· Fire Extinction· Land Management

Ta1 - 1 | Iterated Local Search for Firefighting Helicopter Planning

Marta Rodríguez Barreiro[1], María José Ginzo Villamayor[2], Fernando Pérez Porras[3], María Luisa Carpente Rodríguez[4], Silvia María Lorenzo Freire[5]

[1]Modes Group, Department of Mathematics, University of A Coruña, Galician Centre of Mathematical Research and Technology (CITMAga), Spain, marta.rodriguez.barreiro@udc.es

[2]Modestya Group, Department of Statistics, Mathematical Analysis and Optimisation, University of Santiago de Compostela, Galician Centre of Mathematical Research and Technology (CITMAga), Spain, mariajose.ginzo@usc.es

[3]Department of Graphic and Geomatic Engineering, University of Córdoba, Spain, o12pepof@uco.es

[4]Modes Group, Department of Mathematics, University of A Coruña, Spain, luisa.carpente@udc.es

[5]Modes Group, Department of Mathematics, University of A Coruña, Centre for Information and Communications Technology Research (CITIC), Spain, silvia.lorenzo@udc.es

This study presents a mathematical optimisation model developed to plan the work of firefighting helicopters. The main objective of this model is to maximise the efficiency of the water drops made by the aircraft, based on criteria established by the user. Its secondary objectives are to minimise a series of penalties related to helicopters performance, aimed at improving their efficiency. The model solution indicates when and in which area of the wildfire each helicopter should work, where it should load water and where it should rest, taking into account current Spanish air regulations. Given the emergency context in which this model is to be applied, it must be resolved in periods of 15 minutes at most. However, given the complexity of the model, when running it with real data instances, it is found that Gurobi solver is not capable of reaching the optimum in 24 hours. Because of this, two heuristics are developed to solve the model, a Simulated Annealing and an Iterated Local Search. Both heuristics are tested with several real data instances: small, medium and large. It is found that both heuristics achieve feasible solutions in reasonable times for datasets where Gurobi is not able to find feasible solutions. Furthermore, it is shown that the Iterated Local Search heuristic gives better results than Simulated Annealing in all the runs.

Keywords: Helicopters Planning· Iterated Local Search· Simulated Annealing

Ta1 - 2 | Covering and Network Design for Wildfire Preparedness

Elsa Silva[1], Marco Marto[2], Filipe Alvelos[3]

[1]Centro ALGORITMI/LASI, Dept. Produção e Sistemas, Universidade of Minho, Braga, Portugal,
elsa@dps.uminho.pt

[2]Centro ALGORITMI/LASI, Dept. Produção e Sistemas, Universidade of Minho, Braga, Portugal,
marcovmarto@gmail.com

[3]Centro ALGORITMI/LASI, Dept. Produção e Sistemas, Universidade of Minho, Braga, Portugal,
falvelos@dps.uminho.pt

We consider the problem of designing a network for positioning and moving wildfire resources in a landscape. This general description includes the particular cases of defining the network for i) surveillance, ii) fire detection, iii) fire suppression.
The problem consists in, given a network where the nodes are potential locations for a given resource (e.g. a vigilance tower or a firefighting crew) and the arcs correspond to a direct link (e.g. roads) between potential locations, selecting a subset of nodes and arcs linking the selected nodes with a given topology.
We propose a mixed integer programming model that integrates covering (for selecting positions) and network design (for selecting the arcs). For network design, we consider three different topologies: spanning tree, shortest path tree and Hamiltonian circuit. We discuss different objectives, including the maximization of the coverage and the minimization of the length of the network.
We discuss computational experiments for an actual landscape.

Keywords: Covering· Network Design· Mixed Integer Programming Model

Ta1 - 3 | Robust Optimisation for Dispatching Fire Suppression Resources

André Bergsten Mendes[1], Filipe Alvelos[2]

[1]Department of Naval Architecture and Ocean Engineering, Sao Paulo, Brazil, andbergs@usp.br

[2]Centro Algoritmi & Department of Production and Systems, University of Minho, Braga, Portugal, falvelos@dps.uminho.pt

Wildfires are among the most common natural disasters, causing significant damage to ecosystems, human life, and property. The initial attack is the first response stage, initiated as soon as a fire is detected, and involves dispatching resources to the burning area. However, making decisions during this stage is complex due to the dynamic behaviour of the flames, which is influenced by weather conditions, the landscape's topography, and the available fuel. In this research, we aim to develop optimisation-based planning tools to assist fire management teams in deploying resources effectively to contain and extinguish fires quickly, or to minimize the resources required for a given protection task. We address scenarios where the estimated number of resources may be insufficient to handle the fire intensity, which only becomes fully apparent at the scene. In such cases, additional resources may be needed to contain the fire effectively. This worst-case scenario approach is modelled using the robust optimisation paradigm. We propose a deterministic mathematical programming model and its robust optimisation counterpart. By adapting instances from the literature, we demonstrate the effectiveness of robust solutions under different budgets of uncertainties, according to the paradigm proposed by Bertsimas and Sim (2004).

Reference:

Bertsimas, D., Sim, M., 2004. The price of robustness. *Operations Research*, 52, 1, 35-53.

Keywords: Fire Suppression· Mathematical Programming· Robust Optimisation· Initial Attack

Ta2 - 1 | Constructive Heuristics to Solve the TOPVTW Applied to Wildfire Suppression

Bibiana Granda-Chico[1], Begoña Vitoriano[2]

[1]HUMLOG Research Group, Interdisciplinary Mathematics Institute (MI), Universidad Complutense de Madrid, Madrid, Spain, bibianag@ucm.es

[2]HUMLOG Research Group, Interdisciplinary Mathematics Institute (MI), Universidad Complutense de Madrid, Madrid, Spain, bvitoriano@mat.ucm.es

The Team Orienteering Problem with Variable Time Windows is a recent variant of the traditional Orienteering Problem with time-windows constraints. It arises in the context of spread processes that must be stopped. Thus, this generic OR problem can be used to devise a decision support tool for optimizing wildfire suppression operations and others.
Exact methods have been applied to solve the problem. They offer a good framework to study its structure, yet they are incapable of solving realistic-sized instances. Response times are important in a wildfire suppression context, where decisions are urgent. Thus, in this work, a heuristic framework based on a GRASP is proposed, aimed at reducing running times and increase the size of the solvable instances.

Keywords: Heuristics· Wildfire Suppression

Ta2 - 2 | Intelligent Decision Making in Resource Management for Wildfire Suppression

Mahdi Bashiri[1], Preetha Ramia[2], Maureen Meadow[3]

[1]Centre for Business in Society, Coventry University, Coventry, UK, mahdi.bashiri@coventry.ac.uk

[2]Centre for Business in Society, Coventry University, Coventry, UK, ae4235@coventry.ac.uk

[3]Centre for Business in Society, Coventry University, Coventry, UK, ac3495@coventry.ac.uk

Effective decision-making in disaster preparedness is a crucial factor for mitigating the impact of such events. This is much more important for the wildfire events. In this study, a novel methodology is proposed that utilizes image processing to identify the pattern of fire spread over time, taking into account environmental factors and all fire suppression activities. This intelligent mechanism will be helpful to identify a pattern of the fire spreading. Then after analysing such behaviour, a mathematical model is utilized to identify the best resource allocation of any preventive or fire suppression activities during the upcoming time. The proposed mechanism will enhance decision-making for fire suppression teams, enabling more effective control of fire behaviour with greater efficiency in terms of quick response and operational costs. A simulated numerical study is provided to discuss the applicability of the proposed methodology. The analysis results are compared with the following cases: case a (without image processing), case b (without optimization), and case c (without either image processing or mathematical modelling). Effectiveness of the proposed methodology is evaluated considering some potential scenarios.

Keywords: Fire Suppression· Image Processing· Optimization·Machine Learning·Decision Making

Ta2 - 3 | Heuristics for Wildfire Suppressibility in Victoria, Australia

Kristy Butler[1], Elena Tartaglia[2], Jason Rennie[3], Stephen Deutsch[4], Nick McCarthy[5]

[1]Country Fire Authority, Melbourne, Australia, kristy.butler@cfa.vic.gov.au

[2]Department of Energy, Environment and Climate Action, Melbourne, Australia, elena.tartaglia@delwp.vic.gov.au

[3]Department of Energy, Environment and Climate Action, Melbourne, Australia, jason.rennie@delwp.vic.gov.au

[4]Department of Energy, Environment and Climate Action, Melbourne, Australia, stephen.deutsch@delwp.vic.gov.au

[5]Country Fire Authority, Melbourne, Australia, nick.mccarthy@cfa.vic.gov.au

In bushfire response, rapid decision-making is critical to determining the appropriate allocation of resources when respond to an incident. Heuristics, or rules-of-thumb, are simple decision-making frameworks that are widely used in bushfire operations. These rules often arise from operational experience, rather than being developed scientifically through experiments or observational data. Prior research has scientifically verified heuristics related to wildfire rates of spread [1,2], and this provides practical, evidence-based guidelines which operations staff can apply in the field with basic intelligence such as wind speeds.

Fire practitioners also use similar rules-of-thumb for predicting suppressibility of wildfires in the initial attack phase. These are related to weather, fuel and topography attributes. We will test heuristics currently used in operations for bushfire response in Victoria, Australia, through empirical data collected on fires in Victoria from 2008 to present day. We will also explore the trade-off between the accuracy provided by complex statistical models versus simpler heuristic rules and discuss when each method is appropriate. This work shows the value of simple decision-making frameworks like heuristics for making rapid decisions in time- and intelligence limited environments.

References:

[1] Cruz, M. G. & Alexander M. E. (2019). The 10% Wind Speed Rule of Thumb for Estimating a WildfireŠs Forward Rate of Spread in Forests and Shrublands. *Annals of Forest Science*, 76 (44). https://doi.org/10.1007/s13595-019-0829-8

[2] Cruz, M. G., Alexander, M. E., & Kilinc, M. (2022). Wildfire Rates of Spread in Grasslands under Critical Burning Conditions. *Fire*, 5 (55). https://doi.org/10.3390/fire5020055

Keywords: Heuristics· Suppression· Statistics· Empirical Data

Ta3 - 1 | Data-driven Approach for the Optimization Problem in Fire Suppression

Mauro Rebelo Barros[1], André Bergsten Mendes[2], Filipe Alvelos[3], Mostafa Rezaei[4]

[1]Dep. de Engenharia Naval e Oceânica, Universidade de São Paulo, mauro.rebelo.barros@usp.br

[2]Dep. de Engenharia Naval e Oceânica, Universidade de São Paulo, andbergs@usp.br

[3]Departamento de Produção e Sistemas, Universidade do Minho, falvelos@dps.uminho.pt

[4]Information and Operations Management, ESCP Business School, mrezaei@escp.eu

The increasing number and intensity of wildfires represents a serious threat to the environment and human communities. As a form of aiding computational strategies of fire control and suppression, this study presents an approach to data modeling and preparation through the treatment and integration of different data sources and formats, enhancing machine learning and optimization frameworks.

We apply procedures that include value normalization, null values filling, and inconsistency correction in order to prepare the data for statistical analysis and a subsequent use in robust and stochastic optimization models. Data integration is achieved using flexible frameworks that combine meteorological, topographical, and historical fire data, among others.

The developed data processing environment enables the application of techniques involving the use of fire specific predictive libraries. We use specialized libraries like the Canadian Forest Fire Danger Rating System (CFFDRS) to assess and predict wildfire danger.

Future development will refine the integration framework and validate optimization models through simulations and real-world applications. Our goal is to create a system for effective wildfire management that takes advantage of different predictions systems through data to achieve better optimization quality.

Keywords: Data-Driven· Wildfires· Fire Behavior

Ta3 - 2 | Leveraging Automatic Vehicle Location Data to Quantify Fireground Operations in Victoria, Australia

Kristy Butler[1], Nick McCarthy[2]

[1]Country Fire Authority, Melbourne, Australia, kristy.butler@cfa.vic.gov.au

[2]Country Fire Authority, Melbourne, Australia, nick.mccarthy@cfa.vic.gov.au

Optimization of fireground operations is a key challenge for fire agencies, particularly as wildfires trend towards more destructive. As response resources become stretched, trade-offs in safety and effectiveness will require resources to do more with less. Empirical data on fireground operations is important for decision support in these cases, but challenging to collect in active emergency situations.

In Victoria, Australia, fire agencies have been utilising Automatic Vehicle Location (AVL) data from fireground vehicles and aircraft to collect this evidence. Our approach combines AVL points with field and fire progression data to quantify aspects of response, such as fire control production rates (e.g. “pump and roll” by fire trucks) and bottlenecks like refilling water and offroad mobility. We have developed activity profiles, showing resource time proportioned by response tasks like direct attack, asset protection and auxiliary operations. Critical to this has been the development of ’resource tracking explorers’, custom dashboards that allow sub-sampling of AVL data alongside reanimations of modelled and real fire progression.

The dashboards and analysis demonstrate a passive data collection approach that provides empirical evidence on fireground operations at a state-wide scale. Linking operations with training, fleet analytics and research in Victoria has led to advances in thinking about our current response patterns, and how to improve our future response.

Keywords: Automatic Vehicle Location· Quantification· Resource Allocation

Ta3 - 3 | Forest Road Network for Firefighter Access

Miguel Constantino[1], Marta Mesquita[2], Mariana Sempiterno[3]

[1]Faculdade de Ciências da Universidade de Lisboa and Centro de Matemática, Aplicações Fundamentais e Investigação Operacional, Lisbon, Portugal, mfconstantino@fc.ul.pt

[2]Instituto Superior de Agronomia and Centro de Matemática, Aplicações Fundamentais e Investigação Operacional, Lisbon, Portugal, martaoliv@isa.ulisboa.pt

[3]Faculdade de Ciências da Universidade de Lisboa, Lisbon, Portugal, fc53757@alunos.ciencias.ulisboa.pt

Forest fires pose a growing threat to the environment, economy, and human life, demanding immediate prevention and firefighting strategies. Despite the vital role of forest roads in granting access to firefighters, their planning frequently overlooks firefighting requirements. In this presentation, we introduce models designed to identify the most cost-effective road network for ensuring firefighter access to the forest within a 200-meter range. We discuss models for both single-path and dual-path access. Additionally, we present results from a case study conducted in the Vale do Sousa forest.

Keywords: Forest Roads· Firefighter Access· Integer Programming Models

Ta4 - 1 | The Graph Burning Problem under Constrained Diffusion

Enrico Iurlano[1], Günther R. Raidl[2], Marko Djukanović[3]

[1]Algorithms and Complexity Group, TU Wien, Austria, eiurlano@ac.tuwien.ac.at

[2]Algorithms and Complexity Group, TU Wien, Austria, raidl@ac.tuwien.ac.at

[3]Faculty of Natural Sciences and Mathematics, University of Banja Luka, Bosnia and Herzegovina, marko.djukanovic@pmf.unibl.org

The Graph Burning Problem [1] is a combinatorial optimization problem yielding a metric for social contagion. It relies on a simplified model of the spread of fire, reflected in a discrete-time process on a simple undirected graph $G = (V, E)$ having in each timestep a propagation phase of fire locally and entirely around "burned" vertices and a phase where a next not-yet burned vertex is made burned.

As solutions to this problem may be of higher relevance when we take into account the fact that, e.g., fire, a virus, or information is hardly spread around without any local spread-preventing countermeasures or obstacles, we propose the *Constrained Diffusion Graph Burning Problem* (CDGBP, or θ-GBP for short): Here we consider thresholds $\theta_v \in \mathbb{N} \cup \{0\}$, $v \in V$, on how many neighboring vertices can at most be ignited by v while permitting burned vertices to spread their fire only immediately after their status changed to burned, but not to a later timepoint.

The first assumption is here in the spirit of the aforementioned countermeasures (such as, e.g., units of firefighters) and the second one mimics the fact that burned territories cannot reignite.

We provide and empirically compare two different mixed integer linear programming formulations, both relying on a multi-commodity flow approach.

Finally, we state several open questions concerning combinatorial properties of the θ-GBP.

Reference:

[1] Bonato, A., Janssen, J., & Roshanbin, E.: Burning a graph as a model of social contagion. In: Bonato, A., Graham,F.C., Prałat, P. (eds.) Algorithms and Models for the Web Graph. WAW 2014. LNCS, vol. 8882, pp. 13–22. Springer International Publishing, Cham (2014).

Keywords: Social Contagion Model· Fire Spread Simulation· Integer Linear Programming

Ta4 - 2 | A Dash Interface for the pyO3F Framework

Marco Marto[1], Filipe Alvelos[2]

[1]ALGORITMI Research Center / LASI, University of Minho, 4710-057 Braga, Portugal, marcovmarto@gmail.com

[2]Department of Production and Systems / ALGORITMI Research Center / LASI, University of Minho, 4710-057 Braga, Portugal, falvelos@dps.uminho.pt

We present a Dash interface for the Python framework, pyO3F, which aims to support the development of optimization approaches for wildfire-related problems. We provide an overview of the main modules of pyO3F, their interactions, and the information they use to model fire behavior, fire spread scenarios, and different types of firefighting resources.

The interface was built as a prototype to assist the user of pyO3F in selecting an area of interest in mainland Portuguese territory. All the required information for the available methods (i.e. land use and elevation) is gathered in a transparent way to the user. Based on that information and some configuration parameters (e.g. resolution), networks representing firefighting resources movements and fire potential transmission between adjacent cells are created and displayed.

At current state of development of the interface, after choosing a wind behavior, the user can simulate fire spread or optimize the dispatching, positioning and routing of multiple resources types in the initial attack.

The interfaces are built with the support of NetworkX, Geopandas, GDAL, Rasterio, Dash, and other related Python modules. This working environment interacts with the main modules of the pyO3F framework, and has the final goal of demonstrate the potential of the pyO3F approaches to fire-related decision-makers.

Keywords: pyO3F· Python Dash· Fire Spread· Fire Suppression

Ta4 - 3 | The Wildfire Safety Paths Problem

Marta Pascoal[1], Marco Marto[2], Iftikhar Ahmad[3], Filipe Alvelos[4]

[1]Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Italy; Universidade de Coimbra, INESC-Coimbra, Portugal, marta.brazpascoal@polimi.it

[2]ALGORITMI Research Center / LASI, University of Minho, 4710-057 Braga, Portugal, marcovmarto@gmail.com

[3]ALGORITMI Research Center / LASI, University of Minho, 4710-057 Braga, Portugal, iftikharsaim825@gmail.com

[4]Department of Production and Systems / ALGORITMI Research Center / LASI, University of Minho, 4710-057 Braga, Portugal, falvelos@dps.uminho.pt

We consider a network representing a landscape in which some of the areas become unavailable or too dangerous to cross after a certain time. The distance, or time, associated with each arc of the network are assumed to be known. Moreover, in the context of wildfires spreading, we also assume that the time at which each arc becomes unavailable can be estimated. We address the problem of determining a pair of paths that link a given origin node to a given destination node in that network, so as to minimize the total distance, or time, of the two paths and in such a way that both are distant enough from the areas that are expected to be affected by the fire. The disjointness of the two paths is imposed for the sake of reliability, to increase the odds that at least one of them is viable in case of an unforeseen change in the fire spread. The problem is formulated as a maximum flow problem in a time-dependent network. An algorithm based on augmenting paths in an extended time network is described and computational experiments are presented.

Funding: Partially supported by FCT - Fundação para a Ciência e Tecnologia within the R&D Units projects UIDB/00308/2020, UIDB/00319/2020, UIDB/00324/2020 and the project PCIF/GRF/0141/2019 "O3F - An Optimization Framework to Reduce Forest Fire".

References:

[1] Mendes, A. B., & e Alvelos, F. P. (2023). Iterated local search for the placement of wildland fire suppression resources. *European Journal of Operational Research*, 304(3), 887-900.

[2] Sherali, H. D., Ozbay, K., & Subramanian, S. (1998). The time-dependent shortest pair of disjoint paths problem: Complexity, models, and algorithms. *Networks: An International Journal*, 31(4), 259-272.

Keywords: Disjoint Paths· Wildfires· Time-Dependent Networks· Maximum Flow Problem

Fm1 - 1 | The Use of a Cell-based Forest Fire Growth Model to Support Strategic Landscape Management Planning in a Portuguese Landscape

Susete Marques[1], Jaime Carrasco[2], Andrés Weintraub[3], José C. Borges[4]

[1]Centro de Estudos Florestais, Laboratório Associado TERRA, Instituto Superior de Agronomia, Lisboa, Portugal. smarques@isa.ulisboa.pt

[2]Complex Engineering System Institute-ISCI, Santiago, Chile, jaimecarrasco@fire2a.com

[3]Department of Industrial Engineering, University of Chile, Santiago, Chile, aweintra@dii.uchile.cl

[4]Centro de Estudos Florestais, Laboratório Associado TERRA, Instituto Superior de Agronomia, Lisboa, Portugal, joseborges@isa.ulisboa.pt

Cell2Fire is a cutting-edge simulator for wildland fire growth that uses a cell-based approach to integrate data-driven landscape management planning models. By dividing the landscape into cells defined by fuel, weather, moisture content, and topographic attributes, it models the fire environment effectively. This simulator incorporated existing national fuel models developed by Fernandes et al 2009 and fire spread parameters to simulate fire growth. Its structure allows for easy prediction of individual fire growth and integration into landscape management simulation models.

Decision-making models like fuel treatment, fuel break design and harvesting plans can be seamlessly integrated and evaluated within this simulator. The simulator includes a range of pre-configured planning heuristics, providing benchmarks for comparison. We demonstrated the application of these heuristics by evaluating various harvesting plans in a forested landscape, (Vale do Sousa), 50km East from Oporto, Portugal.

Keywords: Fire Behaviour Simulators· Optimization· Fuel Break Design· Harvest Plans

Fm1 - 2 | A Surrogate-Model-Based Algorithm for Multi-objective Optimization

Aboozar Mohammadi[1], Davood Hajinezhad[2]

[1]CIBIO - Centro de Investigação em Biodiversidade e Recursos Genéticos, Vairão, Portugal, aboozar.mohammadi@cibio.up.pt

[2]AI Center of Excellence, Fidelity Investment Corp., Boston, USA, dhajinezhad@gmail.com

Multi-objective optimization spans various disciplines, having applications in fields such as science, engineering, finance, and medicine. In the context of wildfire decision-making, it can be particularly valuable where the goal is to address various issues simultaneously.

Since objective function components often conflict with each other, it is impossible to find a single point that optimizes all components simultaneously. Instead, the solution is found within the Pareto front, which consists of a set of nondominated points representing the best trade-offs among the conflicting objectives.

In this work, we present a surrogate-model-based algorithm to approximate the complete Pareto front for multi-objective optimization problems where the objective function components are black-box functions. We work under the assumption that the derivatives of the objective function components are unavailable and impossible to estimate, such as in simulation optimization. This algorithm can be particularly useful in wildfire decision problems, where the conflicting objectives are represented by black-box functions.

To address the challenge posed by the lack of derivatives, we introduce a new technique based on the polynomial interpolation approach to build models that approximate different objective function components. We will present numerical results to demonstrate that this algorithm is numerically competitive against state-of-the-art algorithms.

Keywords: Multi-Objective Optimization· Interpolation-Based Models· Black-Box Optimization· Pareto Front

Fm1 - 3 | Alleviating the Impact of Wildfires in Forest Management Planning and Supply Chain Activities

Shuva Gautam[1], Luc LeBel[2], Bibek Subedi[3]

[1]Université Laval, Quebec City, Canada, shuva-hari.gautam@sbf.ulaval.ca

[2]Université Laval, Quebec City, Canada, Luc.Lebel@sbf.ulaval.ca

[3]Université Laval, Quebec City, Canada, Bibek.subedi.1@ulaval.ca

Forest management planning on public land in the province of Quebec, Canada has become quite complex due to an increasing emphasis on social and environmental concerns. As a result, harvest plans at the operational level have become quite rigid. An elaborate multi-hierarchical planning process precedes harvesting activities. Occurrence of uncertain events such as fire on the planned harvest areas severely impacts both the government and forest products supply chains financially. This research focuses on two important issues, i) optimization of salvage operations to recuperate damaged wood and ii) rapid replanning to identify new harvest areas to ensure forest supply chains are not impacted. A linear programming model was used to quantify feasible levels of salvage volumes that can be brought to processing mills. In the highest disturbance rate scenario, salvage logging could make up for approximately 20% of the loss. Additionally, the use of artificial intelligence to facilitate rapid replanning is being explored. In Quebec, cutblocks are embedded within Spatial Organization Compartments (COS). The delineation of COS is a rigorous and prolonged process carried out manually using GIS software. As such, delineation of COS is a bottleneck for rapid replanning when disturbance events such as fire occur. Machine learning-based methods are being explored to automate the delineation process. The proposed method will be integrated into the provincial planning process to evaluate its performance. Preliminary research findings will be discussed.

Keywords: Forest Management Planning · Spatial Constraint · Replanning

Fm1 - 4 | Modelling Wind Behaviour for the Development of Scenarios in the Context of Wildfire Spread

Helena Alvelos[1], Francisco Marques[2], Ana Raquel Xambre[3], Agostinho Agra[4], Filipe Alvelos[5]

[1]CIDMA, DEGEIT, University of Aveiro, Aveiro, Portugal, helena.alvelos@ua.pt

[2]DMAT, University of Aveiro, Aveiro, Portugal, franciscocmarques@ua.pt

[3]CIDMA, DEGEIT, University of Aveiro, Aveiro, Portugal, raquelx@ua.pt

[4]CIDMA, DMAT, University of Aveiro, Aveiro, Portugal, aagra@ua.pt

[5]ALGORITMI Research Center and LASI, University of Minho, Braga, Portugal, falvelos@dps.uminho.pt

Wildfires cause significant losses in both material value and human lives and are becoming a frequent problem, also due to climate change. Preventing their occurrence or reducing their effect is a crucial issue.
This work is part of a project that uses optimisation models for the prepositioning of resources, and for resource movement during the suppression phase. These problems involve several sources of uncertainty, one of which is the behaviour of the wind (direction and speed).
It is then of the utmost importance to obtain statistical information about wind speed and direction. The aim of this work is to model historical wind data of a case study region in Portugal. For that purpose, several statistical techniques were used (e.g. descriptive statistics, correlation analysis, goodness of fit tests, cluster analysis) in order to better understand the data.
It was decided to use the empirical distributions of wind speed and wind direction instead of fitting theoretical distributions like the Weibull Distribution used in the literature, as there is a large quantity of data available. For this, the data was split into three wildfire risk seasons: low (November, December, January), medium (March, April, May and October) and high (June, July, August and September).
Using the data from the high risk season, the values of wind speed (5 values) and of wind direction (8 values) and their respective estimated probabilities were used in order to create scenarios for optimisation models.

Keywords: Wildfire· Wind Speed· Wind Direction· Statistical Analysis

Fm2 - 1 | Predicting Demand for Wildfire Suppression Resources

Ilbin Lee[1], Yasser Zeinali[2], Mostafa Rezaei[3]

[1]Alberta School of Business, University of Alberta, Edmonton, Canada, ilbin@ualberta.ca

[2]Alberta School of Business, University of Alberta, Edmonton, Canada, yzeinali@ualberta.ca

[3]ESCP Business School, Paris, France, mrezaei@escp.eu

Wildfires posed significant damage recently as a global threat. For example, Canada reports over 8,000 wildfires annually, burning millions of hectares. The situation escalated in 2023, and the total burned area in Canada was over 18.5 million hectares. Wildfire management agencies are under intense pressure to devise an effective resource allocation strategy. In this work, collaborating with the Alberta government, we integrate machine learning, queuing theory, and robust mixed integer programming to develop a predictive and prescriptive system for deploying wildfire suppression resources. This system predicts the total resource hours and the number of fires for tomorrow and then determines the number of resources to satisfy a waiting time target. Although our case study focuses on Alberta, our methodologies are adaptable and can potentially be tailored to meet the challenges of wildfire management in other regions.

Keywords: Wildfire Suppression· Resource Deployment· Prediction and Optimization

Fm2 - 2 | Experimental and Numerical Study of Biomass Thermal Conversion in a Small-scale Reactor

Senhorinha F. C. F. Teixeira[1], João Pedro V. Silva[2], José Carlos F. Teixeira[3]

[1]Department of Production and Systems, University of Minho, Guimarães, Portugal, jt@dem.uminho.pt

[2]Department of Mechanical Engineering, University of Minho, Guimarães, Portugal, js@dem.uminho.pt

[3]Department of Mechanical Engineering, University of Minho, Guimarães, Portugal, st@dps.uminho.pt

The development of experiments in a controlled environment, and repeatable conditions, allow precise measurements. This task is fundamental to understanding the transport phenomena at the particle level in order to further obtain reliable results and information for further proper biomass combustion modeling in large-scale equipment. During the combustion of biomass in a grate-fired boiler, each particle undergoes a sequence of different reactions, and the phenomena differ from the conversion of a single, thermally thin, particle. Hence, this work presents the results of isothermal conversion experiments using large particles in a small-scale reactor. Firstly, the weight loss characteristics of eucalyptus samples were investigated at isothermal temperatures equivalent to conditions equivalent to the environment inside industrial furnaces. Additionally, the mass loss rate together with the composition of the gases over the devolatilization period was analyzed. This is particularly important to identify the transport phenomena effect and the gaseous products released during the combustion of biomass. Finally, all the information collected in this work was used to develop an effective numerical model to predict the thermal conversion behavior observed in the experiments from the small-scale reactor. Regarding the results, the numerical model provided similar weight loss values compared to the experimental results. Therefore, the model fitted well to the experiments, although in the second stage of the particle conversion, the char combustion, the kinetic model adopted in this work presents some difficulties in predicting the same mass loss behavior. It should be pointed out that this work is particularly important to validate the mathematical model that will be the basis for the development of a CFD model to study the combustion behavior inside an industrial grate-fired boiler.

Keywords: Biomass· Combustion· MacroTGA· Thermal Decomposition

Fm2 - 3 | Comparing Post-fire Mortality in Spanish Forests: Mixed Stands and Different Fire Strategies Exhibit Higher Damage

Marina Peris-Llopis[1], Blas Mola-Yudego[2], Frank Berninger[3], Jordi Garcia-Gonzalo[4], José Ramón González-Olabarria[5]

[1]School of Forest Sciences, University of Eastern Finland, Joensuu, Finland, marina.peris.llopis@uef.fi

[2]School of Forest Sciences, University of Eastern Finland, Joensuu, Finland, blas.mola@yudego.fi

[3]Department of Environmental and Biological Sciences, University of Eastern Finland, Joensuu, Finland, frank.beringer@uef.fi

[4]Joint Research Unit CTFC - AGROTECNIO, Solsona, Spain, j.garcia@ctfc.cat

[5]Joint Research Unit CTFC - AGROTECNIO, Solsona, Spain, jr.gonzalez@ctfc.cat

Mixed forests are recognized for promoting biodiversity and providing various ecosystem services and have long been regarded as having higher resilience and resistance to disturbances, notably fire. However, recent research challenges this notion, suggesting that the composition of mixed forests influences their vulnerability to fire damage. To investigate this, we compare post-fire tree mortality in mixed and pure stands across Spain, analysing data from 2,782 plots for the period 1986-2007. Contrary to prevailing assumptions, our findings reveal that mixed stands can exhibit higher post-fire mortality than pure stands. Notably, specific mixtures of tree species with differing fire-related strategies were identified as exacerbating the vulnerability of stands to fire damage when compared to pure stands of either species. Our analysis also indicates that fire damage varies with changes in species occupation in the mixtures. This underscores the significance of considering not only the presence of multiple species but also their levels and interactions within mixed forests. These findings call for a reassessment of the role and management strategies for mixed forests in the context of fire resilience. Rather than viewing mixed forests as uniformly resilient to fire, it is important to acknowledge the dynamics at play concerning species composition and fire-related strategies.

Keywords: Mixed Forest· Fire Damage· Fire Strategy· Species Traits

Fm2 - 4 | Rethinking Milling Capacity Investments in Support of Fuel Reduction Thinning Programs in the Western United States

Greg Latta[1], Zoey Roberts[2]

[1]University of Idaho, Moscow, United States, glatta@uidaho.edu

[2]University of Idaho, Moscow, United States, zroberts@uidaho.edu

At 64%, the Federal Government is the largest forestland owner in the Western United States. These lands provide essential ecosystem services, including wildlife habitat, recreational opportunities, air and water filtration, as well as forest products and jobs in local economies. Decades of fire suppression coupled with reduced federal harvest levels have led to a buildup of fuels, increased forest density, and escalating fire, disease, and insect epidemics. Between 1987 and 2001, the volume of timber sold from national forests dropped 90%, with a modest increase since. Mortality has increased 388.8%, causing eight of eleven western states become a source of greenhouse gas (GHG) emissions. The reduction in federal harvest led to a mill closures, indirectly affecting costs and management opportunities. This is exacerbated by merchantability issues due to long-haul distances. We aim to inform policymakers and market participants about the potential effects of expanding federal harvest in the western U.S. on national GHG accounts and rural economies. We use a spatial partial equilibrium model to explore scenarios based on expanding federal harvest and mill capacity. For each scenario, we evaluate changes in rural economies related to transportation logistics and merchandizing of logs at manufacturing facilities. The study provides insights for balanced forest management policies supporting both environmental and economic objectives.

Keywords: Capacity Investment· Partial Equilibrium Model· Forest Products Markets

Fm2 - 5 | FyMIS Simulator: A Versatile Tool for the Economic Evaluation of Alternative (Re)Forestation Strategies

Abílio Pereira Pacheco[1], Fábio A. Gonçalves[2], Rui Almeida[3], Pedro V. Lopes[4], A. Miguel Gomes[5]

[1]CoLAB ForestWISE, FEUP, INESC TEC (CITE), Porto, Portugal, abilio.p.pacheco@gmail.com

[2]Euronext, Porto, Portugal, fabiogoncalves_fafe@hotmail.com

[3]ICNF, FEUP (DEGI), INESC TEC (CITE), Lisboa, Portugal, rui.almeida@icnf.pt

[4]FEUP, Porto, Portugal, up201505806@edu.fe.up.pt

[5]FEUP (DEGI), INESC TEC, Porto, Portugal, agomes@fe.up.pt

The fire situation in Portugal over the years demonstrates a forest management problem. Therefore, there is a need to rethink alternative reforestation strategies in post-fire scenarios. This work aims to develop a simulator to support decisions in post-fire scenarios better.

FyMIS (Forestry Management Investment Simulator) evaluates the economic feasibility of different alternative reforestation strategies for different species present in the Portuguese forest. These strategies are based on two distinct reforestation methods in a post-fire scenario: active regeneration (planted forest and seeded forest) and passive regeneration (natural regeneration). Additionally, simulators that include growth models of forest stands were used to project the evolution of forest stands of these species over the defined time horizon. The results of these simulators were grouped to be used in the calculation of the operational results of each strategy. In addition to indicating the best investment strategy, the simulator allows the simulation of a fire occurrence during the considered time horizon and evaluating its impact on the operating result, the analysis of the weight of each forestry operation in the total costs, the annual evolution of the costs of forestry operations and the annual evolution of the Net Present Value, the Internal Rate of Return and payback.

Keywords: Post-Fire· Decision Support Systems· Economic Evaluation· Public Policy

Authors Index

Keywords Index

Supported by

- Portuguese Foundation for Science and Technology (FCT) through Project O3F - An Optimization Framework to reduce Forest Fire (PCIF/GRF/0141/2019, https://doi.org/10.54499/PCIF/GRF/0141/2019)
- International Union of Forest Research Organizations (IUFRO)
- Portuguese Association of Operational Research (APDIO)
- University of Minho
- University of Aveiro
- School of Agriculture of University of Lisbon
- ALGORITMI Research Center (UIDB/00319/2020)
- CIDMA - Center for Research and Development in Mathematics and Applications (UIDB/04106/2020, https://doi.org/10.54499/UIDB/04106/2020)
- CMAFcIO - Center of Mathematics, Fundamental Applications and Operations Research (UIDB/04561/2020, https://doi.org/10.54499/UIDB/04561/2020)