

# Networks for Integrated Wildfire Management: A Social Network Analysis Approach

**Diogo Vallim**

Copenhagen Business School  
dv.msc@cbs.dk

**Anna Schmid**

Copenhagen Business School  
ajcs.msc@cbs.dk

**Efthymios Altsitsiadis**

Copenhagen Business School  
ea.msc@cbs.dk

**Amalia Giannakopoulou**

Copenhagen Business School  
agi.msc@cbs.dk

**David Struthers**

Copenhagen Business School  
dst.msc@cbs.dk

**Isabel Fróes**

Copenhagen Business School  
ifr.msc@cbs.dk

## ABSTRACT

Wildfires, exacerbated by climate extremes, pose escalating global threats. Despite advancements in technology, current wildfire management policies lack specific details about integrated management and stakeholder engagement. This study provides empirical evidence on how five European wildfire management locations align with networked governance models by analyzing how their stakeholder networks are configured through social network analysis (SNA). This is measured by assessing network configuration and stakeholder group profiles. Measurements at the network level assess the size, density, diversity of sectors, scalar levels of operation, and phases. At stakeholder level, relevance is assessed by measuring in degree, eccentricity, closeness centrality, and betweenness centrality. Analysis qualitatively assesses the network profile, leading to the discussion on the primary factors influencing network configurations and the potential outcomes of these attributes.

## KEYWORDS

Integrated Wildfire Management, Social Network Analysis, Stakeholders Analysis

## FUNDING DECLARATION

*This research has received funding from the European Union's Horizon 2020 programme under grant agreement No 101036926 (A Holistic Fire Management Ecosystem for Prevention, Detection and Restoration of Environmental Disasters [TREEADS]). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.*

## INTRODUCTION

The frequency of wildfires and the risk they pose is increasing, exacerbated by extreme climate events such as heatwaves and droughts. In the past five years, Portugal (2017), Greece, (2023), and other locations experienced devastating fires, highlighting the severity of the issue. Inadequate disaster and forest management increase the short-term impact and long-term repercussions of wildfires (Marie & Labossière, 2015; Pearce, 2003; Pereira et al., 2016). These events prompted extensive discussion on the necessity of improving existing mechanisms, collaborations, and management approaches. Beyond advancements in technology, stakeholders emphasize the importance of integrated strategies spanning wildfire management phases, focusing on actors, governance, technology, and socio-economic factors. Within the European Union, the integrated approach is promoted through projects funded by Horizon 2020 Innovation Action grants and Union Civil Protection Calls.

Wildfire management is as a collective action problem requiring strong coordination among stakeholders (Chamley et al., 2020). Engaging diverse stakeholders in collaborative processes that integrate environmental information into decision-making is crucial, but also challenging. It is necessary to work at and across the boundaries of knowledge types, which involves navigating complex environments and multiple stakeholder-engagement processes that can promote knowledge exchange and co-creation (Sitas et al., 2016). Despite developments in comprehensive wildfire management, prevailing strategies lack detail about how to identify relevant stakeholders and the purpose of stakeholder engagement. Crucially, there is also little research evaluating existing levels of stakeholder engagement in the contexts where these processes are situated. A changing environment, the need to disseminate information, complex decision-making processes, and insufficient understanding of all actors increase the risk of managerial mistakes (Battistoni et al., 2020).

A central tenant in comprehensive wildfire management involves transitioning from a paradigm focused solely on enhancing the efficiency of civil protection services in response to wildfires to a model that prioritizes risk identification and assessment, coupled with proactive prevention measures. The use of SNA methods in wildfire management research is justified by recent calls from academics, land managers, and policymakers for an approach to wildfire risk management that works across sectors to consider the needs of different stakeholders in risk assessment and communication efforts (AGIF, 2023; Casartelli, & Mysiak, 2023; Chuvieco et al., 2023; United Nations, 2015). These calls to bridge gaps across sectors and scalar levels of operations fits into the debate on integrated wildfire management that began in the 1980s. The issue has become more pressing in recent years as the frequency of catastrophic fires increases along with demand that land management processes align with economic, public, and environmental pressures (Ferrara et al., 2019; Moore, 2019).

Successfully implementing this new approach to wildfire risk management is contingent on stakeholder engagement. For example, the significance and effectiveness of governing institutions may not align with their formal roles, or specific information on practices may be held by stakeholders not formally participating in governance. Social network analysis (SNA) is a valuable tool for examining the dynamics of social interactions, which cannot be fully grasped by only examining formal institutions in a natural resource governance system. It provides insights on the most relevant actors within a given a network, how these actors collaborate, and how information flows in systems across different scalar levels in wildfire management contexts within the European Union.

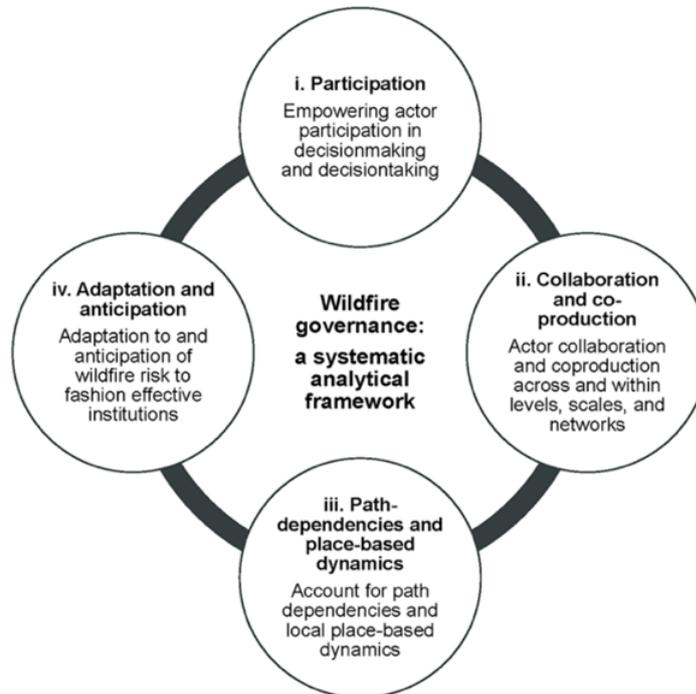
## LITERATURE REVIEW

Changes in wildland-urban interfaces, climate change, and inadequate forest and disaster management increase the severity of wildfires and the complexity of wildfire management (Marie & Labossière, 2015; Pearce, 2003; Pereira et al., 2016). A new wildfire management approach is needed to effectively adapt to these changes.

Governments, policy experts, and researchers have extensively discussed the necessity of improving existing governance mechanisms, collaborations, and management approaches to wildfires. Beyond the adoption of new technologies, they emphasize the importance of integrated strategies encompassing all wildfire management phases by focusing on stakeholders, governance, technologies, and socio-economic factors. Understanding wildfire management as a collective action problem that requires strong coordination among stakeholders is key to successfully shifting approaches (Chamley et al., 2020). Engaging diverse stakeholders in collaborative processes involves navigating complex environments (value systems, social conventions, and mental models) through multiple stakeholder-engagement processes that can promote knowledge exchange and co-creation (Sitas et al., 2016). The long-term complexity of these issues is evidenced by what researchers refer to as the “wildfire paradox” created by fire suppression strategies, including public awareness campaigns aimed at preventing wildfires. Fewer fires in the short term raises the fire risk from stored fuel (Calkin et al., 2015).

Limiting management fires also contributes to excess fuel storage. Scholars and policy makers in wildfire-prone regions argued that past approaches to fire suppression and climate change necessitate society creating “a new relationship with fire” (Thompson et al., 2018, p. 382).

Efforts to formulate pathways to change entail realigning priorities and risk sharing among multiple public and private stakeholders and viewing wildfire governance as a “social-ecological problem” (Stelman, 2016). Making these shifts, however, opens complexity that needs to be managed by policy makers, practitioners, and researchers. Relationships between stakeholders and distinct stakeholder understandings of the risks posed by wildfires need to be factored into effective wildfire governance strategies. However, Kirschner et al. (2023) noted imprecise definitions and the lack of a consistent approach to studying wildfire governance. The authors proposed a four-part analytic framework of participation, collaboration and co-production, path-dependencies and place-based dynamics, and adaptation and anticipation.



**Figure 1: Wildfire Governance Framework (Source: Kirschner et al., 2023)**

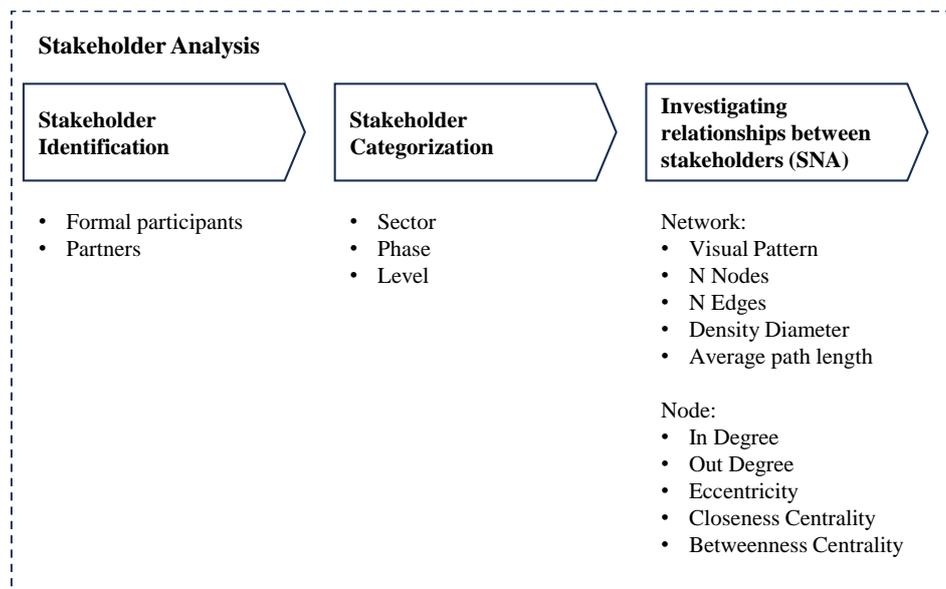
Kirschner et al. (2023) is an important reframing that provides analytical categories for understanding relationships among stakeholders and governance processes. Research by networked governance scholars resonate with these categories. Provan and Kenis (2007) documented three types of network governance—participant-governed networks, lead organization-governed networks, and network administrative organization—and developed criteria for evaluating the effectiveness of network governance. Addressing complex issues demanding multilateral coordination in areas such as disaster management, economic development, or social services requires achieving the goals of multiple organizations (Provan and Kenis, 2007; O’Toole, 1997).

Bodin & Nohrstedt (2016) built on this knowledge to develop a model to “empirically investigate relationships between task interdependency and collaborative (social) network structures” (p. 184). The authors argued for “the importance of moving beyond simplified assertions of the utility of collaborative governance in addressing disasters by enabling more precise and theoretically informed empirical inquiries regarding the mechanisms that shape the structure and performance of collaborative networks” (p. 192). Carboni et al.’s (2019) examination of purpose-oriented networks draws our attention back to the goal of the project pilots, namely, improving wildfire response, which their work provides theoretical insight to evaluate.



or are impacted by wildfire regimes in the target regions, develop knowledge about their relationships, and determine their relevance in the wildfire management process. The approach follows Wasserman and Faust (1994) and Carrington et al. (2009) that advocate for the importance of networks as the primary units of analysis. The relationships between stakeholders are of primary interest and the attributes of stakeholders arise from the relational processes in which they are integrated.

Our approach follows Reed et al. (2009) and Ahmadi (2019) work on stakeholder analysis in natural resource governance. Stakeholder analysis is a process that starts with identifying stakeholders (I), before categorizing (II) and mapping (III) their relationships through social network analysis (SNA).



**Figure 3. Stakeholder Analysis Method**

Adapted from Reed et al., 2009.

### Area of Study

The study was conducted as part of a Horizon 2020 project aimed at developing technological solutions to promote holistic wildfire management in the European Union. Technology development was performed in pilot regions where a stakeholder group or organization (henceforth “pilot leader”) established a network of collaborators to achieve specific project objectives such as conducting experiments, exercises, prototype testing, or developing risk management plans. Governmental institutions formally participated in all the pilots from their launch and new actors were engaged during implementation, with the networks growing as the project progressed.

The pilots are being implemented over a 42-month period between December 2022 and May 2026. For the purposes of this study, we selected the pilots with the five largest networks out of the eight project pilots. The pilots selected were in Austria, Greece, Italy, Norway, and Spain. These pilots comprise different scopes, landscapes, weather conditions, socio-economic characteristics, and wildfire management systems.

**Table 1. Profiles of the Pilot Cases**

Country	Leader Profile	Focus	Scope
Norway	Research Institution	Preparedness for wildfires in northern Europe	Field exercises on forest fires to enhance prevention and preparedness. Test fire protection technologies. Development of guidelines for safety zones and technical requirements.
Italy	Consultancy	Prevention, detection, and adaptation in densely populated areas	Feasibility study for the development of fire-resilient solutions for infrastructure. Analysis of the interactions between wildfire and critical infrastructure. Establish a resilient connection during wildfire occurrences, extending beyond traditional car accessibility.
Spain	Consultancy	Wide area wildfires in high-risk zones	Development of innovative tools for data collection, analysis as, and exploitation. Offer immediate post-fire information, assessing fire severity and recovery. Analysis of the environmental impact of fires in the region.
Austria	Rescue Service Provider	Prevention, protection, and fast response of (peri)-urban wildfire	Fire prevention and a fast response in peri-urban areas. Improve aerial-data use for prediction of fire evolution.
Greece	Research Institution	Human and animal evacuation	Enhance cross-sectorial collaboration and distribution of critical information. Facilitation of more effective rescue operations for humans and animals.

### Stakeholder Identification

The first step of the stakeholder analysis process consisted of identifying the stakeholders participating in the local governance wildfire management networks at mapping workshops conducted between September and December 2022. Pilot leaders invited an initial group of stakeholders to workshops aimed at analyzing their local wildfire management context to identify the challenges, needs, and potential contribution of the stakeholders. The list of stakeholders in each pilot was completed through an iterative process with the pilot leaders and participants during the project. Participants finalized the lists after the workshops. The networks documented are unbounded, where membership is not set by a specific affiliation to a policy process, nor to formal engagement in the pilot.

### Stakeholder Categorization

Stakeholder categorization aimed to identify the types of stakeholders participating in wildfire management networks. Categorization was performed directly after the initial workshops through a top-down approach where

the study team collaborated with the pilot leaders to identify the stakeholder groups according to three categories:

- Sector (government / civil society / private): categorization based on the governance mode and strategic objectives of each stakeholder group.
- Level (local / regional / national / international): categorization based on the main level of operation for the stakeholder groups.
- Phase (review / risk reduction / readiness / response / recovery): categorization of phases based on Moore's framework of wildfire management phases (2019) where each stakeholder group is attributed a primary management phase according to their mission.

### Stakeholder Relationship Mapping

The third and final step of the stakeholder analysis process involved investigating the relationships among stakeholders through social network analysis. Analysis was divided into two parts: a survey and a workshop. The survey aimed to identify active stakeholders in the region, their relationships, and connections requiring improvement. The workshop was designed to provide a preliminary analysis and validate the survey findings. In this part, stakeholders under the guidance of a pilot leader were asked to visually represent the survey results in a preliminary social network graph.

Data for the surveys and workshops was treated and analyzed in Gephi to create individual network graphs for each area of interest. The analysis process used information from the previous phases to characterize each network according to the attributes in Table 2.

**Table 2. SNA variables**

Network-level statistics	Node-level statistics
N Stakeholder Groups	In degree
N Connections	Eccentricity
N Stakeholders Groups per sector	Closeness Centrality
N Stakeholders Groups per level	Betweenness Centrality
N Stakeholders Groups per phase	
Network diameter	
Average degree	
Average) Weighted degree	
Average path length	

Ultimately, the study aims to provide empirical evidence to evaluate five European wildfire management contexts through networked governance models by analyzing the configuration of their stakeholder networks. This is measured by assessing network configurations and stakeholders. At the network level, the measurements assess the size, density, and diversity of sectors, in addition to scalar levels of operation and phases. At the stakeholder level, relevance is assessed by measurements such as in degree, eccentricity, closeness centrality, and betweenness centrality. Analysis is completed by a qualitative assessment of the network profile, leading to the discussion on the main factors determining the network configurations and the potential outcomes of these attributes.

## RESULTS

### Network Configuration Analysis

The first relevant result of the stakeholder analysis process are the profiles of each pilot network in terms of number of stakeholder groups, connections, average degree, network diameter, average path length, density, and the diversity of sectors, levels, and phases of operation. Analysis of network-level statistics allowed an in depth understanding of each network profile and the comparison of results across groups in information provided about the size, the interconnectedness, and the diversity of each pilot network.

The first relevant result of the SNA mapping is that the project is a building a diverse set of networks. The pilot

networks range from complex networks with dozens of stakeholders spanning three or four countries to very localized connections, where a handful of stakeholders interact to conduct specific experiments or test some of the technologies under development. Other attributes vary considerably such as interaction density, the diversity of sectors and scalar levels of operation represented, and the average degree.

Regarding network size statistics, the average number of stakeholders is 46, with the smallest network having 34 and the largest 79. The number of connections ranged from 80 to 295, with an average of 176. The diameter of networks ranges from 3 to 4, with an average of 3.4. The degree of interconnectedness of stakeholders within the networks ranges from 1.66 to 6.97, with an average score across the five pilots of 3.83. The average path length ranges from 1.42 to 2.38, with an average of 1.87. Finally, the graph density ranges from 0.04 to 0.21, with an average of 0.09.

**Table 3. SNA Results Overview**

Variable	Austria	Greece	Italy	Norway	Spain	TOTAL	AVG
Stakeholders Total	38	38	44	76	34	230	46,00
Connections Total	119	139	80	291	246	875	175,00
Government	28	27	26	40	24	145	29,00
Civil Society	9	4	10	26	7	56	11,20
Private Sector	1	7	8	10	3	29	5,80
Level - Local	20	14	20	15	17	86	17,20
Level - Regional	0	2	8	1	1	12	2,40
Level - National	17	17	15	38	14	101	20,20
Level - International	1	5	1	22	2	31	6,20
Phase - Review	4	10	0	6	2	22	4,40
Phase - Prevention	13	11	23	32	17	96	19,20
Phase - Preparedness	3	5	2	15	9	34	6,80
Phase - Response	18	12	19	22	4	75	15,00
Phase - Recovery	0	0	0	1	2	3	0,60
Average Degree	3,13	3,66	1,66	3,83	6,97	NA	3,85
Avg. Weight. Degree	3,13	4,63	2,59	3,86	10,00	NA	4,84
Network Diameter	3,00	3,00	4,00	4,00	3,00	NA	3,40
Avg. Path Length	1,42	1,87	1,86	2,38	1,81	NA	1,87
Graph Density	0,09	0,10	0,04	0,05	0,21	NA	0,10
Avg Clustering Coef	0,68	0,35	0,31	0,25	0,55	NA	0,43

Data was processed according to the categories to access the diversity of sectors. On average, the pilot networks have 63% of representatives from government, 24% from civil society, and 13% of the private sector. Concentration of actors from government ranges from 74% to 59%. Civil society and private sector participation ranges from 34% to 11% and 18% to 3% respectively. All pilot networks in the study had at least one representative from each sector.

Information on the phases followed a similar pattern, with stakeholders more concentrated, on average, on the phases of response 32% and prevention 42%. Other phases average lower concentrations: review 10%, readiness 15% and recovery 1%. As for the distribution, the pilots that presented the highest concentration in one single phase were the Austrian and Italian pilot networks, with 47% and 43% of its stakeholders concentrated in the response phase respectively. Three out of the five pilot networks did not have stakeholders with priority focus on the recovery phase. Moreover, the Italian pilot did not have stakeholders in the review phase.

### Network Composition Analysis.

The investigation of the network attributes of individual nodes complements the analysis across pilots by providing insights on the most well-connected types of stakeholders in each pilot, along with the identification of gaps identified by poorly connected stakeholders in key areas.

The first analysis identified of the most relevant stakeholder in each pilot according to the number of connections received. An investigation of the stakeholders with the highest in-degree scores indicates that NGV43 (Norway, 21), SGV27 (Spain, 17), DD Chania (Greece, 16), and IGV2 (Italy, 6) are the actors receiving the highest number of connections. In Austria, the AGV8, AGV13, ACS16 and AGV19 are tied for the most connections with five each. All stakeholders with the highest in-degree scores are from government, except for ACS16, which is a civil society entity providing public services. In terms of the phase focus, four out of five of the most highly ranked stakeholders perform functions in the “Risk Reduction – Prevention” phase, while one is in “Risk Reduction – Readiness” and two in “Response - Fire Fighting Operations.”

The second analysis identified the stakeholder most strategically connected with betweenness centrality scores. Betweenness centrality is a measure of the dependency of other nodes on a given node (Brandes et al., 2016) and refers to the number of times a given node appears in the optimal connection between two other nodes in the graph. In our analysis, the pilot leaders in Spain (SGV14, 191), and Italy, (IGV2, 152) had the highest scores. In Austria, ACS10 (36), a stakeholder that specializes in networking for the improvement of wildfire management had the highest score. In Greece, HGV13 (116), a governmental agency responsible for coordinating emergency response, and in Norway, NCS47 (1013), a research center that partners with the pilot leaders, had the highest scores. In all cases the highest scores are attributed to actors that are central to the pilot’s operation or to the management of networks of wildfire management in the implementation region.

A final investigation into the stakeholders’ strategic placement was performed through closeness centrality measures. The results from this variable also indicate the strategic placement of the stakeholders in relation to the network but using its distance to all other nodes as a measure of interconnectivity. Here the lowest values are attributed to the most well-connected stakeholders, with only stakeholders that actively responded to the survey considered in the analysis. Of note, the highest scores in closeness centrality are attributed to stakeholders that might not be central to the network in terms of in-degree and out-degree scores, but are directed connected to them, as the case of SCS2 in Spain (0.40), HGV15 in Greece (0.42), ICS1 in Italy (0.46), AGV7 in Austria (0.49), and NGV64 (0.33) in Norway. These best scoring cases showcase the benefits of reaching out to network brokers not only to the performance of everyday duties but also to the development of integrated wildfire management actions.

## Norway

The Norwegian pilot is led by a Norwegian center with expertise in fire resistance, reaction to fire, firefighting, fire tests, and fire simulations. The pilot conducted a hybrid SNA workshops, with stakeholders completing the survey prior to the on-site event in September 2023. The SNA survey yielded 30 responses resulting in the identification of 79 different stakeholders. The network of the Norwegian pilot is diverse and extensive, involving 44 stakeholders from the government, 25 from civil society, and 10 from the private sector. The stakeholders represent a broad spectrum, ranging from government bodies (e.g., local and regional authorities, fire brigade departments, and directorates) and educational institutions to agricultural associations and fire research organizations. The private sector also has a notable presence among the stakeholders, representing forest owner associations, technology development, and manufacturing companies, among others.

Connections within the network are intricate, linking entities involved in wood processing, fire safety, agriculture, meteorology, research, and technology innovation. Notably, the network includes international associations and research institutions, European agencies, and global non-profits, showcasing a comprehensive and multi-dimensional approach. The network appears to be well balanced, with various stakeholders able to contribute their expertise and resources to address fire-related issues comprehensively. This inclusive approach involves key players from different sectors, emphasizing a holistic strategy in managing and preventing wildfires.

The Norwegian pilot’s activities were conducted in forested inland areas in the east and coastal landscapes with heather, grass, and scrub vegetation in the west. The exercises and experiments are designed and implemented in coordination with local authorities.

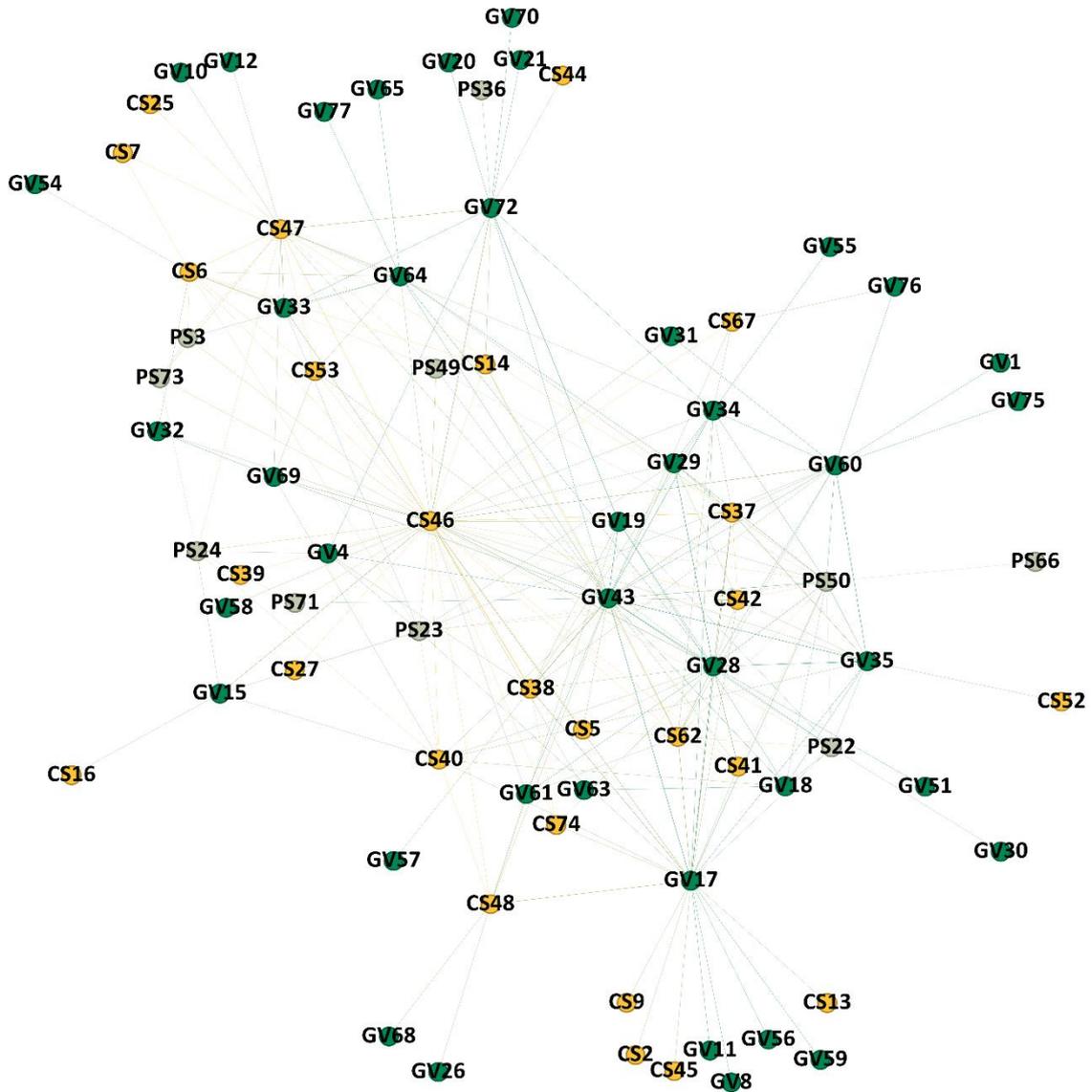


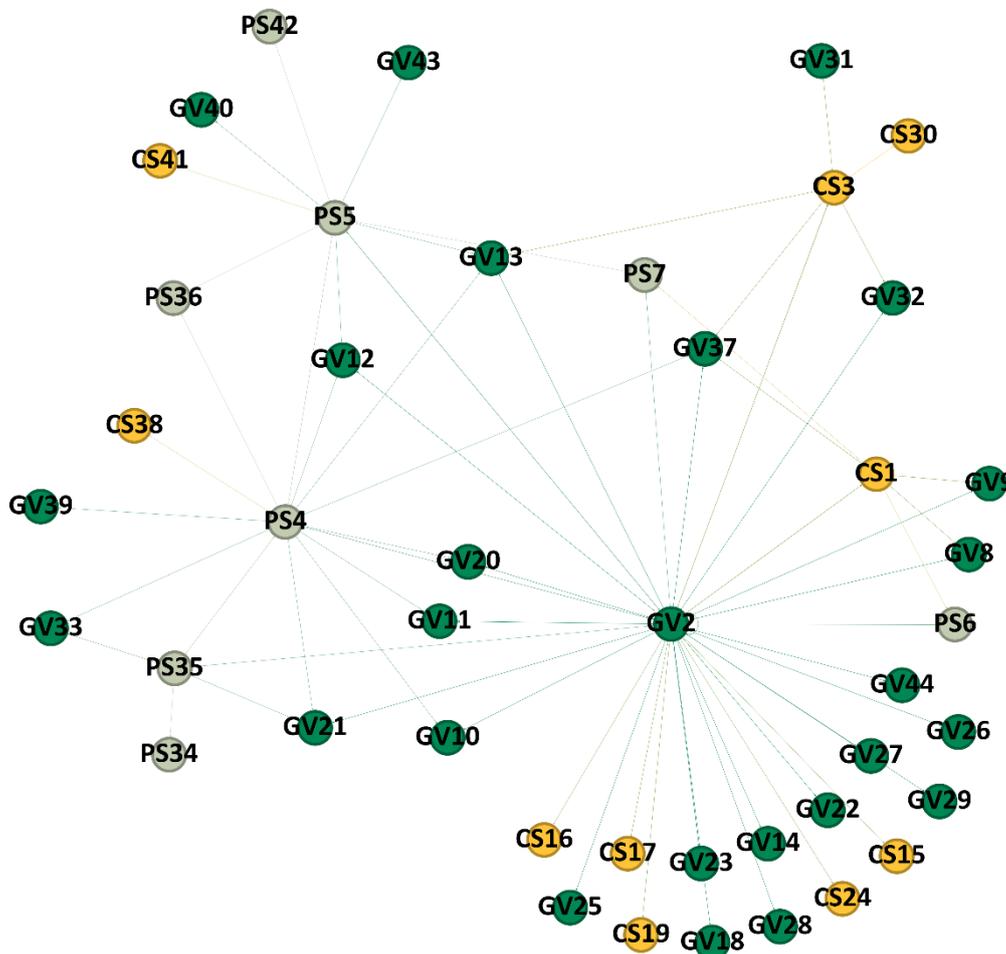
Figure 4. Norway Stakeholder Network

**Italy**

The Italian pilot is led by a private non-profit company engaged in research activities and the experimental demonstration of innovative technologies for the construction sector. The pilot leader organized an online SNA workshop in May 2023. The SNA survey was completed by 6 respondents from different organizations, resulting in the identification of 44 stakeholders.

The Italian network of stakeholders exhibits a comprehensive structure with robust connections to regional and local authorities. This is evident by the significant involvement of stakeholders from municipal, regional, and community levels. The identification of 26 stakeholders from government and 10 from civil protection emphasizes the active involvement of local entities in addressing wildfire management. The modest representation of private sector stakeholders (8) reinforces the idea that the predominant role in wildfire management is played by governmental and civil protection bodies. Such an approach emphasizes the vital role of community participation and collaboration at the local level in effectively managing and mitigating the impact of wildfires.

The Italian pilot focuses on the Sorrento Peninsula, a densely populated area with urban areas and forests on the surrounding slopes.



**Figure 5. Italy stakeholder network**

**Spain**

The Spanish pilot is led by an innovation and high-tech engineering consulting company. The SNA survey conducted in October 2023 had 21 respondents that identified 34 stakeholders across a diverse range.

The stakeholder types included 24 types of government entities, 3 from the private sector, 7 from the civil society. The governmental stakeholders appear to be the most common in the pilot network, including different municipalities of the autonomous community of Castile and León, and state environmental and forest protection services. Civil society is represented by environmental agencies and associations, forest management advisors, and forest owner associations. Lastly, the private sector brings stakeholders to the technological, innovation, and research fields.

While there is a substantial government presence, particularly of local authorities, firefighting, and forest management services, the involvement of civil society organizations, ecological associations, and private companies like Capgemini indicate a distributed network. This mix suggests a more balanced strategy rather than a purely top-down approach. The pilot is set to investigate the wildfire-prone Pinus species and mixed forest, recognized as high risk.

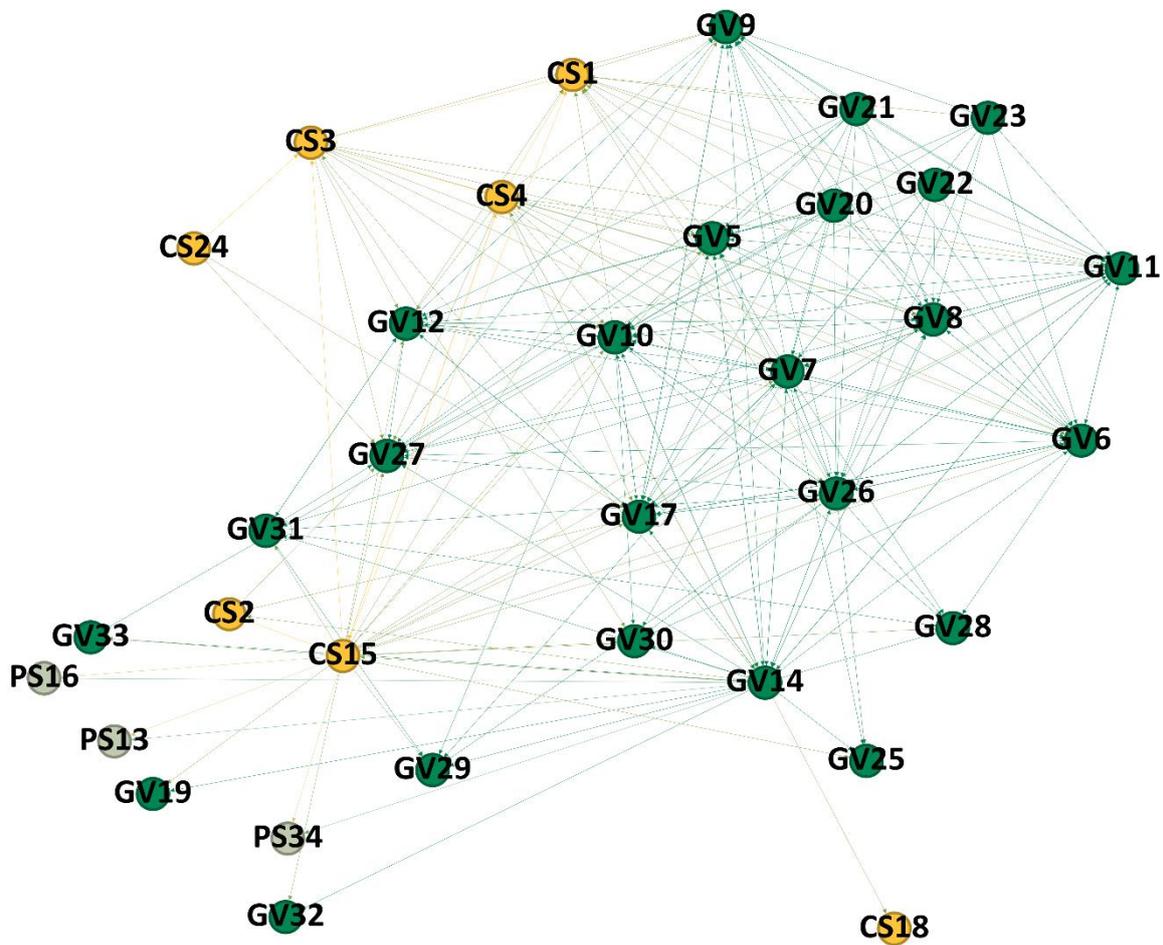


Figure 6. Spanish Stakeholder Network

### Austria

The Austrian pilot is led by an organization that emphasizes health-related education and training. The pilot team

held a physical SNA workshop in October 2023. The SNA survey, conducted with 5 respondents, identified a total of 38 stakeholders, revealing a network predominantly composed of 28 government entities, 9 from civil society, and only 1 from the private sector.

Analysis reflects a blended approach, characterized by a significant top-down influence from governmental entities, coupled with engagement from civil society, but limited participation from the private sector. The pilot is set to evaluate the tools and solutions provided by the technical partners under realistic conditions and data with the end-users.

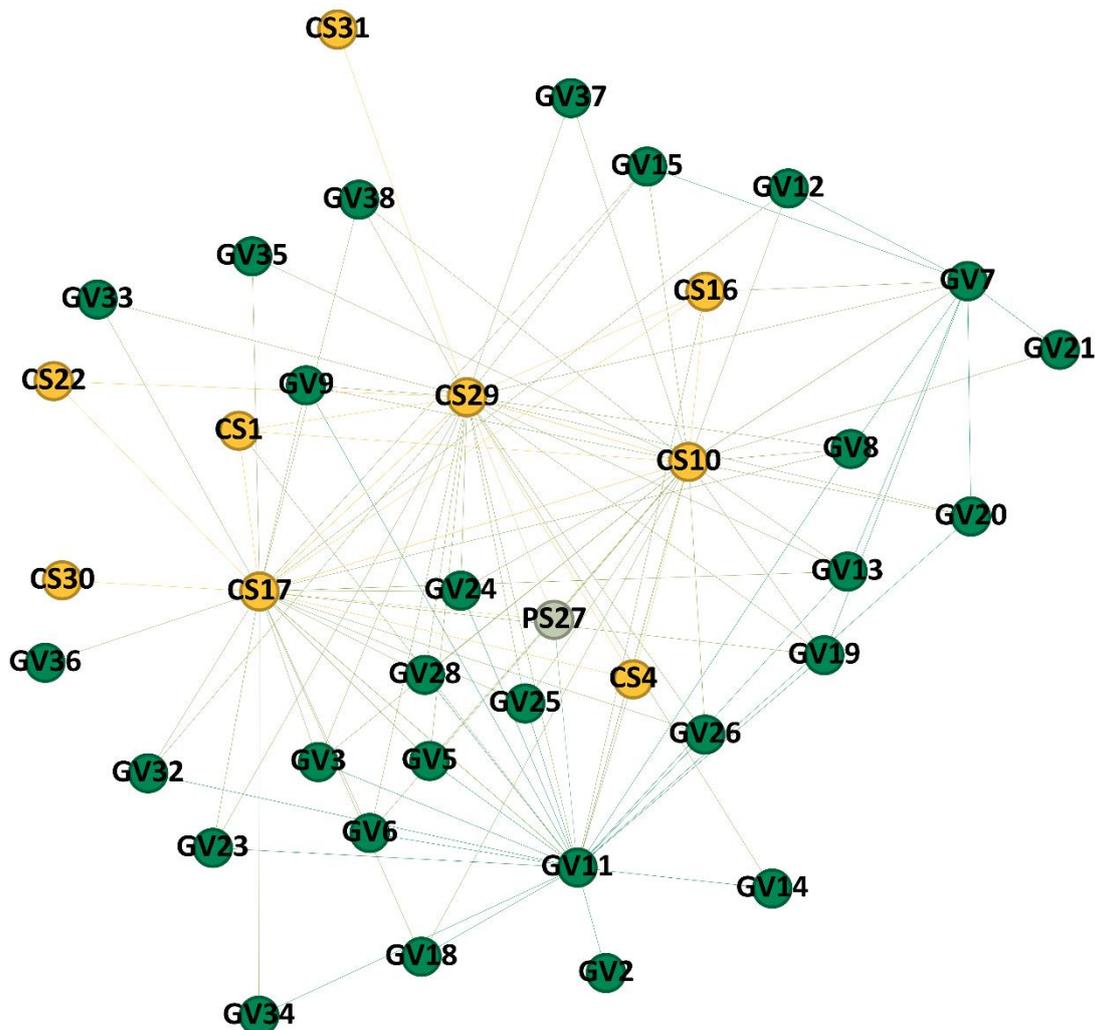


Figure 7. Austria Stakeholder Network

### Greece

The Greek pilot is led by a university investigating wildfire management in the challenging terrain of the Samaria Gorge. The university organized a physical SNA workshop in October 2023. 15 participants completed the SNA survey, resulting in the identification of 38 stakeholders. The government sector, counting 27 stakeholders, takes a central position, involving fire brigade departments, local authorities, and public research centers, alongside entities like Police and forest services. The private sector is represented by 7 organizations, including research and innovation centers, and tourist and hospitality local companies that contribute cutting-edge technologies. 4 types of stakeholders represent civil society, with humanitarian organizations and mountaineering clubs in the network. The analysis reveals a harmonious top-down and bottom-up approach.

The use case is in southwest Crete in the regional unit of Chania, a closed canyon that limits the applicability of standard procedures.

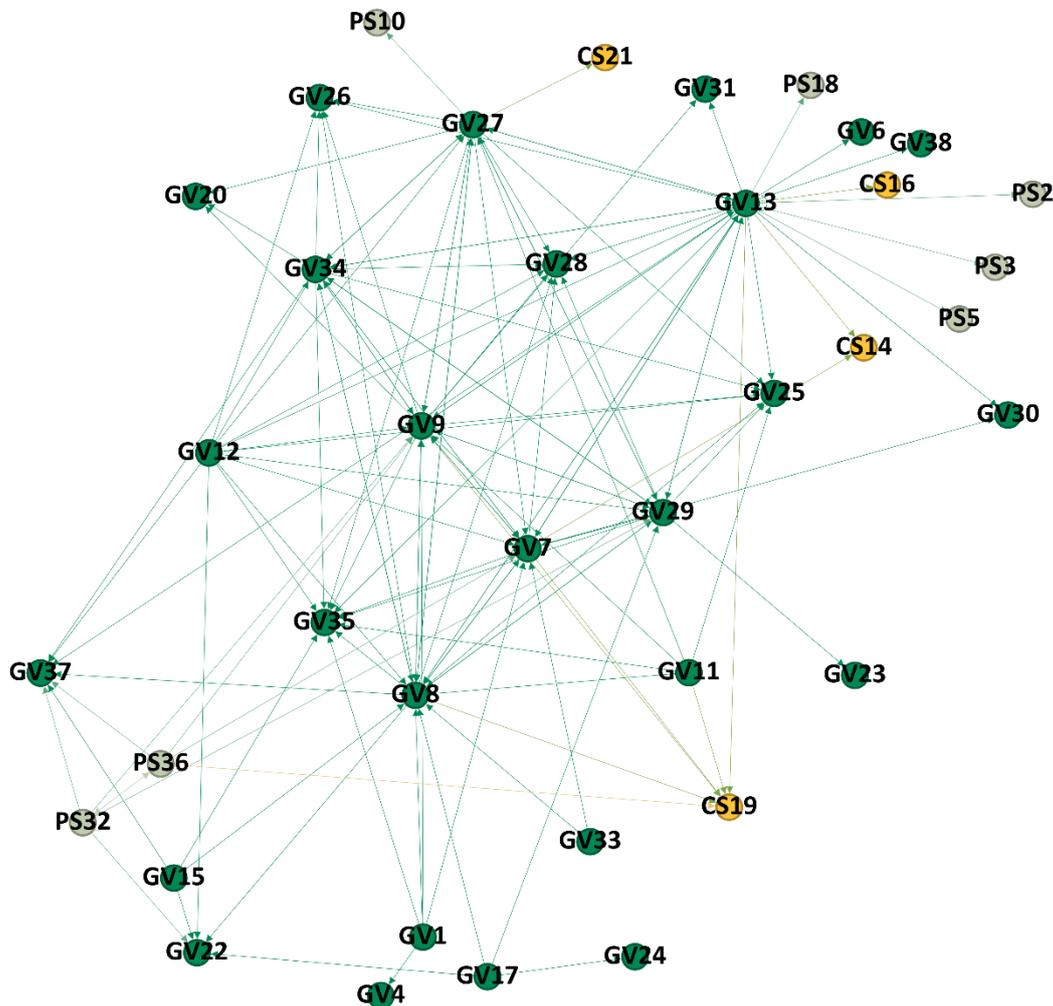


Figure 8. Greece Stakeholder Network

## CONCLUSION

The project is designed to implement a holistic wildfire management approach. In practical terms, the approach involves the development of solutions across the wildfire management cycle and the coordination among different stakeholders and sectors. By profiling each of the eight pilots, the SNA first illustrates how this coordination is carried out. The scope of action, the profile of stakeholders and the density of connections are seen as evidence of this engagement.

The SNA analysis also identifies the key stakeholders in each pilot and provides insights on the connection gaps. The identification of these gaps provides two immediate inputs for the project: it supports local engagement in the pilot regions, and it assesses fit between technologies and local challenges.

In the wildfire management and disaster response policy debate, the analysis adds to the few empirical studies on natural resource governance networks in the European Union. It is relevant that the study is being performed while the project is under implementation, which allows the results to be shared with other similar EU fire projects and officials in the European commission. The results contribute to the fields of wildfire studies and networked governance by assessing how efforts such as the project contribute to improving governance in the territories of implementation.

## REFERENCES

- AGIF. (2023). *Landscape Fire Governance Framework 2023* (pp. 1–20). Portuguese Agency for Integrated Rural Fire Management. <https://www.wildfire2023.pt/conference/framework>
- Battistoni, P., Di Gregorio, M., Giordano, D., Sebillio, M., Tortora, G., and Vitiello, G. (2020). Wearable Interfaces and Advanced Sensors to Enhance Firefighters Safety in Forest Fires. *In Proceedings of the International Conference on Advanced Visual Interfaces*, Salerno Italy: ACM, 1–3. doi:10.1145/3399715.3399961.
- Carrington, P. J., Scott, J., & Wasserman, S. (Eds.). (2005). *Models and methods in social network analysis*. Cambridge University Press.
- Chuvieco, E., Yebra, M., Martino, S., Thonicke, K., Gómez-Giménez, M., San-Miguel, J., Oom, D., Velea, R., Mouillot, F., Molina, J. R., Miranda, A. I., Lopes, D., Salis, M., Bugaric, M., Sofiev, M., Kadantsev, E., Gitas, I. Z., Stavrakoudis, D., Eftychidis, G., ... Viegas, D. (2023). Towards an Integrated Approach to Wildfire Risk Assessment: When, Where, What and How May the Landscapes Burn. *Fire*, 6(5), Article 5. <https://doi.org/10.3390/fire6050215>
- Edgeley, C. M., & Paveglio, T. B. (2016). Influences on stakeholder support for a wildfire early warning system in a UK protected area. *Environmental Hazards*, 15(4), 327–342. <https://doi.org/10.1080/17477891.2016.1209155>
- Ferrara, C., Salvati, L., Corona, P., Romano, R., & Marchi, M. (2019). The background context matters: Local-scale socioeconomic conditions and the spatial distribution of wildfires in Italy. *Science of the Total Environment*, 654, 43–52. <https://doi.org/10.1016/j.scitotenv.2018.11.049>
- Giuliani, E., & Bell, M. (2005). The micro-determinants of meso-level learning and innovation: Evidence from a Chilean wine cluster. *Research Policy*, 34(1), 47–68. <https://doi.org/10.1016/j.respol.2004.10.008>
- Grimble, R., & Wellard, K. (1997). Stakeholder methodologies in natural resource management: A review of principles, contexts, experiences and opportunities. *Agricultural Systems*, 55(2), 173–193. [https://doi.org/10.1016/S0308-521X\(97\)00006-1](https://doi.org/10.1016/S0308-521X(97)00006-1)
- Hamilton, M., Nielsen-Pincus, M., & Evers, C. (2023). Wildfire risk governance from the bottom up: Linking local planning processes in fragmented landscapes. *Ecology and Society*, 28(3), art3. <https://doi.org/10.5751/ES-13856-280303>
- Hauck, J., Schmidt, J., & Werner, A. (2016a). Using social network analysis to identify key stakeholders in agricultural biodiversity governance and related land-use decisions at regional and local level. *Ecology and Society*, 21(2). <https://doi.org/10.5751/ES-08596-210249>
- Hauck, J., Schmidt, J., & Werner, A. (2016b). Using social network analysis to identify key stakeholders in agricultural biodiversity governance and related land-use decisions at regional and local level. *Ecology and Society*, 21(2), art49. <https://doi.org/10.5751/ES-08596-210249>
- Kirschner, J., Clark, J., & Boustras, G. (2023). Governing wildfires: Toward a systematic analytical framework. *Ecology and Society*, 28(2), art6. <https://doi.org/10.5751/ES-13920-280206>
- Krupa, M., Cenek, M., Powell, J., & Trammell, E. J. (2018). Mapping the Stakeholders: Using Social Network Analysis to Increase the Legitimacy and Transparency of Participatory Scenario Planning. *Society & Natural Resources*, 31(1), 136–141. <https://doi.org/10.1080/08941920.2017.1376140>
- Lecina-Díaz, J., Campos, J., Pais, S., Carvalho-Santos, C., Azevedo, J., Fernandes, P., Gonçalves, J., Aquilué, N., Rocés-Díaz, J. V., Agrelo De La Torre, M., Brotons, L., Chas-Amil, M.-L., Lomba, A., Duane, A., Moreira, F., Touza, J., Hermoso, V., Sil, Â., Vicente, J., ... Regos, A. (2023). Stakeholder perceptions of wildfire management strategies as nature-based solutions in two Iberian biosphere reserves. *Ecology and Society*, 28(1), art39. <https://doi.org/10.5751/ES-13907-280139>
- Marchi, M., Chianucci, F., Ferrara, C., Pontuale, G., Pontuale, E., Mavrikakis, A., Morrow, N., Rossi, F., & Salvati, L. (2018). Sustainable land-use, wildfires, and evolving local contexts in a Mediterranean Country, 2000-2015. *Sustainability*, 10(11). <https://doi.org/10.3390/su10113911>
- Moore, P. F. (2019). Global Wildland Fire Management Research Needs. *Current Forestry Reports*, 5(4), 210–225. <https://doi.org/10.1007/s40725-019-00099-y>

- Provan, K. G., & Kenis, P. (2007). Modes of Network Governance: Structure, Management, and Effectiveness. *Journal of Public Administration Research and Theory*, 18(2), 229–252. <https://doi.org/10.1093/jopart/mum015>
- Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C. H., & Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*, 90(5), 1933–1949. <https://doi.org/10.1016/j.jenvman.2009.01.001>
- Roberts, R. M., Jones, K. W., Duke, E., Shinbrot, X., Harper, E. E., Fons, E., Cheng, A. S., & Wolk, B. H. (2019). Stakeholder perceptions and scientific evidence linking wildfire mitigation treatments to societal outcomes. *Journal of Environmental Management*, 248, 109286. <https://doi.org/10.1016/j.jenvman.2019.109286>
- Steelman, T. (2016). U.S. wildfire governance as social-ecological problem. *Ecology and Society*, 21(4), art3. <https://doi.org/10.5751/ES-08681-210403>
- Steelman, T., Nowell, B., Velez, A.-L., & Scott, R. (2021). Pathways of Representation in Network Governance: Evidence from Multi-Jurisdictional Disasters. *Journal of Public Administration Research and Theory*, 31(4), 723–739. <https://doi.org/10.1093/jopart/maab004>
- Thompson, M. P., MacGregor, D. G., Dunn, C. J., Calkin, D. E., & Phipps, J. (2018). Rethinking the Wildland Fire Management System. *Journal of Forestry*, 116(4), 382–390. <https://doi.org/10.1093/jofore/fvy020>
- UNISDR. (2017). *Technical Guidance for Monitoring and Reporting on Progress in Achieving the Global Targets of the Sendai Framework for Disaster Risk Reduction*. United Nations. <https://www.undrr.org/publication/technical-guidance-monitoring-and-reporting-progress-achieving-global-targets-sendai>
- United Nations. (2015). *Sendai Framework for Disaster Risk Reduction 2015—2030*. United Nations. [https://www.preventionweb.net/files/43291\\_sendaiframeworkfordrren.pdf?\\_gl=1\\*\\_goneqo\\*\\_ga\\*MzczNTAzNDcwLjE2OTM5OTE1NzM.\\*\\_ga\\_D8G5WXP6YM\\*MTY5NTI4MDU5OC4yLjAuMTY5NTI4MDU5OC4wLjAuMA..](https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf?_gl=1*_goneqo*_ga*MzczNTAzNDcwLjE2OTM5OTE1NzM.*_ga_D8G5WXP6YM*MTY5NTI4MDU5OC4yLjAuMTY5NTI4MDU5OC4wLjAuMA..)
- Valeri, M., & Baggio, R. (2021). Italian tourism intermediaries: A social network analysis exploration. *Current Issues in Tourism*, 24(9), 1270–1283. <https://doi.org/10.1080/13683500.2020.1777950>
- Wagner, K. R. H. (2022). Designing insurance for climate change. *Nature Climate Change*, 12(12), 1070–1072. <https://doi.org/10.1038/s41558-022-01514-2>
- Wasserman, S., & Faust, K. (1994). *Social Network Analysis\_ Methods and Applications (Structural Analysis in the Social Sciences)*. Cambridge University Press.