



Deliverable 15

Summary of new methods

to stimulate transdisciplinary research in fire science

Call/Topic	H2020-MSCA-ITN-2019
Project Acronym	PYROLIFE
Project Title	Training the next generation of integrated fire management experts
Project Number	860757
Project Start Date	1 October 2019
Project Duration	63 months
Contributing Work Package	WP 3- Risk Communication
Dissemination Level	Internal: Project Consortium & Commission Made public after PhD dissertation publication (2024)
Contractual Delivery Date	March 2023
Actual Delivery Date	March 2023

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Keywords	Transdisciplinary, Co-production, Transformation, Wildfire Research
How to cite this document	Uyttewaal, Kathleen, N. Prat Guitart, E.R. Langer, C. Kroeze, I. Ottolini, P. Pandey, E. Verdiani, I. Rodríguez Giralt, Míriam Arenas Conejo (2023). PyroLife Deliverable 15: Summary of new methods to stimulate transdisciplinary research in fire science.

Table of Contents

Table of Contents	2
List of Tables and Figures	3
Glossary	3
I. Executive summary	4
II. Introduction to transdisciplinarity	5
III. Why is transdisciplinarity important in wildland fire?	9
IV. Lessons from secondments: Transdisciplinary projects in the Netherlands and Aotearoa New Zealand	10
i. The Netherlands	11
ii. Aotearoa New Zealand	12
V. Wildfire-specific transdisciplinary literature review	13
i. Phase of fire cycle	14
ii. Topic	14
iii. Methods	15
iv. Location	15
v. Actors involved	15
vi. Advances for Integrated Fire Management	16
VI. Guiding considerations for future transdisciplinary wildfire research	16
VII. Example: ESR 12 approach	18
VIII. Conclusion & recommendations	21

Annex I	23
References	23
Transdisciplinary Fire Literature Review	29

List of Tables and Figures

Table 1: Examples of approaches in transdisciplinary projects	7
Table 2: Considerations for fire-specific transdisciplinary projects.....	17
Figure 1: Representation of dynamics in multidisciplinary, interdisciplinary and transdisciplinary research	5
Figure 2: Summary of ESR 12 participatory workshop objectives	19
Figure 3: Co-construction of timeline in workshop 1	19
Figure 4: Co-creation of adaptation pathway options in workshop 2	20
Figure 5: Reflections and next steps in workshop 3	21

Glossary

Adaptation Pathways: decision-focused approaches in climate adaptation research and planning, recognized as sequences of actions, which can be implemented progressively, depending on how the future unfolds and the development of knowledge (Werners et al. 2021).

Adaptive co-management: sharing of power and responsibility between institutions and local resource users, accepting that ecological and social uncertainty is best faced with collaborative processes (Hakkarainen et al. 2020).

Co-creation: a concept which encompasses the whole TD process both temporally and conceptually. It does not necessarily provide solutions but contributes to solution options (Hakkarainen et al. 2020).

Co-design: actors in a project conceptualize the first phase together to articulate positions, determine concepts, skills and solutions required (Hakkarainen et al. 2020).

Co-learning: an active intention to learning along a TD process, as it enables adaptation capacity and reflexivity (Hakkarainen et al. 2020).

Co-production: a central concept to both recognize and organize the interface between knowledge and management or governance. Knowledge and action are considered reciprocal (Hakkarainen et al. 2020).

Facilitated Inclusion: choices for participant involvement are justified by desires to empower participant positions through humility, inclusivity and/or plurality, with initiators' expertise/power seen as supporting that process (Chambers et al. 2022).

Interdisciplinary Research: scientific approach that analyzes, synthesizes and harmonizes links between disciplines into a coordinated and coherent whole (Choi and Pak 2006, 359). This can be seen as an interactive approach to research (Alvargonzález 2011).

Multidisciplinary Research: scientific approach that draws on knowledge from different disciplines but stays within the boundaries of those fields (Choi and Pak 2006, 359). This can be seen as an additive approach (Alvargonzález 2011).

Transdisciplinary Research (TD): aims to identify, structure, analyze and handle issues in problem fields in order to: a) grasp the relevant complexity of a problem, b) take into account the diversity of life-world and scientific perceptions of problems, c) to link abstract and case-specific knowledge, and d) develop knowledge and practices that promote what is perceived to be the common good (Pohl and Hadorn 2008; Hirsch Hadorn et al. 2007).

I. Executive summary

OBJECTIVES:

This report aims to provide a summary of transdisciplinary methods used in fire science to date and to outline guiding considerations for future transdisciplinary fire research.

AUDIENCE:

The target audience includes researchers and project managers interested in applying transdisciplinary methods in wildfire-related projects. The core of transdisciplinary approaches is to combine multiple forms of knowledge from research, practitioners and wider societal actors to address social and ecological issues in the realm of wildland fire.

APPROACH TO THIS REPORT:

1. The report overviews transdisciplinary research approaches and definitions.
2. The report then shares learning examples from PyroLife ESR 12 Secondments at Wageningen University in the Netherlands and Scion, the New Zealand Forest Research Institute.
3. The report reviews specific transdisciplinary research that has been conducted to date in the area of wildland fire.

4. From the learnings of the wider transdisciplinary field, along with specific considerations in the arena of wildland fire, the report offers guiding considerations to inform future fire science projects using transdisciplinary methods.
5. As an example, the authors use the guiding considerations to reflect on PyroLife ESR 12’s transdisciplinary research approach.
6. The report concludes with considering challenges and opportunities in transdisciplinary research, and how these may be fine-tuned for fire science.

II. Introduction to transdisciplinarity

The time of rapid anthropogenic climate change paired with rising social inequality creates multiple overlapping crises around the world (Heinrichs et al. 2016). The effects manifest in different areas including disasters such as increasingly severe wildfires and floods, market crashes and wars over resources. The impacts are felt most acutely on a local day-to-day level by vulnerable species and human populations (Díaz et al. 2015; IPCC 2022). More than ever, these complex and inter-related issues require collaborative approaches from science, governance, and civic action to disrupt the “business as usual” trajectory to a warming planet over 1.5C (Hirsch Hadorn et al. 2007). Collaborations between multiple forms of knowing and understanding the world are necessary to advance the broader projects of sustainability and social justice. Transdisciplinary (TD) approaches to these issues can help create the connections, tools and ways of knowing that respond to the daunting global challenges at hand (Pohl, Krütli, and Stauffacher 2017).

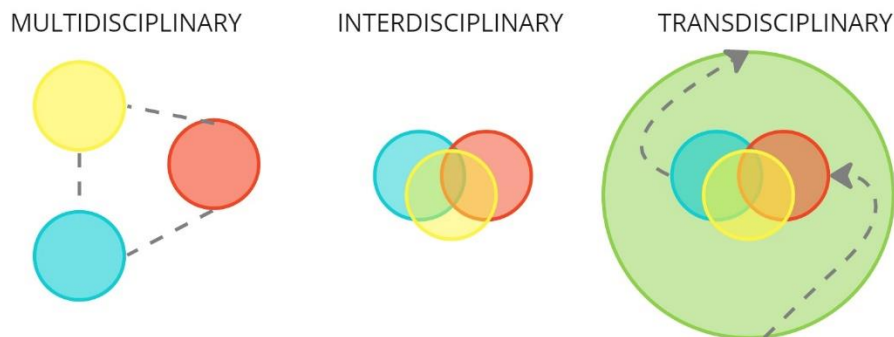


Figure 1: Representation of dynamics in multidisciplinary, interdisciplinary and transdisciplinary research

Figure 1 helps to visualize the differences between multidisciplinary, interdisciplinary, and transdisciplinary approaches. We understand multidisciplinary research as a scientific approach that draws on knowledge from different disciplines but stays within the boundaries of those fields (Choi and Pak 2006, 359). Interdisciplinary research is a scientific approach that analyzes, synthesizes and harmonizes links between disciplines into a coordinated and coherent whole (Choi and Pak 2006). For example, studies like environmental anthropology, social psychology, and environmental health all exhibit interdisciplinary characteristics. Finally, transdisciplinary research (TD) aims to identify, structure, analyze and handle issues in problem fields in order to: a) grasp the relevant complexity of a problem, b)

take into account the diversity of life-world and scientific perceptions of problems, c) to link abstract and case-specific knowledge, and d) develop knowledge and practices that promote what is perceived to be the common good (Pohl and Hadorn 2008; Hirsch Hadorn et al. 2007). TD is embedded and interacting with wider systems of knowledge beyond academia (represented in green in Figure 1). The difference between these fields is that multidisciplinary research is additive, interdisciplinary research is interactive, and transdisciplinary research is more broadly holistic (Alvargonzález 2011). In this way, transdisciplinary research has both challenged and expanded scientific paradigms. Transdisciplinary discourse emerged primarily from three different fields starting in the 1970s: science and policy interactions, systems approaches analyzing education and innovation, and solutions-oriented frameworks geared toward environmental sustainability and public health issues (Knapp et al. 2019). Today, as the field grows, transdisciplinary projects find synergies between these different fields and continue to grow new forms of collaboration, even encouraging “unusual” partnerships, such as the [Centre for Unusual Collaborations](https://www.unusualcollaborations.com/)¹ in Utrecht, the Netherlands.

Leading TD scientist Christian Pohl states that transdisciplinarity can be mapped under three different categories: to transcend and integrate disciplinary paradigms for socially relevant issues, to expand the inclusion of non-academic actors, and to unite knowledge forms beyond disciplines (Hakkarainen et al. 2021). The crowning aspect of TD is that it seeks to exchange, challenge, integrate and create knowledge from plural sources within and beyond academia (Hakkarainen et al. 2021).

These approaches emerged out of a need to fill gaps between research and “the real world”: to produce research that is societally relevant and readily integrated into different sectors. Transdisciplinary work promotes “co-production”, a reflexive learning process involving academics and non-academics, to address socioenvironmental issues (Mauser et al. 2013). This approach challenges the narrative that there are knowledge “producers” and “end-users”, as well as “experts” and “lay-people” —instead, every party participates in a learning process.

The process of knowledge co-production varies widely. It consists of different phases and frameworks according to the goals of the TD project, and according to how the project evolves over time. The primary stages of co-production are: framing the problem, analyzing the problem and exploring the project’s impact (Pohl, Krütli, and Stauffacher 2017). Different stages require the collaboration of different disciplines and societal actors according to their experience, interests, and availability. Research-specific analysis needs to be balanced with the societal relevance of the project throughout the process, requiring good communication skills between groups and a willingness to learn (Pohl, Krütli, and Stauffacher 2017). Additionally, these stages all require skills in *facilitated inclusion*: diverse actors must navigate different and sometimes conflicting agendas, which could suppress or exacerbate tensions and power dynamics between participants (Chambers et al. 2022). To address this, leaders in transdisciplinary projects are encouraged to engage in self-reflection to recognize their own positionality (Lloro-Bidart and Finewood 2018; Staffa, Riechers, and Martín 2021), while also fostering ethical

¹ <https://www.unusualcollaborations.com/>

representation in the process, balancing power between among participants and ultimately creating safe spaces for dialogue that can navigate conflict (Chambers et al. 2022).

Different transdisciplinary research projects take form according to varying baseline assumptions and goals. Several authors have overviewed collections of transdisciplinary projects and categorized them according to their varied approaches and aims (Knapp et al. 2019; Lam et al. 2021; Moallemi et al. 2021; Lang et al. 2012). Several of these approaches are illustrated in Table 1 below, expressing the various forms of collaboration that can exist in a transdisciplinary project. Moreover, several requirements can influence the choice of transdisciplinary methods. Moallemi and other authors identified 27 such requirements that can be summarized in 3 primary categories: outcome-oriented, research-oriented, and stakeholder-oriented (Moallemi et al. 2021). Transdisciplinary researchers argue that this diversity of approaches is a strength: they contribute to change in distinct ways and can help to proactively manage different risks (Chambers et al. 2022). As Hakkarainen et al. have found, many transdisciplinary approaches are intertwined, especially in “co-creation” and “co-production” frameworks (see definitions in the glossary above). Other approaches such as co-design, co-learning, and adaptive co-management also have overlapping elements, though the authors point to each co-concepts’ unique approaches to reflexivity, power analysis and process orientation (Hakkarainen et al. 2021).

As the transdisciplinary field rapidly expands, these approaches should not be taken as an exhaustive list. A more detailed theoretical overview of transdisciplinary research can be found in ESR 12’s PhD dissertation from Wageningen University (available as of 2024).

Table 1: Examples of approaches in transdisciplinary projects

Approach to Transdisciplinary Project	Aims	Further Reading
Co-creation & Co-production	Outcome oriented: actors can implement research outcomes	(Hakkarainen et al. 2021)
	Practical/pragmatic: enhanced co-ownership of knowledge	
	Empowering: all partners are equal co-producers of knowledge	
	Transformative: celebrates epistemological differences and engages in political action	
	Researching solutions: practical scientific knowledge to influence policies and interventions	(Chambers et al. 2021)

	Empowering voices: explicitly include the voices of marginalized actors and embrace social diversity	
	Brokering power: projects for direct policy and management actions through new institutions	
	Reframing power: shifting power from dominant agendas to marginalized actors	
	Navigating differences: managing processes of relating, valuing all expertise and minimizing hierarchies	
	Reframing agency: creating safe spaces for diverse knowledge to be expressed, without explicit solution agendas	
	Context-based: situate the methods in a particular context, place, case, and issue	(Moallemi et al. 2021)
	Goal-oriented: clearly articulate the purpose and the challenge at hand	
	Pluralistic: explicitly recognize multiple ways of knowing and doing	
	Interactive: allow for frequent interactions among actors and ongoing learning	
Co-design	Planning joint research agendas, research questions, and implementation	(Hakkarainen et al. 2021)
Co-learning	Learning based on non-hierarchical relationships, collaboration, trust, full participation, and shared exploration	
Adaptive co-management	Collaborative learning and adaptation process that requires joint experimentation, implementing and monitoring in management	

III. Why is transdisciplinarity important in wildland fire?

Transdisciplinary approaches have become increasingly necessary in fire science, as wildfire regimes are evolving rapidly around the world under the conditions of climate and land use change (Kelly et al. 2020). The following points illustrate in which cases TD approaches can be especially relevant for research and societal issues in wildland fire:

- In situations of high complexity, systems thinking is necessary.
 - Wildfire is widely understood as a disturbance process which influences and is influenced by other agents and processes in any given social-ecological system (Thompson and Dunn 2016). As with any social-ecological system, we can consider wildland fire issues as composed of a complex array of elements, interconnections, functions and purposes, flows and stocks, functions over time, and feedback loops that increase or decrease effects in other parts of the system (Meadows 2009).
 - Multiple actors like scientists, foresters, fire managers, administrators, and residents all will have varied understandings on the causes, problems, responsibilities and potential solutions to wildland fire issues (Wunder et al. 2021). As such, there is no single “right” approach to wildland fire management.
 - The burgeoning field of integrated fire management aims to address this complexity, encouraging ecological, social and economic management objectives into fire management (Silva et al. 2010). It promotes an understanding of human and wildland fire interactions as a cycle, consisting of prevention, preparedness, recovery and management, response, and adaptation.
- In situations involving high degrees of uncertainty.
 - Moreover, the impacts of climate change on fire events will greatly increase the uncertainty of the effectiveness of current management approaches (Castellnou et al. 2019). As such, research demands to be made more relevant and applicable for a wide range of societally engaged actors, as solutions to entrenched issues lie in collaborating across multiple areas of experience and values (Leemans and Fortuin 2021). Transdisciplinary projects related to wildland fire management therefore provide an entry point for a host of interests and knowledges as they relate to different sectors of land management, landscapes, populations and climates.
- In situations with potential for transformative work.
 - There is an urgent need for changes in ownership of knowledge to include and center local and indigenous expertise (Christianson, McGee, and L’hirondelle 2014; Eriksen and Hankins 2014; Lambert and Scott 2019). Many fire scientists, activists and decision-makers recognize the need for a change in ownership of knowledge. This is needed most

of all for indigenous and local knowledge holders to reclaim power and management rights in their ancestral territories (Long and Lake 2018).

- To confront the damaging and outdated top-down narrative of total fire suppression to protect national and colonial resource interests (Norgaard 2014), and to redistribute fire management knowledge in the hands of more actors.
- In order to adapt toward “living with fire”(Stoof and Kettridge 2022), we must work toward a deep knowledge of local context (Paveglio, Abrams, and Ellison 2016). At the same time, creative adaptations will require projects to test, implement and monitor new land management practices through “adaptive co-management” methods that deeply collaborate with local actors in a learn-by-doing process (Armitage et al. 2011)

These situations are all interrelated. According to O’Brien and Sygna, “most research on transitions is based on systems thinking and complexity science, which emphasize learning processes, adaptive management, innovation and experimentation across multiple levels, such as landscapes, regimes and niches” (2013).

Particularly in European Mediterranean regions, the wildland fire management sector is aiming to transform decades-old policies of fire suppression, change negative public opinions of prescribed burns (Fernandes 2013) and address governance gaps between communities and institutions (Wunder et al. 2021). For example, European-wide policies have generated frameworks to spark fire-smart territories (Rego et al. 2018), and the Spanish government recently released strategic guidelines for wildland fire management that include ecosystem adaptation actions and increased community participation in fire risk reduction actions (CLIF2022). Scholars also voice the need to change from “passive expectation of institutional intervention” to local communities initiating bottom-up processes for prevention and preparedness (Tedim, Leone, and Xanthopoulos 2016, 147). This shift therefore demands transdisciplinary methodologies in the form of participatory community engagement, empowering and weaving local knowledge, and increasing a sense of solidarity (Huffman 2013; Martínez-Sastre et al. 2017; Tedim et al. 2021; Wunder et al. 2021). Since fire is a transversal element, it requires creative co-management on local levels to understand local social diversity and changes in the landscape to better inform adaptive capacities and future action (Otero et al. 2018).

IV. Lessons from secondments: Transdisciplinary projects in the Netherlands and Aotearoa New Zealand

The secondments that ESR 12 conducted in the Netherlands and Aotearoa New Zealand throughout the PyroLife project provide insight on transdisciplinary processes in different regions of the world, whether directly linked with fire management or not. Following are a few examples of transdisciplinary projects in these countries. While the PyroLife project is not directly implicated in them, the ESR in question was given the opportunity to observe a few of these projects in development. These projects’ respective challenges and opportunities provide insight for future transdisciplinary fire research.

i. The Netherlands

At Wageningen University, the [KLIMAP](https://www.klimap.nl/)² project (“Climate Adaptation in Practice”), gathers diverse partners such as regional governments, researchers, and companies to create “climate-proof” designs of Dutch soil and water systems. The aim is to create development pathways that allow for adapted water and soil management, where food security, natural ecosystems, freshwater supply, water and soil quality are all stewarded in the conditions of a changing climate. As a key tenant of transdisciplinary endeavors, the partners “view the project as a dynamic process of learning, participation and implementation” (KLIMAP web 2023). The KLIMAP project is based on the framework of adaptation pathways, a transdisciplinary method that aims to create sequences of actions for adaptation to various climate and development challenges, acknowledging the uncertainties of the future and embedding flexibility within planning and research-action approaches (Werners et al. 2021). Within this project, it is important for the participants to acknowledge the challenging endeavor of collaboration itself and the reflexive outcomes of this learning process, not merely the research and technical outputs.

[WATERAPPS](http://www.waterapps.net/waterapp/home/)³ presents another significant transdisciplinary water project, aimed to co-develop climate information services for farmers in the lower Ganges Delta of Bangladesh. It intends to amplify smallholder farmers’ resilience to climate change, contributing both to sustainable agricultural goals and food security (Kumar et al. 2020) through the following approaches:

- 1) combining mobile information technology (like apps) with latest insights on knowledge sharing
- 2) integrating weather model results with observations of groundwater trends and river flows, and
- 3) attuning knowledge about adaptive decision-making and enabling governance structures to local situations (WATERAPPS web 2023).

In this way, the project situates the goals and needs of smallholder farmers first. It co-develops new technologies with local participants in order to increase their usability and relevance, helps to integrate cutting-edge climate modeling science, and engages with local policy and decision-making. This multi-faceted approach has its challenges and opportunities. While it is resource-intensive and requires many facilitators to honor the many actors’ interests and needs over a long period of time, it can also help secure the durability and legitimacy of project results beyond the research findings for sustainable development under the uncertain conditions of climate change.

Within the PyroLife project, researchers at Wageningen University identified how governance lessons from water management in the Netherlands could be translated into the domain of wildland fire management (Lambrechts et al. 2023). Authors reviewed literature on integrated and adaptive water management in the Netherlands, finding that holistic and integrated approaches, adaptive management, and fostering resilient landscapes through stakeholder participation were key to widespread success in Dutch water management. These lessons in turn could improve global wildland

² <https://www.klimap.nl/>

³ <http://www.waterapps.net/waterapp/home/>

fire prevention and integrated management strategies. This article is a call by researchers to make knowledge more shareable and actionable between different sectors of society, including landowners, civil protection, and policy makers. By nature, this requires increasing transdisciplinary partnerships in research, governance, and adaptive management.

ii. Aotearoa New Zealand

While on secondment with Scion in Aotearoa, New Zealand, the ESR was exposed to new transdisciplinary wildland fire projects. In the primarily temperate landscapes of Aotearoa, natural risks have long included flooding, volcanic activity and earthquakes. However, the onslaught of climate change creates new conditions for wildfire to proliferate in native vegetation, which is primarily not adapted to natural fire regimes (Perry, Wilmschurst, and McGlone 2014; Baillie et al. 2019). Increasing wildfire incidents in recent years have alarmed civil protection, residents, and researchers alike, leading to new partnerships to attend to this emerging complex problem (Jakes and Langer 2012). In a collection of wildfire social science case studies, Scion researchers reported several lessons:

- It is essential to improve wildland fire awareness and preparedness among communities and homeowners
- Agencies must be mindful of the range of perceptions and attitudes about wildland fire mitigation
- While many residents are highly aware of wildfire risks and have taken steps toward mitigation and preparedness, others seem to lack awareness and have taken few wildfire risk precautions
- Māori must be part of the wildfire preparedness conversation in order to enhance community engagement and knowledge transfer
- National and district level planning does not yet adequately address wildfire risk
- Most social engagement around wildfire risk happens too late, once homes and landscapes have already developed, creating scenarios where changes are expensive and difficult (Langer, Wegner, and Pearce 2021)

Equipped with this knowledge, Scion researchers embarked on a transdisciplinary project in [Extreme Wildfire](#)⁴ to learn how decisions in the planning, design and construction systems influence wildfire risk, the likes of which has never been attempted in the country. The aim of the project is to work both from the top down and bottom up: to understand how chains of decisions create cascading effects from the national to local level, shaping overall community and resident wildfire risk. The project also aims to incorporate recent science modeling wildfire spread and human behavior into planning and design decisions, consulting with planners, developers, building architects and landscape architects. The project

⁴ <https://www.scionresearch.com/about-us/about-scion/corporate-publications/scion-connections/past-issues-list/about-us/about-scion/corporate-publicationsscion-connections/current-issue/preparing-new-zealand-for-extreme-fire>

additionally seeks to create comparative case studies within communities that better represent Aotearoa’s social diversity, engaging especially with Māori and under-resourced populations. A primary challenge in this kind of project is engaging with sectors of planning and governance that do not have significant historical experience with the emerging complexity of wildfire issues. However, some key aspects of transdisciplinary collaborations have been widely accepted throughout Aotearoa, namely the rights and ethical considerations of Māori.

Community advocates and researchers in Aotearoa have demonstrated exemplary practice in transdisciplinary partnership for indigenous Māori empowerment and action, for example in the fields of water catchment management, waste management and earthquake recovery (Moewaka Barnes et al. 2021; Goven et al. 2015; Kenney and Phibbs 2015). Such mutual relationships between indigenous and non-indigenous partners, “signals a shift from harvesting cultural knowledge, to kaupapa Māori⁵ research where indigenous knowledge and perspectives are central to projects.” (Moewaka Barnes et al. 2021). Mātauranga Māori⁶ knowledge encompasses many ways of knowing, including language, philosophy, technology, beliefs, cosmology, methods and practices. As with all indigenous knowledges, it is dynamic and evolving (Tengö et al. 2017). Māori scholars share that mātauranga Māori knowledge systems are inherently transdisciplinary, “crossing divides of researcher and researched, science and story, discipline and liberation” (Moewaka Barnes et al. 2021). Partnerships that honor kaupapa Māori and mātauranga Māori also necessarily challenge current power dynamics, political and epistemic injustices, and notions of expertise. Indigenous scholars warn that, given how promises have been knowingly trespassed time and again since the colonial period, indigenous communities may be rightly wary of transdisciplinary partnerships that could in fact serve settler interests more than local indigenous people (Macfarlane and Macfarlane 2019). As such, these initiatives should be driven and led by indigenous leadership as much as possible. Some primary challenges in addressing this include allocating adequate time and resourcing to create transdisciplinary teams committed to trust and respect while embracing complexity (Moewaka Barnes et al. 2021).

As transdisciplinary fire projects centering indigenous knowledges gain visibility and power in decision-making (Copes-Gerbitz, Hagerman, and Daniels 2021), these aspects of indigenous partnerships are fundamental to bear in mind for future research-action projects.

V. Wildfire-specific transdisciplinary literature review

We conducted a literature search for fire-specific transdisciplinary studies in order to learn about the contexts and methods used in the field up to date. This search provides a needed synthesis on the kinds

⁵ Kaupapa Māori: “is used popularly by Māori in a fairly broad way to refer to any particular plan of action created by Māori, expressing Māori aspirations and certain Māori values and principles. There might be a range of purposes for the action taking. However, it is generally held that the design of the proposed action is created by Māori, reflecting Māori aspirations, ideals, values and perspectives” (Te Ahukaramū 2012, 31.

⁶ “Mātauranga Māori is a modern phrase used to refer to a body or a continuum of knowledge with Polynesian origins, which survives to the present day albeit in fragmentary form. Mātauranga Māori labels this body of knowledge” (Te Ahukaramū 2012, 33).

of projects yet attempted while also shedding light on ways forward in transdisciplinary fire science. While many transdisciplinary project outputs include technical reports and usable materials, we condensed our literature search to peer-reviewed academic articles only for the purposes of this report.

We conducted a search in Scopus and Google Scholar for literature from 2000-2022, using the following keywords: “Transdisciplinary*”, “Co-production”, “Co-creation”, “Adaptive Management”, in combination with the keywords: “Wildland Fire”, “Forest Fire”, “Wildfire”. Even with 12 possible combinations of results, this generated a relatively low number of studies: 59 total. After filtering the articles for their relevance to the review, we found that 42 studies maintained characteristics of transdisciplinary science. We further categorized our findings from the literature into case studies and more general overviews of transdisciplinary fire science. While several of the studies *call* for more transdisciplinary and inclusive approaches and may outline some guiding conceptual frameworks^{10, 11, 12,15, 20, 21, 31-42}, fewer case studies actually *apply* transdisciplinary methods in practice^{1-9, 13, 14, 16-19, 22-30}. In total, 25 articles truly represented case studies, which are noted separately in the literature table labelled in dark orange (Annex 1). This demonstrates how the field of transdisciplinary fire science is nascent in an academic setting, though we recognize there may be many more transdisciplinary partnerships that do not necessarily seek to publish results in academic journals. Additionally, our search was constrained to primarily academic articles in English, though a few surfaced in Spanish and French. For more information about each article, consult Annex 1 in the supplementary materials. We recommend the use of this literature table for a more detailed understanding of transdisciplinary fire projects conducted to date.

We organized and analyzed the literature according to the following aspects:

i. Phase of fire cycle

We first organized our findings according to the phase of the fire cycle represented in the studies, as it may provide a helpful guiding post for future transdisciplinary fire researchers. Results demonstrate that roughly half of transdisciplinary fire studies to date treat wildfire management as a multiple-phase issue²²⁻⁴², followed by 15 studies focused on wildfire prevention and preparedness¹⁻¹⁵, only 4 dedicated specifically to restoration aspects¹⁸⁻²¹, and a mere 2 transdisciplinary studies dedicated to wildfire response¹⁶⁻¹⁷. This demonstrates maturity in the literature about treating wildland fire as a multi-faceted issue, aiming to create adaptive and transformative action to prepare for the complex and uncertain fire landscapes of the future. However, this also demonstrates that there is still room for transdisciplinary interventions at specific points in the fire cycle. Particularly, wildfire response and restoration efforts can be better represented in future projects.

ii. Topic

Topics ranged widely in transdisciplinary fire studies, including wildfire risk governance^{1, 18, 26}, social and ecological vulnerabilities and resilience^{4, 5, 8, 13, 19, 26, 27, 30, 36, 39}, addressing aspects of ecosystem conservation and restoration^{3, 7, 12, 18, 19, 20, 21, 24, 25}, land use planning,^{4, 8, 12, 18, 20, 21, 24, 26, 29, 32, 33, 36, 40} education and communication around risk mitigation and wildfire preparedness^{5, 14, 15, 28, 35}, public health effects of smoke exposure^{20, 22}, design and climate service needs in wildfire response^{10, 16, 17, 27}, uplifting

indigenous and local knowledges in fire adapted landscapes^{13, 20, 30, 42}, increased integration of fire science and management^{23, 24, 27, 28, 31, 32, 35, 36, 37, 38}, and proposals of conceptual frameworks for more transdisciplinary fire science approaches^{11, 22, 33, 39, 42}.

iii. Methods

A variety of methods proliferate in transdisciplinary fire studies to date, the most participatory methods of which include: co-productive/collaborative workshops, focus groups, transdisciplinary conversations, art and science collaborations, direct community engagement, connecting with local learning groups, and more^{4, 13, 15, 18, 19, 20, 26, 40}. Other studies employ social-oriented qualitative methods like participant observation, process overviews, literature reviews, surveys, interviews (in-depth, semi-structured, etc.), and presenting integrative conceptual frameworks^{2, 21, 23, 24, 27, 29, 31, 33, 38}. Still others combine more quantitative data from natural sciences such as historical landscape analysis, ecological inventories, multi-hazard risk assessments, biophysical data, burned area data, standard precipitation and evaporation index, water balance values for fire management operations, and geospatial analyses into participant-oriented projects^{5, 10, 14, 16, 24}.

iv. Location

Currently, the locations of transdisciplinary fire projects are relatively constrained to geographic areas that have historically dominated wildland fire science literature. While some studies take on a more global framework for transdisciplinary fire science^{10, 22, 35, 36, 37, 39, 40, 42}, most studies focus on the western United States^{1, 4, 7, 14, 20, 21, 23, 28, 31, 32, 33, 41}, Canada^{27, 29, 30}, Australia^{9, 13, 15, 41} and western Mediterranean Europe^{2, 3, 8, 11, 12, 16, 19, 26, 38}. A few more countries and regions are starting to find representation in transdisciplinary fire literature, including northern Europe (Norway)⁶, South America (Chile and Colombia)^{17, 18, 24}, and Sub-Saharan Africa (Kenya, Zambia, South Africa, Mali, Guinea, Zimbabwe, Benin, Ghana, Tanzania, Mozambique, and others)²⁵. This leaves much room to be explored in transdisciplinary partnerships throughout the world: both in places that have historically experienced wildland fire and those experiencing it as an emerging phenomenon due to climate and land use change.

v. Actors involved

To date, the various sectors involved in different transdisciplinary projects depended largely on the social context and aims of the projects. For instance, researcher profiles varied widely from fire ecology, public health sectors, social sciences, design and engineering, natural scientists, policy researchers, and social-environmental systems thinkers^{2, 3, 15, 17, 25, 38, 40}. Fire management sectors could include emergency responders, infrastructure operators, prescribed burning groups, volunteer firefighters and wildfire analysis specialists^{1, 4, 6, 9, 14, 16, 17, 19, 20, 26, 29, 31, 38}. Broader land managers included profiles such as forestry unions, natural park managers, private landowners, and farmers (especially livestock managers)^{1-8, 13, 15, 18, 21, 23-31}. Government representatives could vary from local, regional to national scales, including profiles such as Tribal governments, the USDA and bureaus of forest service in the USA, city staff, and regional governance representatives such as forest fire prevention offices in Catalonia^{1, 3-8, 16, 24-27, 29}. Community members involved in these processes included Indigenous residents, non-indigenous residents, artists, and community leaders^{2, 3, 5, 7, 13, 15, 18, 24, 27, 28, 30, 31}. Other areas of interest included nature conservation NGOs^{4, 26}, learning and stewardship networks^{7, 33}, the tourism sector^{3, 6}, the public health sector^{20, 22}, and social housing agencies for survivors of wildland fires¹⁸.

vi. Advances for Integrated Fire Management

These studies represent important advances for integrated fire management: they treat social-ecological fire issues as a complex problem that must be addressed through multiple forms of knowledge, often through participatory methods. Several studies report positive findings on increasing collaboration and coordination with different entities: including local communities, partnering science with practical resource management, coordinating at a landscape scale, coordinating between crisis management and resource sharing between agencies, encouraging community co-management of landscapes, sharing information across siloes of hazard management, building social capacity over the long term, and engaging in collaborative group strategies for restorative planning after fire events^{1, 4, 5, 7, 12, 18-21, 23, 24, 28, 29, 31-33}. Others emphasize the importance of learning initiatives between project partners, such as seeking to establish common narratives to better manage landscapes, co-creating knowledge for actionable social science and emergency decision-making, testing new methods like creating adaptation pathways, and fostering broader public understanding of fire in the landscape through art and science collaborations^{1, 2, 7, 26, 33}. Several studies also actively engage in empowering marginalized voices in fire management, such as co-producing dialogues post-disaster to increase equity in city planning¹⁸, and other studies especially focus on Indigenous communities in the Americas and Africa to promote biocultural lenses on fire management and encourage decolonization of methodologies^{13, 20, 25, 30, 42}. Still other studies focus more on the role of governance institutions, reflecting on their adaptability and roadmaps for possible transformation^{1, 18, 26, 27, 29}. The literature also begins to explore the intersections of public health, forests, and fire management, especially when it comes to community smoke exposure^{20, 22}. Finally, while several of the studies do not report findings on specific case studies, they do encourage new transdisciplinary frameworks around conservation and restoration of landscapes¹², defining extreme wildfire events³⁵, finding intersections between human and fire ecology^{34, 41}, opening dialogues in “translational fire science”³⁷, encouraging “fire smart territories”¹¹, and promoting further studies in emerging fields like “pyrogeography”⁴⁰. These findings all aid in advancing the field of integrated fire management: by addressing social, ecological, economic, technological and political aspects of wildland fire in its many phases, they actively pursue systemic change and sustainability through varied approaches.

VI. Guiding considerations for future transdisciplinary wildfire research

The following guiding considerations were developed out of the literature review on broader transdisciplinary projects, fire-specific transdisciplinary projects, and ESR 12’s exposure to international transdisciplinary projects. The aim of Table 2 is to provide a reflexive guide to orient future project managers and researchers in their approach to transdisciplinary fire studies, as they consider the framing, feasibility and desirability of their co-created projects with local actors. Such considerations may help tailor their methods and approaches. See section VII for an example on how Table 2 is used.

Table 2: Considerations for fire-specific transdisciplinary projects

TD Fire Category	Explanation	Examples
Stage of Fire Cycle	First considering the point of entry in the fire cycle can greatly determine the kinds of processes and participants involved the TD project	Prevention, Preparedness, Response/Management, Recovery/Adaptation, Multiple
Connection to other hazards	Many TD projects aim to reach beyond “siloes” of scholarship in hazards management. Considering other connected hazards may become increasingly relevant in the context of climate change.	Storms and floods, Avalanches, Drought, Other
Academic Knowledge	Fire is a transversal topic across many academic disciplines in natural and social sciences. The kinds of academic knowledge involved will depend on the aims and scope of the project.	Natural Sciences (eg. Fire ecology, environmental science, climate science, soil science, atmospheric science, hydrology, botany...), Social Sciences (eg. sociology, human geography, economics, psychology, political science, human behavior, anthropology...) Engineering & Design (eg. landscape architecture, architecture, structural engineering, etc.) Social-Environmental Systems (eg. political ecology, water management, pyrogeography...)
Broader forms of Knowledge	Fire is a transversal topic across many ways of knowing and interacting with the landscape. The kinds of broader knowledge involved in the TD project will depend on the aims and scope of the project.	Indigenous Knowledge, Traditional Ecological Knowledge, Local Knowledge, Fire Practitioners’ Knowledge, Land Managers’ Knowledge, Political and Administrative Knowledge...
Possible Participant Profiles	Fire is a transversal topic of concern and interest across many sectors of society. TD research can better aim to serve the diverse voices that impact and are impacted by fire regimes.	Indigenous People, Fire managers, Operational sector (including volunteers), Civil protection, Technology developers, Land use planners & developers, Architects, Land managers, Farmers, Foresters, Policy makers, Local administrators, Conservation and environmental advocates, Residents, Homeowner associations, Tourists, Artists, Community advocacy groups (e.g. hiking,

		local cultural events, outdoor education, social inclusion, equitable housing, etc.)
Scale of Action	Determining the scale of action for the TD project will greatly influence the kinds of actors involved, and can help frame the scale of the issue and possible entry points for co-creation of solutions.	Administrative boundaries (neighborhoods, municipalities, counties, etc.), Social boundaries (communities and neighborhoods), Environmental boundaries (catchment scale, watersheds, “firesheds”, bioregions...), Cross-regional, International
Role and timing of research team	Researchers must reflect on their own roles and resources within the project frame. This will influence the dynamics and longevity of the project and its results.	Facilitators, Funders, Reflexive approach
Role and timing of participants	This must be a transparent dialogue throughout the project between promoters and participants: to ensure co-ownership of the process but to not overstep participant resources or capacities.	“End Users”, Informants, Co-creation, Co-design, Assessment, Validation and evaluation, Monitoring impacts
Project Aims	The prior categories of TD considerations may help orient realistic project aims, which can therefore help determine appropriate TD methods for the project aims. For a complete overview of TD methods, consult Moallemi et al. 2021.	“Outcome”/product oriented, Research oriented, Stakeholder oriented (Empowerment, Transformation, Learning), Pluralistic, Interactive, Science-policy interactions...

VII. Example: ESR 12 approach

Within the framework of the Pyrolife project, ESR 12 developed a transdisciplinary approach in a case study in Catalonia, Spain (Uyttewaal et al., forthcoming). Wildland fire risk is increasing due to changes in the climate, landscape, and social values in Mediterranean areas. Transdisciplinary strategies that support adaptive and transformational action on the landscape scale are necessary to address arising

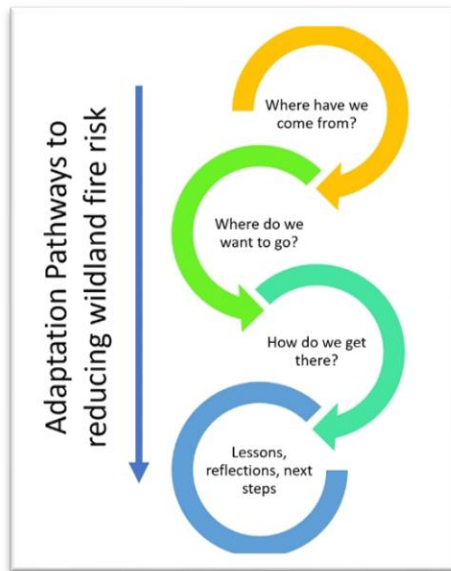


Figure 2: Summary of ESR 12 participatory workshop objectives

uncertainties, and to bridge gaps between top down and bottom-up approaches to fire risk reduction (Uyttewaal et al. 2023).

In the semi-rural area of the Montseny massif in Catalonia, Spain, we co-created adaptation pathways to reduce wildland fire risk. We collaborated with agents of change in the territory like fire managers, local administrators, sustainable farmers and foresters, researchers, education and tourism sectors, and other local knowledge holders. We aimed to leverage local knowledge as a strategic tool for adaptation, and we created space for social learning and amplifying networks between sectors. The three co-creative workshops focused on increasing shared understanding and recognizing pluralities in: where we have come from and where we want to go, how we get there, and focusing on lessons, reflections and next action steps. The results and conclusions of this research are forthcoming in several academic publications and ESR 12’s dissertation from Wageningen University (available 2024).

Here, we use the guiding considerations laid out in Table 2 as a heuristic tool to reflect upon ESR 12’s research process:

Stage of fire cycle: Prevention, adaptation.

In the case study area, fire events tend to be infrequent though severe (P. Costa et al. 2011). The last significant fire emergency occurred in 1994, and local actors are keen to adapt to the uncertainties of climate change.

Connection to other hazards: Storms, flooding, drought.

Adaptive water management projects have also been carried out in the region in prior years (Verkerk et al. 2017), the results of which provide theoretical and methodological reflections for this project. Furthermore, the area has experienced significant drought conditions over the past two years: water use restrictions are in place even during the winter, and much local vegetation is under stress. Participants in the project have voiced their increasing concerns about these inter-related hazards.



Figure 3: Co-construction of timeline in workshop 1

Academic knowledge: fire ecology, participatory methods, adaptive water management, social-ecological systems, analysis of traditional ecological knowledge, semi quantitative and qualitative methods, landscape architecture.

Through partnership with the Pau Costa Foundation and Wageningen University, several spheres of interdisciplinary academic knowledge come together both through the primary researchers’ efforts and collaborators throughout the project.

Broader forms of knowledge: Local knowledge, fire practitioners’ knowledge, administrative knowledge.

The range of participants embodied many of these knowledges through their livelihoods and life histories. It was critical to include these diverse forms of knowledge in our co-creative process in order to increase understanding between these different ways of interacting with the landscape.

Participants: Volunteer and professional firefighters (operational sector), land managers, farmers, foresters, administrators, technicians in natural parks and protected areas, associations dedicated to local knowledge, NGOs, conservation entities, local educational and tourism businesses.

Several of these profiles of participants do not often have the chance to connect in person over land management issues that concern them all. However, imbalances in political and economic power highly influence the study area and have led to deep-seeded social tensions in the territory, especially in the sectors of tourism, conservation, and primary production (agriculture and forestry). In this case, facilitated inclusion techniques helped to navigate some of these tensions to best represent voices that are not often given a platform. Other participant profiles were not included due to their difficulty to reach or their lack of organizing bodies in the territory, such as tourists and residents in suburban areas who do not necessarily demonstrate engagement or interest in land management issues.



Figure 4: Co-creation of adaptation pathway options in workshop 2

Scale of action: River catchment

The project focused on the river catchment scale of the Tordera River Basin. We chose this approach as many land management challenges extend beyond administrative boundaries and geographic massifs. The upstream effects of land management also highly impact management options and water tables downstream. As many innovative strategies take place in different parts of the river basin, this widened framework also provided an opportunity for actors from different municipalities and ecosystems to appreciate the work carried out by other initiatives in the area. In total, the project area spanned over 3 counties, more than 25 municipalities, 2 natural park areas, and a mixture of private and public land ownership.

Role and timing of research team: Funders and facilitators

Throughout this process, the research team acted as the primary funders and facilitators of the co-creative events. While this provided unique opportunities for dialogue with diverse actors, this also may have limited local interaction over time. Since no participants received funding or resource incentives to participate and volunteered their time to contribute to these spaces, it significantly limited their availability.

Role and timing of participants: Informing of initial values/perspectives/needs in the region via interviews, co-creators of adaptation pathways, evaluation of pathways results, consultation and involvement in next steps.

Actors participated in the process through varying capacities, depending on their availability and interest. Numerous actors informed the research team of preliminary values, perspectives, challenges and opportunities in the region via interviews. Approximately 20 participants from various sectors assisted in the co-creation of the adaptation pathways, as well as their evaluation. Beyond the research process, actors are also consulted and involved in next steps for implementing some of these pathway options in the territory.



Figure 5: Reflections and next steps in workshop 3

Aims of the project: Research & Stakeholder Oriented.

This co-creative process has research outcomes in the form of academic publications and a PhD dissertation, while it also focuses closely on amplifying local knowledge and social learning networks with participants. Summary reports and videos are also provided to the participants, and will be further circulated with other local entities and administrations. This informed our choice of methods to explicitly recognize local knowledges in the territory and create spaces for dialogue that would foster social learning. Our methods included: co-constructing a timeline of important changes in the territory (Hill et al. 2020; Bosomworth 2018), informing participants about changing local fire regimes under climate change (Fundació Pau Costa et al. 2019), conducting a visioning exercise to determine ideal future scenarios (informed by climate change scenarios) (Sharpe et al. 2016; Kuiper et al. 2021), conducting a back-casting exercise to project the needed transitions to arrive to an ideal state (Pereira et al. 2020; Sharpe et al. 2016), and finally a reflecting dialogue for participants to situate themselves and others within these processes of change (Bosomworth 2018).

VIII. Conclusion & recommendations

Many of the considerations in broader transdisciplinary research are also relevant for fire-related projects, as many themes intersect toward sustainable transitions. As some reviews of transdisciplinary processes have demonstrated, “there are often tradeoffs between complexity, applicability, and generalizability” in such projects (Knapp et al. 2019, 18). Since transdisciplinary projects are intentionally embedded in real-world complex problems at varying scales, the knowledge generated in such projects should therefore fit and benefit the local context and caution should be taken when aiming to scale up transdisciplinary approaches (Knapp et al. 2019).

Some primary challenges and opportunities in transdisciplinary research (including fire-specific projects) include:

- Navigating the risk of misunderstanding, misappropriation, or lack of recognition and respect between differing epistemologies (Iago Otero et al. 2021; Pascual et al. 2022). For fire-related projects, this is especially true when interacting with Indigenous and local knowledges
- Pursuing adequate facilitation and training on interpersonal skills, communication and conflict management (Faysse 2006; Iago Otero et al. 2021). Skills like cognitive training, active listening, meditation, and harm reduction can be essential in order to “stay with the trouble” of complexity and high conflict in order to truly transform power relations (Chambers et al. 2022). In the case of fire, this can especially be true for communities and ecosystems that have suffered traumatic incidents.
- Creating space for researcher reflexivity and acknowledgement of personal transformation throughout the process (Chambers et al. 2022).
- Clearly defining “workflows”, roles and responsibilities throughout the process. Not all actors need to participate in every phase, but participants do need to be made aware of their roles in order to ethically engage in the process, protect participants from burnout and to ensure scientific integrity (Pohl et al. 2010). In the case of fire, as actors and interests vary widely according to the point in the fire cycle that is being addressed, this is an especially important consideration.
- Acceptance of heterogeneous data from differing academic and non-academic disciplines that may present conflicting perspectives (Schneider et al. 2015).
- Consider broader dissemination of project impacts: encourage networks for exchanging stories, experiences, and best management practices whose lessons could be adapted to other settings (Goldstein and Butler 2010)
- Ensuring institutional support over long-term processes and continuity when funding ends (Mauser et al. 2013; Leemans and Fortuin 2021)
- Establishing integrated educational and research institutions that value and seek to fund projects that bridge fields of knowledge. This could also ensure career advancement for transdisciplinary researchers and would require explicit integrated funding mechanisms (Mauser et al. 2013; Leemans and Fortuin 2021)
- Flexible approaches in the research that allow for “serendipitous” developments, according to the participants’ learning process and evolving needs (Iago Otero et al. 2021)
- Deliberately making space for free time in project agendas to foster a more natural and collaborative environment over the long term (Iago Otero et al. 2021)
- Confronting personal and institutional inertia to change “business as usual” approaches (Pascual et al. 2022; Mauser et al. 2013)
- Addressing power and resource inequalities: accessing scientific funding requires significant power, and these resources may not reach the communities who need them. The format of output-driven research could pose fundamental challenges for more profound and transformative collaborations over the longer term (Blythe et al. 2018)

- Encourage active communities of practice that engage young scientists and other knowledge holders in exchanges and co-creative approaches (Knapp et al. 2019)

As the transdisciplinary field evolves and grows, this document can assist in orienting fire-specific researchers and project managers to consider various methods and approaches when creating collaborative transdisciplinary endeavors to maximize their impact in co-developing solutions to living with wildland fire.

Annex I

See attached document.

The annex presents more in-depth information on the transdisciplinary fire publications reviewed. The table is organized according to phases of the fire cycle, presenting a more relevant guidepost for future projects and research rather than an alphabetical categorization. Furthermore, the studies highlighted in dark orange present specific case studies, while the studies in light orange present more general frameworks and reviews of transdisciplinary projects. The studies are numbered 1-42 and are referred to as such in the transdisciplinary fire literature review section of this document.

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ANNEX I. TD FIRE LITERATURE REVIEW

No.	Phase of Fire Cycle	Title	Authors	Journal	Date	DOI	Topic	Location(s)	Methods	Objectives	Actors Involved	Advances/Implications for IFM
1	Prevention (Adaptation)	Achieving Adaptive Governance of Forest Wildfire Risk Using Competitive Grants: Insights From the Colorado Wildfire Risk Reduction Grant Program	Antony S. Cheng, Lisa Dale	Review of Policy Research	2020	https://doi.org/10.1111/ropr.12379	Achieving Adaptive Governance of Forest Wildfire Risk Using Competitive Grants	Colorado	Adaptive governance theory is used as a lens to assess the adaptability of the Colorado Wildfire Risk Reduction Grant (WRRG) program, which awards funds to successful applicants to reduce fuel on non-federal lands at a community scale. Four best practices from the theory were applied: participation of and collaboration among diverse actors; co-production of knowledge and learning toward adaptive management; cross-scale interactions and fit between the scale of governance and the scale of the ecological problem; and the capacity for innovation and re-organization.	Adaptability of competitive grants as a new governance approach	Colorado Wildfire Risk Reduction Grant (WRRG) program participants	Encourages wildfire community to critically reflect on the adaptability of institutions and governance approaches: emphasis on proactive collaborative actions involving government, non-government and community-based organizations
2	Prevention	La contextualisation des recherches en environnement: Une approche multiscalaire et multi-acteurs en Cévennes	Nathalie Couix, Bernard Hubert	Natures Sciences Sociétés	2012	DOI: 10.1051/ns/2012045	Case study in wildfire prevention and land management in the local and policy level.	France	13 years of participant observation in research interventions. Several stages of working groups. Observation of research dynamics and changes occurring in institutional arrangements.	Promote complementarities between forestry and livestock farmign to create resilient landscapes toward fires	Technical team, facilitators, universities and agricultural research institutions, societal actors like administrators, forestry unions, farmers, and others.	There is a need for reciprocity of learning between researchers and non-researchers to allow the contextualization of science. It is difficult to translate the reflexivity and learnings that happen on an individual level to an institutional level. Authors encourage researchers to act as go-betweeners between local contexts and the decision-making spheres of public action.
3	Prevention	"Wilderness": What it means when it becomes a reality - A case study from the southwestern Alps	Franz Höchtl, Susanne Lehringer, Werner Konold	Landscape and Urban Planning	2005	doi:10.1016/j.landurbplan.2003.10.006	The impacts of uncontrolled nature development on the landscape's structural diversity, plant species richness, as well as on the local population and tourists	Southwestern Alps	The methods include: conducting historical landscape analysis, ecological inventories and empirical-social research were combined in accordance with the transdisciplinary research	The objective of this project is to develop perspectives for the future of the national park community of Premosello Chiovena and the Upper Strona Valley	Community of Premosello Chiovena and the Upper Strona Valley: residents, tourists, politicians, nature conservation representatives	Large-scale projects on initiatives such as rewilding should include local communities in decision-making processes as much as possible. Researchers and decision-makers need to make this effort in order to foster sustainable development and positive local relationships
4	Prevention	Using science management partnerships to develop landscape level indicators and assessments to measure vulnerability of Piñon-Juniper woodlands	Megan Friggens, Stephanie Mueller, Mary Williams	Ecological Indicators	2020	https://doi.org/10.1016/j.ecolind.2020.106830	This paper describes the collaborative process used to identify and vet potential indicators of vulnerability, present a framework for using those indicators to assess piñon-juniper ecosystems (PJ) vulnerability, and demonstrate its application for predicting current and future PJ vulnerability within landscapes in the Southwest with the intent to inform resource management decision making processes	Southwest U.S.	Co-production method: meetings and discussions among federal, state, and local governments, tribes and first nations, and nongovernmental organizations to identify common priorities and needs within the region	The object was to create data products that would assist resource managers dealing with rapidly changing landscape	Universities, NGOs, Native American Tribes (State and Federal), USDA, Bureau of Indian Affairs, Bureau of Reclamation, Bureau of Land Management, Fish & Wildlife Service, National Park Service, National Resource Conservation Service, US Army Corps of Engineers, US Forest Service, US Geological Survey	Applied science projects must be developed in partnership with resource management audiences in order to meet management needs. Vulnerability assessments provide first steps to develop adaptive management plans. Continued dialogue is needed through Adaptation Forums. Coordination at the landscape scale requires significant time investment from science and manager partners but can lead to more effective management strategies.
5	Prevention	Boundary crossing for urban community resilience: A social vulnerability and multi-hazard approach in Austin, Texas, USA	R. Patrick Bixler, Euijin Yang, Steven M. Richter, Marc Coudert	International Journal of Disaster Risk Reduction	2021	https://doi.org/10.1016/j.ijdrr.2021.102613	Urban community resilience and a social vulnerability and multi-hazard approach	Texas, USA	this paper presents a methodology for a multi-hazard risk assessment that combines exposure to multiple natural hazards (flood, wildfire, and extreme heat) and social vulnerability	How the process and the maps operated as boundary objects giving rise the co-production between hazard scientists and disaster risk reduction practitioners.	Academics, city staff, and community groups	Research reached across traditional hazard science silos and communication with community groups. It is difficult to know how this momentum will become more pluralistic over time, or if the information generated will empower marginalized voices or transform institutions.

No.	Phase of Fire Cycle	Title	Authors	Journal	Date	DOI	Topic	Location(s)	Methods	Objectives	Actors Involved	Advances/Implications for IFM
6	Prevention	Study of heathland succession, prescribed burning, and future perspectives at Kringsjå, Norway	Anna Marie Gjedrem and Torgrim Log	Land	2020	doi:10.3390/land9120485	The coastal heathland of Western Europe, dominated by <i>Calluna vulgaris</i> L., was previously maintained by prescribed-burning and grazing to the extent that the Calluna became anthropogenically adapted to regular burning cycles. This study addresses the analysis of Heathland Succession, Prescribed Burning, and Future Perspectives at Kringsjå	Norway	Network analysis aiming to understand the levels of co-creation, and how stakeholders ought to situate themselves.	The motivation for the present study is to analyse this facility and investigate possibilities for synergies between landscape management and tourism as a route to sustainable transitions. The present study compares restored heathland vegetation with unmanaged heathland at Kringsjå. An objective of the study is to identify possible synergies between tourism and landscape management.	The tourist sector, local population, land-owners, local government, academia, civic burning groups, and the natural environment	Prescribed burning may return to cultural landscapes in Norway. Establishing common narratives and visions between stakeholders in tourism and heathland management may encourage mutually beneficial landscape and cultural management outcomes.
7	Prevention	A boundary-spanning organization for transdisciplinary science on land stewardship: The stewardship network	A. Paige Fischer	Ecology and Society	2020	http://www.ecologyandsociety.org/vol20/iss4/art38/	Process of learning around conservation and restoration that improves social and ecological knowledge	USA	The model engages local and regional groups in an ongoing process of learning around conservation and restoration that improves social and ecological knowledge	The initial goal was to build a community of conservation practitioners to coordinate conservation in the Huron River watershed to improve the efficiency and quality of their work	The Stewardship Network: local school district, volunteers, local land conservancies, watershed councils, municipal parks, scientific experts, property owners, citizens.	Social capacity building makes TSN's model scalable and transferable. Engaging in problem definition, design, study and interpretation in phases of stewardship is crucial at every land management scale. This program allowed for the use of prescribed fire as a management tool for restoration.
8	Prevention	How does land management contribute to the resilience of Mediterranean forests and rangelands? A participatory assessment	Jucker Riva Matteo, Baeza Jaime, Bautista Susana, Christoforou Michalakis, Daliakopoulos Ioannis, Hadjimitsis Diofantos, Keizer Jan Jacob, Liniger Hanspeter, Quaranta Giovanni, Ribeiro Cristina, Sallia Rosanna, Tsanis Ioannis K, Urgeghe Anna M., Valdecantos Alejandro, Schwilch Gudrun	Land Degradation & Development	2018	doi: 10.1002/ldr.3104	In this study, we focus on the resilience of semi-natural Mediterranean ecosystems in relation to multiple disturbances that can reduce the provision of ecosystem services, so-called "specified resilience" (Folke et al., 2010) or "resilience of what to what" (Carpenter et al., 2001).	Mediterranean area	Data about disturbances, ecosystem services, the role of LMPs, and the resistance of LMPs to disturbances are combined using a semi-quantitative index, and analysed to evaluate how the LMPs implemented are suited to the disturbances affecting each study site	In this study, we assess the contribution of land management practices (LMPs) to the resilience of eight Mediterranean forests and rangelands to multiple disturbances	Scientists, land managers, land users, local administrators, and experts/consultants	A knowledge co-creation approach leads to several practical indications on how to increase resilience in Mediterranean ecosystems, relevant for land management planning and policy-making. Multiple ecosystem services need to be promoted, as well as multiple LMPs that focus on preventing, mitigating or fostering recovery with various disturbances.
9	Prevention	'Opening up' policy to reflexive appraisal: a role for Q methodology? A case study of fire management in Cape York, Australia	David G. Ockwell	Policy Sci	2008	DOI 10.1007/s11077-008-9066-y	Theory and practice to participatory approaches to policy appraisal	Cape York, Australia	Q methodology: roots in psychology and is increasingly applied across the social sciences in an attempt to map the subjective responses of individuals to a specific issue in such a way as to reflect the broader discourses that exist within the public sphere in relation to that issue	In this paper the potential of Q to open up policy discourses to reflexive appraisal is tested by applying it in the context of fire management policy in Cape York, a region of northern Australia	Actors involved in fire management	Novel participatory method to assist sustainable fire management projects in understanding different stakeholder discourses. Can provide more nuanced responses to issues and pave the way for more participatory institutional structures. Highlights a need to consider expanding institutional capacities to better facilitate stakeholder engagement in developing fire management policy.
10	Prevention	Resilient landscapes to prevent catastrophic forest fires: socioeconomic insights towards a new paradigm	Sven Wunder, Dave E. Calkin, Val Chariton, Sarah Feder, Inazio Martínez de Arano, Peter Moore, Francisco Rodríguez y Silva, Luca Tacconi, Cristina Vega-García	Forest Policy and Economics	2021	https://doi.org/10.1016/j.forpol.2021.102458	Socioeconomic insights to encourage integrated fire management	Global	Authors describe socioeconomic dimensions for creating more fire-resilient landscapes, discuss cost-benefit gaps and externalities, create an integral theory of change in European Mediterranean region	Provide socioeconomic, science-informed analysis to envision more fire resilient landscapes and communities through integrated fire prevention	N/A	Provides socioeconomic considerations to pair with biophysical drivers of wildfires. Maps distributions of costs and benefits in fire response, and promotes a theory of change in Mediterranean forests

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11	Prevention	A wildfire risk management concept based on a social-ecological approach in the European Union: Fire Smart Territories	Fantina Tedim, Vittorio Leone, Gavriil Xanthopoulos	International Journal of Disaster Risk Reduction	2016	http://dx.doi.org/10.1016/j.ijdrr.2016.06.005	Fire Smart Territories in Europe	Europe	Framework: Promotion of transdisciplinary concept	Present an innovative model of wildfire management focused at the territory scale. Fire Smart Territory provides a theoretical, context-specific, and place-based operational framework.	N/A	Provides roadmap for transformational projects and narratives around wildfire in Europe. It provides a holistic strategy based on a coupled human-natural system understanding of relations between human systems and fire. It is a tool to decrease wildfire risk, reduce probabilities of disaster, and aims to cope with social, economic and environmental problems of wildfires
12	Prevention	Transdisciplinary challenges for sustainable management of mediterranean landscapes in the global information society	Zev Naveh	International Association for Landscape Ecology	2009	DOI: 10.3097/L0.200914	Transdisciplinary discourse for land use planning in Mediterranean regions	Mediterranean Region	Perspective paper	Encourage restoration of Mediterranean uplands through cultural landscape biodiversity: active fire and fuel management	N/A	Recognition of perturbation-dependent semi-natural Mediterranean landscapes, requires maintaining "dynamic homeorhetic flow equilibrium between the tree-shrub-grass cover". Dynamic conservation and restoration management through transdisciplinary approaches is vital.
13	Preparedness	A linked vulnerability and resilience framework for adaptation pathways in remote disadvantaged communities	Yiheis Taddele Maru a, Mark Stafford Smith, Ashley Sparrow, Patricia F. Pinho, Opha Pauline Dube	Global Environmental Change	2013	http://dx.doi.org/10.1016/j.gloenvcha.2013.12.007	Adaptation pathways to climate change among people in remote regions	Remote regions around the world (Australian, Botswana and Brazilian Amazon)	Through literature review and community engagement across three remote regions on different continents, They test the potential of the framework to assist dialogue about adaptation pathways in remote marginalized communities.	Develop a systems framework for exploring adaptation pathways to climate change among people in remote and marginalized regions	Communities from remote regions of the world: research and capacity building organizations that focus on remote indigenous peoples	The dynamic and co-productive formulation of adaptation pathways provides ways to reconcile conflicting narratives about resilience and vulnerability in remote regions, and opens a wider toolbox of adaptive responses to natural risks like wildfire and flooding.
14	Preparedness	Actionable social science can guide community level wildfire solutions. An illustration from North Central Washington, US	Patricia A.Champ,Hannah Brenkert-Smith, Jonathan P. Riley,JamesR.Meldrum,Christopher M.Barth,Colleen Donovan, CarolynJ. Wagner	International Journal of Disaster Risk Reduction	2022	https://doi.org/10.1016/j.ijdrr.2022.103388	In this study we illustrate the value of social data compiled at the community scale to guide a local wildfire mitigation and education effort	North Central Washington, US	Biophysical and social data collected at the property level to investigate whether practitioner defined "communities" within a contiguous geographic area are distinct in dimensions relevant to tailoring wildfire preparedness and mitigation	How can local, community-specific social data inform wildfire education efforts across diverse communities?	Social scientists, wildfire practitioners	Co-production that prioritized wildfire practitioners' ideas of community distinctness allowed to move toward a more tailor approach to local fire management strategies. Wildfire social data selected at appropriate scales can help inform actionable social science in other contexts.
15	Preparedness	Design-led strategies for bushfire preparedness	Yoko Akama, Susan Chaplin, Richard Philips, Keith Toh	Proceedings fo the Disaster and Emergency Management Conference	2012	N/A	Dialogic communication on bushfire preparedness	Australia	Participatory workshops	Facilitate co-creation and communication of local knowledge of the environment through visualisation	Residents, researchers	Raising awareness requires dynamic and multi-layered approaches to engagement. Communication should go beyond transmitting information and would benefit if actors feel prepared to enact in a self-empowered way. Communication can catalyse social cohesion.
16	Response	Seasonal prediction of climate-driven fire risk for decision-making and operational applications in a Mediterranean region	Marco Turco, Raül Marcos-Matamoros, Xavier Castro, Esteve Canyameras, Maria Carmen Llasat	Science of the Total Environment	2019	https://doi.org/10.1016/j.scitotenv.2019.04.296	Assess and develop a climate service focused on the production of seasonal predictions for summer wildfires in a Mediterranean region through a participatory approach with end-users.	Mediterranean region (Calalonia)	Accurate data for burned area during the period 1983–2017 were obtained from the Forest Fire Prevention Office of the 'Generalitat de Catalunya' (SPIF).Use the standard precipitation and evaporation index (SPEI; Vicente-Serrano et al., 2010) to estimate drought intensity. The SPEI is obtained by a standardizing the multi-month (e.g., 3, 6 or 12 months) water balance values estimated as precipitation minus potential evapotranspiration (PET). The SPEI was then calculated for the common period 1981–2017 at each point on the 0.5 grid and spatially averaged over Catalonia.	Here it show that a seasonal climate forecast of fire risk, when provided through a service tailored to the user's needs, can enable a more effective adaptation to climate variability and change, offering an under-exploited opportunity to minimise the impacts of adverse climate condition	Forest Fire Prevention Office of the 'Generalitat de Catalunya' (SPIF)	Decision-aid tools for fire managers can provide assessments of forest fire risk in the most critical period of the year. The co-production of climate services aided to create actionable research in the area.
17	Response	Centros de control de incendios forestales en Chile: Experiencia de diseño orientado al usuario	Jimena Alarcón Castro, Javiera Brañes Alarcón y Josefina Brañes Alarcón	Interiencia	2021	N/A	Design of forest fire control centers	Chile	User-oriented design principles (Kansei Engineering), survey and focus groups with participatory decision-making	Improving habitable space of forest fire control centers for emergency personnel	30 fire emergency managers and researchers in design and engineering	Integration of design sciences for emergency management centers that support concentration and socio-emotional connection between users. Co-creation of these spaces between designers and emergency managers can help facilitate decision-making during fire emergencies.

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18	Restoration	Co-production after an urban forest fire: post-disaster reconstruction of an informal settlement in Chile	Lautaro Ojeda , Gonzalo Bacigalupe and Andrea Pino	Environment & Urbanization	2018	https://doi.org/10.1177/0956247818790731	This paper is an examination of a social housing construction process following destruction by an urban forest fire in an informal settlement in Valparaíso, Chile in 2017	Chile	co-production: collaborative design workshop	The aim of the paper is to describe the social housing component of these two reconstruction processes (2017, 2014), and then to assess the extent to which the 2017 process was able to put in place a more co-productive approach.	Professionals at the housing government agency (SERVIU); family composition and the social network, house ownership.	Post-disaster scenarios are ideal for coproduction: it can open dialogues for new forms of governance, planning, and with a focus on inhabitants' basic rights, services, and can strengthen community agency.
19	Restoration	Assessing the effects of forest fires on interconnected critical infrastructures under climate change. Evidence from South France	Athanasios Sfetsos, Frederique Giroud, Alice Clemencau, Vassiliki Varela, Catherine Freissinet, Jean LeCroart, Diamando Vlachogiannis, Nadia Politi, Stelios Karozis, Ilias Gkotsis, George Eftychidis, Ralf Hedel and Stefan Hahmann	Infrastructures	2021	https://doi.org/10.3390/infrastructures6020016	The present work introduces a case study on the climate resilience of interconnected critical infrastructures to forest fires, that was performed within the framework on H2020 EU-CIRCLE project (GA 653824)	South France	The case study has been implemented through a co-creation framework with local stakeholders, which is critical in moving beyond physical damages to the infrastructures, introducing the elements of infrastructure business continuity and societal resilience. Under the framework of the EU-CIRCLE project, the case study was implemented by CEREN with the support of ARTELIA following a civil protection style exercise. Activities included 1.Data collection and scenario development; 2. Table top exercise; 3. Crisis exercise; 4 Final workshop	The scope of the case study is to analyze and quantify the evolution of forest fire risk under climate change and critically appraise the acceptable level of interconnected CI risk in a climate change context	Academia, emergency responders, and infrastructure operators	Though climate change is not considered a high priority with critical infrastructure operators, this methodology and workshops in the project proved the necessity of increased coordination among stakeholders to share crisis management tools and information flows.
20	Restoration	Wildfire, Smoke Exposure, Human Health, and Environmental Justice Need to be Integrated into Forest Restoration and Management	Savannah M. D'Evelyn· Jihoon Jung · Ernesto Alvarado · Jill Baumgartner · Pete Caligiuri · R. Keala Hagmann · Sarah B. Henderson · Paul F. Hessburg · Sean Hopkins · Edward J. Kasner · Meg A. Krawchuk · Jennifer E. Krenz · Jamie M. Lydersen · Miriam E. Marlier · Yuta J. Masuda · Kerry Metlen · Gillian Mittelstaedt · Susan J. Prichard · Claire L. Schollaert · Edward B. Smith · Jens T. Stevens · Christopher W. Tessum · Carolyn Reeb · Whitaker · Joseph L. Wilkins · Nicholas H. Wolff · Leah M. Wood · Ryan D. Haugo · June T. Spector	Current Environmental Health Reports	2022	https://doi.org/10.1111/revs40572-022-00355-7	Intersections between forest and fire management and human health through the impacts of smoke	Western United States	Transdisciplinary conversations, literature review on restorative actions in seasonally dry forests	Establish a transdisciplinary anchor for future discussions and actions regarding human health, health equity, smoke emissions and forest management	Scientists, practitioners, and managers specialized in forest and fire ecology, fires safety, air quality, health care, and public health	Consensus statements for future work: especially the integration of Indigenous voices in fire management, encouraging prescribed and managed fires for resource benefits to keep forests resilient, smoke exposure can be planned and reduced, investment in advanced preparation for smoke-resilient populations, equity in the process and outcomes is needed to protect populations from smoke impact, further integration of fires/forests/health disciplines is needed.
21	Restoration	Social perspectives on the use of reference conditions in restoration of fire-adapted forest landscapes	Lauren S. Urgenson, Cara R. Nelson , Ryan D. Haugo, Charles B. Halpern, Jonathan D. Bakker, Clare M. Ryan, Amy E. M. Waltz, R. Travis Belote, Ernesto Alvarado	Restoration Ecology	2018	doi: 10.1111/revs40572-022-00355-7	Understanding social aspects of restoration and how they influence land management	USA	86 In-depth interviews with diverse stakeholders in collaborative restoration of fire-adapted forest landscapes	Examine social perspectives that influence the determination of ecological reference conditions in restoration	Collaborative members, local external stakeholders, US Forest Service Staff associated with Collaborative Forest Service Landscape Restoration Programs	Acknowledges that historical references continue to play an important role in the practice of restoration. Encourages collaborative groups to develop strategies to address limitations of historical references by considering past, present and future conditions, balancing ecological objectives with social values and needs in restoration planning.

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22	Multiple	A transdisciplinary approach to understanding the health effects of wildfire and prescribed fire smoke regimes	G J Williamson, D M J S Bowman, O F Price, S B Henderson and F H Johnston	Environmental Research Letters	2016	doi:10.1088/1748-9326/11/12/125009	Study of the effects of landscape fire emissions and consider the similarities and differences in smoke from wild and prescribed fires with respect to the typical combustion conditions and fuel properties, the quality and magnitude of air pollution emissions, and the potential for dispersion to large populations. After that, examine the interactions between these considerations, and how they may shape the longer term smoke regimes to which populations are exposed	Global	Review of current knowledge, proposal of conceptual framework to understand smoke health impacts of wild and prescribed fires	objective is to provide a succinct review of this complex problem and to propose a conceptual trans disciplinary framework that can be used to guide further research	N/A	Transdisciplinary review of health impacts from wild and prescribed fires: depends on size of populations, concentration and duration of exposure, and effectiveness of public health interventions. Framework outlines necessary steps to move towards resolution in a critical public health issue.
23	Multiple	Collective action for managing wildfire risk across boundaries in forest and range landscapes: lessons from case studies in the western United States	Heidi R. Huber-Stearns, Emily Jane Davis, Antony S. Cheng and Alison Deak	International Journal of Wildland Fire	2022	doi:10.1071/WF21168	This work highlights context-specific ways to advance cross-boundary wildfire risk reduction efforts and uses a boundary spanning lens to illustrate how collective action in wildfire management evolves in different settings	Western United States	5 case studies using criteria that represent diverse challenges of multiple actors when working together across boundaries to reduce wildfire risk. Interviews were conducted with 102 participants.	Our aims with this research were to use empirical evidence to advance understanding of: (1) the specific roles different actors in a range of settings can fill to support efforts to reduce wildfire risk, and (2) how these roles and actors were spanning organisational, administrative and jurisdictional boundaries	Landscape case study participants in "boundary-spanning" roles in land and fire management agencies, organizations and coalitions	Illuminated the actors and functions required for wildland fire risk reduction, which was contingent on local contexts. Research agendas need to better align with transferrable lessons in co-management of fire risk, while boundary spanning features can target more specific opportunities for strategic and collective action to engage diverse actors in order to reach risk reduction and mitigation outcomes.
24	Multiple	Community-based importance and quantification of ecosystem services, disservices, drivers, and neotropical dry forests in a rural colombian municipality	Yuli Paola Tovar Tique 1, Francisco J. Escobedo 2 and Nicola Clerici	Forests	2021	https://doi.org/10.3390/f12070919	Perception and quantifying of Ecosystem Services, Disservices and Drivers of Change	Colombia	The methods studies was through semi-structured interviews and surveys, as well as ES-proxies and geospatial analyses. We then analyzed the supply and importance of two community identified ES and one ED from adjacent neotropical dry forests during 2005–2017	Studies analyze people's preferences for ecosystem services (ES), disservices (ED) and drivers of change in less populated, tropical municipalities. Understanding such preferences and needs by the community and stakeholder groups before actually assessing, modelling, and measuring the supply of ES is key for decision-making and planning in municipalities, as well as for the conservation of nearby neotropical dry forests	Community leaders, public officials, and residents	Mapping specific communities' ecosystem services and disservices for conserving forests and equitable planning strategies. First steps toward assessing perceived tradeoffs and synergies of ecosystem services/disservices, and drivers of change. Identifies willingness to participate in resource co-management
25	Multiple	Conservation through biocultural heritage-Examples from sub-Saharan Africa	Anneli Ekblom, Anna Shoemaker, Lindsey Gillson, Paul Lane and Karl-Johan Lindholm	Land	2019	doi:10.3390/land8010005	Potential of biocultural heritage in biodiversity protection and agricultural innovation in sub-Saharan Africa	Sub-Saharan, Africa	Reconstructing landscape histories and documenting local heritage values	Review the potential of biocultural heritage in biodiversity protection and agricultural innovation in sub-Saharan Africa. Definition of the concept of biocultural heritage into four interlinked elements that are revealed through integrated landscape analysis.	Farmers, researchers, conservationists, development workers, government officials	Exploration of biocultural research as a transdisciplinary method to help with recognizing fire and land management practices that have been suppressed by state and development policies. New opportunities can emerge for mutual benefit between residents and conservationists. Customary practices and heritage sites can help promote forest conservation. It must be integrated with principles of equity, justice and representation.

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26	Multiple	Social-Ecological Transformation to Coexist with Wildfire: Reflecting on 18 Years of Participatory Wildfire Governance	Iago Otero	Urban Resilience to the Climate Emergency, The Urban Book Series	2022	https://doi.org/10.1007/978-3-031-07301-4_7	The risk of devastating wildfires in the urban areas	Barcelona Metropolitan Region (Spain)	literature review on the links between resilience to wildfire, adaptation and transformation. Analyse of these projects with regard to their achievements, challenges and potential new transformative avenues	The goal is to learn from the experience and to sketch new transformative options to coexist with wildfire.	Groups of forest defense, town councils, forest owners, volunteers, natural parks, expert fire managers, public agencies, NGOs, and others	Reflections on 3 participatory projects show the critical role of locally rooted civil societies when they can network with key agencies and actors over the long term. Transformations require long-term commitments beyond political and project cycles. Integrative planning networks should recognize different ecosystem services and values with public deliberation to encourage dialogue.
27	Multiple	Pathways for inclusive wildfire response and adaptation in northern Saskatchewan	Heidi Walker, Maureen G. Reed, Amber J. Fletcher	Book chapter: Gender, Intersectionality and Climate Institutions in Industrialised States	2021	DOI: 10.4324/978101003052821-13	Analyze how past responses to major wildfire events inform current and future adaptation processes and trajectories	Canada (Saskatchewan)	We apply insights from literature on adaptation pathways and feminist literature on climate change to examine how past responses to a major wildfire event in a jurisdictionally complex region of northern Saskatchewan, Canada, inform current and future adaptation processes and trajectories. Drawing from interviews with community residents and government representatives, we examine how emergency and wildfire management institutions facilitated or constrained pathways for adaptation and how these were shaped by dominant knowledges and values.	The authors consider the implications of these predominant pathways for diverse social groups and whether a transformation is required for building inclusive adaptation processes as communities continue to live with fire in the future.	Community residents and government representatives	Adaptation trajectories in the territory are characterized by resistance and incremental change. A focus on causes of risk, physical and economic impacts and professional knowledge have constrained opportunities to address root causes of risk and vulnerability.
28	Multiple	Integrating art and science to communicate the social and ecological complexities of wildfire and climate change in Arizona, USA	Melanie Colavito, Barbara Satink Wolfson, Andrea E. Thode, Collin Haffey and Carolyn Kimball	Fire Ecology	2020	https://doi.org/10.1186/s42408-020-00078-w	This paper provides information about the development of Fires of Change, surveys to assess its impacts, and a discussion of how science-management relationships, networks, and boundary organizations may have helped facilitate the project	Arizona, USA	Surveys were conducted with Fires of Change exhibit visitors to assess the impacts of viewing the exhibit, as well as with exhibit creators to assess the effects of participating in the project	The objectives is to describes Fires of Change, a collaborative art exhibit designed to communicate about the shifting fire regimes of the United States Southwest through the lens of multimedia art.	Fires of Change exhibit visitors and exhibit creators	Art-science collaborations can be an effective mechanism to increase understanding of fire and climate change, build public support for management actions, and develop partnerships among diverse science, management and artistic audiences.
29	Multiple	Innovative wildfire mitigation by municipal governments: Two case studies in western Canada	Léanne M.M. Labossière, Tara K. McGee	International Journal of Disaster Risk Reduction	2017	http://dx.doi.org/10.1016/j.ijdrr.2017.03.009	Partners in Protection, a non-governmental organization in Canada, developed the FireSmart program and manual in 1999 which recommends how homeowners and municipal governments can reduce their wildfire risks	Western Canada	Semi-structured interviews were conducted with 21 individuals involved in municipal wildfire mitigation plans and activities in the two municipalities	The purpose of this study was to explore how and why two municipal governments in western Canada, Logan Lake and Kamloops in the province of British Columbia, developed and implemented innovative wildfire mitigation measures	individuals involved in municipal wildfire mitigation plans and activities in the two municipalities	Similar factors can influence innovative wildfire mitigation activities in different municipalities: a window of opportunity, issue champions, public and political support, partnerships and collaboration, and funding. Further studies could further examine the perspectives of local residents to understand how they might support these activities.
30	Multiple	Situating Indigenous knowledge for resilience in fire dependent social-ecological systems	Kelsey Copes-Gerbitz, Shannon M. Hagerman and Lori D. Daniels	Ecology and Society	2021	https://doi.org/10.5751/ES-12757-260425	Indigenous knowledge as a primary source of information for enabling resilience of fire-dependent social-ecological systems (SES).	British Columbia, Canada.	Iterative, reflexive, collaborative approach: long-term engagement, iterative data collection, land-based learning, forest walks,	Explore the context of Indigenous fire knowledge and situate Indigenous definitions of resilience in future forest management.	T'exelc Elders, archaeologists, and forest managers	In order for transformational change to occur in wildland fire and SES, Indigenous people can lead and contribute to solutions according to their own definitions of resilience. Collaborative experiments centered in decolonizing methodologies can help shift discussions away from "integrating" knowledges and toward shifting power and knowledging paradigms.
31	Multiple	Organisational influence on the co-production of fire science: Overcoming challenges and realising opportunities	Evora Glenn, Laurie Yung, Carina Wyborn, and Daniel R. Williams	International Journal of Wildland Fire	2022	doi:10.1071/WF21079	Exploring how to institutionalize support and incentivize co-production of knowledge in wildland fire research and management	USA	Investigated 7 co-productive wildland fire projects at the USDA Forest Service Rocky Mountain Research Station through in depth interviews	Helping transform cultures of fire science so that co-production is valued with more conventional scientific activities and products	Scientists, managers and community members	Doing science differently requires institutional support: collaborations can be incentivised to create more useful science especially through better investments, modified funding, performance evaluations, career ladders and translation resources

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32	Multiple	The Use of Science in Wildland Fire Management: a Review of Barriers and Facilitators	Molly E Hunter & Melanie M Colavito & Vita Wright	Current Forestry Reports	2020	https://doi.org/10.1007/s40725-020-00127-2	Evaluation on the use of science in fire management	USA	Literature review, development of conceptual model that describes possible uses of science in fire management	Review the scientific literature on the use of science in wildland fire management and identify factors that act as barriers or facilitators to fire science application	N/A	Conceptual model demonstrates that fire science is used more in wildland fire planning and forecasting rather than assessment and policy. Collaboration and relationships are key to improving science accessibility, relevancy and trust on an individual level, especially through boundary organizations. Most common barriers to applying fire science include external factors like public acceptance and funding/capacity.
33	Multiple	The U.S. Fire Learning Network: Providing a narrative framework for restoring ecosystems, professions, and institutions	Bruce Evan Goldstein & William Hale Butler	Society and Natural Resources	2010	https://doi.org/10.1080/08941920903012494	Examination of the US Fire Learning Network's collaborations in its first 2 years	USA	Review of FLN planning frameworks, with 25 interviews and surveys of FLN participants	Analyze FLN's narrative framework, which helped build collaborative capacity between institutions, ecological and human communities	Fire Learning Network members	Establishing a common narrative from degradation to restored integrity helped unite FLN around shared moral purpose.
34	Multiple	Traditional fire-use, landscape transition, and the legacies of social theory past	Michael R. Coughlan	Ambio	2015	DOI 10.1007/s13280-015-0643-y	Traditional fire use in landscape change	Global	Literature review	Promoting transdisciplinary theories to address variable roles of traditional fire use in the evolutionary history of landscapes	N/A	Historical fire ecology efforts can reframe legacy propositions from contemporary human ecology theoretical perspectives. There is a need for explicit statements on the assumptions underpinning historical fire ecology research. Historical fire ecologists should incorporate ethnological, archeological and other evidence to contribute to ongoing debates about historical fire ecology. Theories in human ecology can help strengthen transdisciplinary research.
35	Multiple	Defining extreme wildfire events: Difficulties, challenges, and impacts	Fantina Tedim, Vittorio Leone, Malik Amraoui, Christophe Bouillon, Michael R. Coughlan, Giuseppe M. Delogu, Paulo M. Fernandes, Carmen Ferreira, Sarah McCaffrey, Tara K. McGee, Joana Parente, Douglas Paton, Mário G. Pereira, Luís M. Ribeiro, Domingos X. Viegas and Gavriil Xanthopoulos	Fire	2018	doi:10.3390/fire101000	Defining extreme wildfire events	Global	Literature review, transdisciplinary approach to understanding fire events	Develop a holistic view of extreme wildfire events as a social-ecological phenomenon	N/A	Developing a definition of extreme wildfire events incorporating social elements. It can facilitate communication within wildfire management organizations and the general public.
36	Multiple	Learning to coexist with wildfire	Max A. Moritz, Enric Batllori, Ross A. Bradstock, A. Malcolm Gill, John Handmer, Paul F. Hessburg, Justin Leonard, Sarah McCaffrey, Dennis C. Odion, Tania Schoennagel & Alexandra D. Syphard	Nature	2014	doi:10.1038/nature13946	Strategies for more sustainable coexistence with wildfire	Global	Review	Summarize research on fire-prone ecosystems and fire effects on human communities through a social-ecological systems lens, identify links in the coupled systems, and discuss recommendations for greater resilience	N/A	Call for research to support better policy, planning and management in all aspects of the coupled wildfire SES problem: encouraging the view of fire as a natural and inevitable hazard in order to anticipate its important positive and negative effects in human and natural systems
37	Multiple	Supporting a shift in wildfire management from fighting fires to thriving with fires: The need for translational wildfire science...	Fantina Tedim, Sarah McCaffrey, Vittorio Leone, Carmen Vazquez-Varela, Yaella Depietri, Petra Buergelt, Raffaella Lovreglio	Forest Policy and Economics	2021	https://doi.org/10.1016/j.forpol.2021.102565	Creating cohesion in scientific knowledge about wildfire science, named translational wildfire science	Global	Informed by science-policy literature	Proposal of 4 interrelated principles to characterize translational wildfire science	N/A	TWFS would provide a more holistic, problem-based field focused on solving real-world wildfire problems by: i) integrating scientific knowledge from different domains, ii) including consideration of experiential and traditional knowledge alongside scientific knowledge, and iii) involving a range of non-scientist actors throughout the research process to ensure that it addresses the real world needs of diverse stakeholders.

No.	Phase of Fire Cycle	Title	Authors	Journal	Date	DOI	Topic	Location(s)	Methods	Objectives	Actors Involved	Advances/Implications for IFM
38	Multiple	Coexisting with wildfire? Achievements and challenges for radical social-ecological transformation in Catalonia (Spain)	Iago Otero, Jonas Ø. Nielsen	Geoforum	2017	http://dx.doi.org/10.1016/j.geoforum.2017.07.020	Transformative Catalan fire management efforts to cope with wildfire risk	Catalonia	Participatory observation and semi-structured interviews, secondary data, observations from researchers and practitioners	Analyze how the expansion of specialist wildfire units have triggered transformative processes in institutions and power dynamics in the wildfire management system	Researcher, GRAF (wildfire management specialists)	Encouragement of wildfire researchers and practitioners to link proposed management options to deeper debates on how to produce alternative, less flammable landscapes, as agents of broader social-ecological transformation to sustainability. Demonstrates how techno-managerial solutions can actually reinforce wildfire problems if not paired with wider systemic change.
39	Multiple	The science of firescapes: Achieving fire-resilient communities	Alistair M.s. Smith, Crystal A. Kolden, Travis B. Paveglio, Mark A. Cochrane, David Mjs Bowman, Max A. Moritz, Andrew D. Kliskey, Lilian Alessa, Andrew T. Hudak, Chad M. Hoffman, James A. Lutz, Lloyd P. Queen, Scott J. Goetz, Philip E. Higuera, Luigi Boschetti, Mike Flannigan, Kara M. Yedinak, Adam C. Watts, Eva K. Strand, Jan W. Van Wagtendonk, John W. Anderson, Brian J. Stocks and John T. Abatzoglou	BioScience	2016	https://www.jstor.org/stable/10.2307/90007548	Bridging fire science efforts for integrated agendas of wildfire research	Global	Overview	Provide a framework that addresses knowledge gaps influencing the future ability of communities to predict, adapt, and mitigate the immediate and cascading impacts of wildland fires on crucial ecosystem goods and services. Science designed to address knowledge gaps must be iteratively developed in ways that consider, support, and help achieve human populations' desired system states.	N/A	Provides key challenges for achieving fire-resilient communities: Characterizing firescape vulnerability, identifying cascading fire consequences, identifying early warning signals of firescape vulnerability, promoting standards and preparing for shifted ecosystem states, addressing barriers and achieving firescape resilience.
40	Multiple	Living on a flammable planet: interdisciplinary, cross-scalar and varied cultural lessons, prospects and challenges	Christopher I. Roos, Andrew C. Scott, Claire M. Belcher, William G. Chaloner, Jonathan Aylen, Rebecca Bliege Bird, Michael R. Coughlan, Bart R. Johnson, Fay H. Johnston, Julia McMorrow, Todd Steelman and the Fire and Mankind Discussion Group	Philosophical Transactions of the Royal Society Biological Sciences	2016	http://dx.doi.org/10.1098/rstb.2015.0469	Living with fire	Global	Outcome of author workshop: international, interdisciplinary group	Outline generalizable properties of fire-adaptive communities in various settings where cultural knowledge of fire is rich and diverse	Authors (researchers)	Advocates for a holistic wildfire scholarship that develops common agreement in working terms and builds across disciplines. Amplifies importance of communicating to the media, politicians and the general public. Acknowledges enthusiasm for transdisciplinary field of "pyrogeography"
41	Multiple	Linking humans and fire: a proposal for a transdisciplinary fire ecology	Michael R. Coughlan, and Aaron M. Petty	International Journal of Wildland Fire	2012	http://dx.doi.org/10.1071/WF11048	Integrative approach linking social and physical aspects of fire	USA & Australia	Literature review and 2 case studies	Discuss how the study of fire ecology can benefit from paying attention to the role of humans in 1) human agency and decision processes, 2) knowledge and practice of landscape fire and 3) socioecological dynamics inherent in the history of social systems of production and distribution	N/A	Proposal of transdisciplinary fire ecology with 3 key human dimensions: human agency and decision-making, knowledge and practice, and the history of social and ecological dynamics.
42	Multiple	Indigenous fire management: A conceptual model	William D. Nikolakis and Emma Roberts	Ecology & Society	2020	https://doi.org/10.5751/ES-11945-250411	Indigenous fire management Synthesis	Global	Literature review	Create a conceptual model of Indigenous Fire Management	N/A	Indigenous Fire Management is a practice that can bridge many epistemologies of fire, and it also exists on its own terms outside the concept of Western fire management frameworks. Acknowledges that this exercise has been conducted by non-Indigenous academics and calls for greater representation in the literature.