

Coexisting with wildfire? Achievements and challenges for a radical social-ecological transformation in Catalonia (Spain)



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ABSTRACT

The challenge of sustainability is not about producing more or better managerial knowledge. It is in fact a transformation of the systems and structures that perpetuate environmental problems that is emerging as the key sustainability goal. In this paper we show the relevance of this argument, by using wildfires as symptoms of the challenges posed by global change to western societies, where wildfires are becoming increasingly problematic. Climate change, land abandonment, exurban expansion and fire suppression schemes are some of the main reasons behind this. Tackling the increasing intensity and complexity of wildfires is consequently emerging as an important research and policy topic. A central question in the literature is how to achieve a more sustainable coexistence with wildfire. Fuel reduction treatments, fire restoration, the reform of current suppression policies and adaptive institutional arrangements have all been debated. However, the social-ecological transformations needed to effectively implement these management options are not sufficiently understood. This paper looks at the efforts of the Catalan wildfire management system to cope with wildfire risk over the last decades. In particular, the emergence of GRAF, a group of wildfire fighting specialists in the Fire Department, is described. Emphasizing the need to understand wildfires as an inherent part of Mediterranean ecosystems, the expansion of GRAF highlights how learning to coexist with wildfire in Catalonia has triggered a set of transformative processes in institutional arrangements and power relationships of the wildfire management system. Our data also illustrate how coexisting with wildfire entails a dramatic social-ecological transformation in terms of land-uses, settlement patterns, energy supply systems and social values about wildfires. Moreover, we warn that in the absence of such systemic changes, management improvements might paradoxically reinforce risk. We conclude that wildfire researchers and practitioners should link the proposed management options to a deeper debate on how to produce alternative, less flammable landscapes, as agents of a broader social-ecological transformation to sustainability.

1. Introduction

As the state of the environment worsens, calls for solutions-oriented knowledge pervade the global environmental change research community (Future Earth, 2013, 2014). Yet techno-managerial solutions promoting sustainability are well known and it is increasingly argued that researchers should shift attention to understanding how to change the systems and structures that perpetuate environmental problems (O'Brien, 2013). Radical voices within the research community accordingly argue that a main barrier to dealing effectively with global sustainability challenges is the absence of counter-hegemonic political processes that are able to facilitate transformative solutions (D'Alisa

and Kallis, 2016). Tschakert et al. (2013) argued, for example, that assessments of vulnerability to climate change should be linked to considerations of structural inequality and combined with the production of transformative change by and for vulnerable populations. Indeed, a new science on transformation has been called for to support efforts to deliberately transform systems and societies at the rate and scale necessary to avoid further danger to humanity from environmental problems (O'Brien, 2011).

A key insight that emerges from this literature is that minor adjustments in knowledge, governance, institutions or behaviours will not suffice to meet the sustainability challenges posed by global change (Moser, 2016). Transformation thus involves altering essential

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attributes of a system towards the creation of a fundamentally new one (Nelson et al., 2007; Brown et al., 2013). Asara et al. (2015), for instance, put forward a vision of social-ecological transformation without economic growth as a guiding societal objective, and Escobar (2015) deliberately linked degrowth, post-development theory and transition discourses to support the politics of global transformation. In a recent synthesis paper on the future directions in human-environment research, a number of transformative inter- and transdisciplinary research avenues were also emphasized (Moran and Lopez, 2016). In terms of dealing with global environmental change and sustainability, these studies essentially propose to rethink societies and produce alternative, radically new, social-ecological orders.

This paper supports this position. With a case study illustrating the efforts to coexist with wildfire in Catalonia (Spain), our data shows why and how dealing with global change entails a radical social-ecological transformation. The paper also suggests that unless transformative efforts reach sufficient rate and reach, techno-managerial solutions might actually end up reinforcing environmental problems. Wildfires are thus used as a symptom of the profound changes needed to effectively address sustainability challenges, in the particular setting of western societies. The paper is structured as follows. Section 2 presents the wildfire literature and the emerging insight that a more sustainable coexistence with wildfires on a rapidly changing Earth requires a rethinking of the underlying systems and structures perpetuating risk. In Section 3 the case study setting and the methods are described. Section 4 describes the creation of GRAF, an internationally renowned group of wildfire fighting specialists in the Catalan Fire Department emphasizing the need to coexist with wildfire. The section focuses on how GRAF's knowledge changed the wildfire management system in conflicting and yet productive ways. Section 5 shows the potential unintended consequences of an improved wildfire management system that operates within the current social-ecological system's constraints. Section 6 shows the consequent attempts of GRAF to transform the social-ecological practices and values underlying risk beyond the wildfire management system. Section 7 discusses the implications of our findings and Section 8 provides some conclusions.

2. Coexisting with wildfires: a challenge to the current social-ecological arrangements

Global projections suggest that climate change will rapidly alter the Earth's fire patterns. Fire activity is expected to increase in some areas of the planet and to decrease in others (Krawchuk et al., 2009; Moritz et al., 2012). The length of fire seasons has increased globally (Jolly et al., 2015) and fire seasons are expected to be more severe in the future (Flannigan et al., 2013). In Europe, forest damage caused by wildfires has increased and is expected to escalate in the coming decades (Schelhaas et al., 2003; Seidl et al., 2014). In the west of the US, large wildfire activity increased markedly in the 1980s (Westerling et al., 2006) with fire seasons likely becoming prolonged (McKenzie et al., 2004). Climate trends are also expected to make wildfire risk worse in some regions of Australia (O'Neill and Handmer, 2012) as well as in regions of the UK where up until now wildfires have not been a major problem (Albertson et al., 2010). These trends are especially worrisome because many fire-prone regions in the world are densely populated and have high social and economic value (Doerr and Santín, 2016; Moritz et al., 2014). Climate change thus adds to other drivers exacerbating risk in fire-prone regions, such as land-use changes and the development of residential areas (Fischer et al., 2016).

New insights into how societies might learn to deal with wildfire risk are therefore greatly needed and a growing literature on how to coexist with it is emerging. Much of this literature looks beyond the techno-managerial aspects of wildfire extinction and prevention. Eriksen (2014), for instance, concluded that wildfire resilience is not only found in the fire department but in the ability of all family members to contribute to fire preparedness, challenging gendered

patterns of risk engagement and vulnerability. The review by McCaffrey (2015) found that social relationships in wildfire prone areas can increase wildfire preparedness by building a sense of community that facilitates the exchange of crucial information. Similarly, Prior and Eriksen (2013) showed that community cohesion supports the adoption of protective measures (such as the reduction of combustible materials around houses) that contribute to adaptive capacity and resilience. In particular, the authors emphasized how people draw on social cohesion to get the support and resources necessary to undertake such measures. Community wildfire resilience was also shown to be potentially enhanced by adaptive governance mediated by institutions at multiple scales, as it opens social opportunities to learn from and adapt to wildfire (Abrams et al., 2015). Community involvement and collaboration across agencies and scales was indeed emphasized as a key factor for effectively planning wildfire risk mitigation schemes (Plana et al., 2015). A better integration between wildfire risk management and land-use planning was likewise highlighted by Moritz et al. (2014), who argued for example that restricting development in the most fire-prone locations should be considered by governments and agencies.

These multi-scale collaborative planning networks including public agencies and stakeholders were shown to facilitate ecological fire restoration in the US by overcoming institutional barriers within the wildfire management system, dominated by a traditional suppression rationale (Butler and Goldstein, 2010). There, an emerging emphasis is detected in the literature on the need for incentives that encourage fire managers to consider the beneficial effects of allowing wildfires to burn under certain circumstances rather than suppressing them all (Donovan and Brown, 2007; North et al., 2015; Thompson et al., 2015). To make fire restoration possible and reduce suppression-driven risk levels, social acceptance of and the demand for alternative fire management strategies have been stressed as crucial (Calkin et al., 2015). Supporting these transitions, models focusing on the complex interplay between the social and ecological conditions and the processes influencing wildfire risk have been proposed to facilitate stakeholders' deliberation about alternative policies, including fire restoration (Fischer et al., 2016; Spies et al., 2014).

Coexisting with wildfire in a rapidly changing Earth thus requires a number of interlinked social, institutional and ecological changes. These changes altogether hint at a substantive transformation of the current social-ecological setup. However, the literature to date has only started to approach the wildfire topic from an outspoken transformative perspective, and it is this gap that we address in this paper. Howitt (2014), for instance, explored what coexisting with wildfire might mean and argued that a profound rethinking of fundamental social-ecological relationships might be required. O'Neill and Handmer (2012) similarly pointed out the need for "transformative adaptation", an adaptation which is concerned with the root causes of wildfire vulnerability and that calls for deep shifts in people's relationships with the environment. The data presented in this paper supports such positions. Inspired by political ecology (Robbins, 2012; Swyngedouw, 2010; Martinez-Alier, 2002; Swyngedouw and Heynen, 2003), we ask how a social-ecological transformation towards coexisting with wildfire might unfold on the ground and at which pace. Furthermore, we ask which social actors promote or resist it, and what the main challenges ahead will be. We use a case study (Yin, 2014) from Catalonia, Spain. There, changing land-uses and settlement patterns, increasing population density, and a warmer climate have resulted in a very fragile human-environment context concerning wildfires. As a reaction to the large wildfires of the 1980s and 1990s changes in public policies were implemented, including a reconfiguration of the wildfire management system that we explore empirically. Following Fischer et al. (2016) we treat current wildfire risk levels as symptoms of a set of interrelated social and ecological conditions and processes considered to be socially undesirable and unsustainable. As wildfires synthesize their surroundings (Pyne, 2009, 2012), analysing them reveals the challenges faced by their social-ecological and politic-economic contexts under global change.

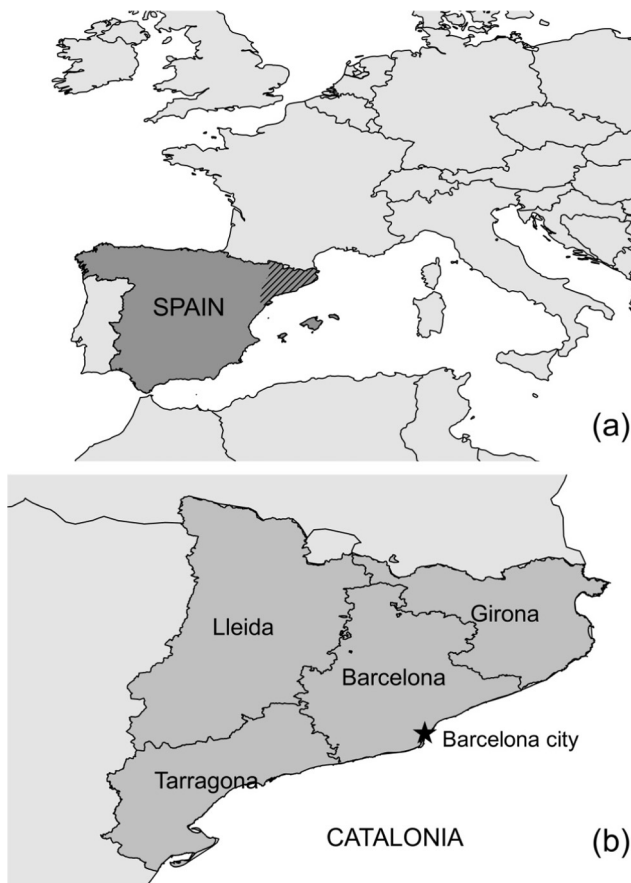


Fig. 1. Map of the study region. (a) The region (*comunitat autònoma*) of Catalonia in Spain. (b) Catalonia with its four provinces and its administrative city. Source: our own.

3. Case study

3.1. Context

3.1.1. Catalonia: a flammable and vulnerable landscape

Catalonia is located in northeastern Spain (Fig. 1). The region has a population of 7.5 million inhabitants and over 60% live in the metropolis of Barcelona (IDESCAT, 2016). It is among the most affluent regions of Spain and a main tourist destination (INE, 2016). The climate is Mediterranean with hot and dry summers. This, combined with a landscape dominated by continuous woody vegetation (resulting from land abandonment) and increasingly dry conditions due to climate variations, have created a particularly vulnerable region to wildfires. Settlement patterns are also contributing to this, with many residential areas expanding into the woodlands. The annual area burnt over the last decades varied greatly with extreme values in 1986 and 1994 (Fig. 2). Wildfires were concentrated in the months of June, July and August, mostly occurring in the afternoons. The main cause was arson (24.5%), followed by out-of-control agricultural fires (13.5%), unknown causes (12.3%), and lightning (10.6%).¹ 73% of the total burnt area was due to wildfires larger than 500 ha, which represented 0.5% of the total number of wildfires.² The number of large wildfires in Catalonia increased during the second half of the 20th century (Díaz-Delgado et al., 2004; González and Pukkala, 2007) and a positive relationship between climate warming and wildfire occurrence was discernible (Piñol et al., 1998). Scenarios for the forthcoming years indicate a considerable increase in the number of fires and the area burnt

as climate becomes warmer and drier (Brotons et al., 2013; Loepfe et al., 2012). The Fire Department expects events where simultaneous large wildfires with virulent behaviour will cause unprecedented civil emergencies, threatening residential areas, transport routes and economic activities (Costa et al., 2011; Fig. 3). As in other countries of Mediterranean Europe, the emergencies due to large wildfires are a relatively new phenomenon in the environmental history of the region, characterized by a long-term use of fire to manage agricultural and pastoral landscapes (Pyne, 1997, 2012).

3.1.2. A wildfire management system based on suppression

Economic development in Catalonia took off in the 1960s. Land abandonment, forest regrowth, urbanization and industrialization called for improved fire and rescue services, especially in the rapidly growing metropolis of Barcelona. In 1962 the Barcelona Province Authority integrated the municipal fire departments and created an umbrella organization to develop fire prevention and extinction on a provincial scale (Savalls, 2009a) but the problem of wildfires remained unabated (Fig. 2). In 1980 the Catalan autonomous regional government – restored after Franco's dictatorship – created a Fire Department that integrated all of the municipal and provincial departments in a common organization consisting of both professional and volunteer firefighters (Savalls, 2009b). The new Fire Department however, was not able to tackle the large wildfires experienced in 1986 which burned approximately 65,800 ha (Fig. 2). As a response, aerial firefighting systems, fire stations and fleets of fire engines were expanded (Savalls, 2009b). At the same time, the government launched a new wildfire prevention model that enabled a rapid detection of fires starting and the active involvement of forest owners through forest defence associations (Peix, 1999). Despite these efforts another adverse wildfire season occurred in 1994 (Fig. 2), resulting in casualties to both firefighters and civilians (Savalls, 2009b). The Fire Department responded again by increasing aerial firefighting systems but also by improving operational organization and information flows including the use of digital communication systems and GPS (Head of the Fire Department in 1994, interviewed in this research). Further developments in the 1990s included the establishment of a legal body on wildfire prevention including compulsory municipal prevention and emergency planning in high risk areas. Low fuel strips around residential areas and along roads and electric lines, and regulation of fire use in forests and pasturelands were also implemented.³ A wildfire management system was thus consolidated based on a reduction of fires starting and a rapid response with water from fire engines and aerial means. In Catalonia the responsibility of wildfire management is distributed across several institutions operating and interacting at different scales. These include the autonomous regional government's ministries of the Interior and Agriculture, municipalities, the Barcelona Province Authority, natural protected areas, and forest defence associations made up of forest landowners, town councils and volunteers (Otero et al., submitted for publication).

3.2. Methods

This paper presents qualitative data collected by combining participant observation in GRAF and semi-structured interviews with relevant actors in wildfire extinction and prevention, and secondary data such as newspaper articles and legislation. Additional data comes from work and long term observations on wildfire management that have been conducted in Catalonia since 2003, both from researcher and practitioner sides (e.g. Otero, 2011; González-Hidalgo et al., 2014).

Participant observation was aimed at obtaining detailed

¹ Wildfire Prevention Service, Ministry of Agriculture. Data for the period 1994–2015.

² Wildfire Prevention Service, Ministry of Agriculture. Data for the period 1983–2012.

³ Catalan Forest Law 6/1988; Order 21 June 1993 on controlled burning in high mountain areas; Civil protection plan for wildfire emergencies, 29 September 1994; Decree 64/1995 on wildfire prevention measures.

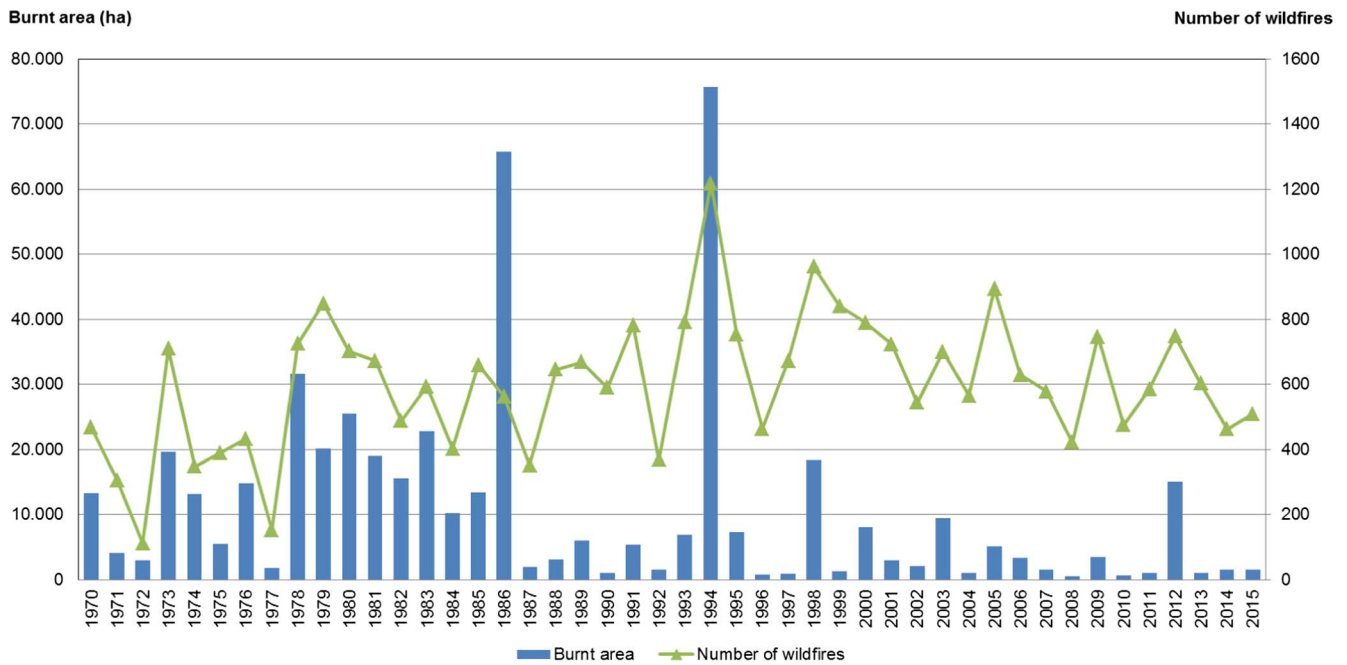


Fig. 2. Burnt area and number of wildfires in Catalonia for the period 1970–2015. Source: Wildfire Prevention Service, Ministry of Agriculture. These statistics include forest fires and exclude fires affecting agricultural and urban areas. ‘Forest’ includes both areas with tree cover and no tree cover such as shrublands and pasturelands. Small wildfires are under-registered for the years prior to 1992. The wildfires occurring in the Lleida province prior to the mid 1980s are missing. Wildfires affecting more than one municipality are sometimes registered more than once. Winter wildfires affecting pastures with no tree cover are only registered from the end of the 1980s.



Fig. 3. Example of the high wildfire risk landscapes currently existing in Catalonia. The orthophoto shows the Montseny area belonging to the Barcelona Metropolitan Region. Strategic transport infrastructures, concentration of industrial activities and dispersed settlement structures among extensively forested ranges make the region highly vulnerable to large wildfires. Source: Institut Cartogràfic i Geològic de Catalunya (flight 08-2016).

experiential knowledge (Bernard, 2002). The first author spent two wildfire seasons in Catalonia (23 June to 24 August 2014 and 15 June to 27 July 2015) with different GRAF teams following their day-to-day

activities. Participant activities included, but were not limited to, internal GRAF meetings, meetings between GRAF fire-fighters and commanders of the Fire Department, monitoring risk at the general Fire

Department's headquarters, patrolling high risk areas, and fighting wildfires. Observation focused on GRAF practices of wildfire fighting, risk forecast, and prevention, as well as the visions of (wild)fire's role in the landscape that underpin these practices. It also focused on the historical and current interaction between the practices and visions of GRAF with those of other actors of wildfire prevention and extinction, both within and outside the Fire Department. Informal and unstructured interviews with GRAF fire-fighters, notably about the creation and consolidation of GRAF, were also conducted. The data collected from participant observation provided insights that were explored further through semi-structured interviews.

Semi-structured interviews were conducted with 35 informants directly involved in wildfire prevention and extinction in Catalonia. We used purposive sampling, a nonprobability sampling method where informants are selected according to their ability to serve the purpose of an inquiry (Bernard, 2002). Our purpose was to explore the range of visions for wildfire prevention and extinction as well as the current practices resulting from those visions. Specifically, we wanted to understand the (dis)agreements, conflicts and syntheses between them and how some became dominant. Informants included forest engineers working in public wildfire prevention schemes, forest landowners, leaders of local wildfire prevention volunteer groups (forest defence associations), managers of protected areas, GRAF fire-fighters from the central technical unit and the regional units, non-GRAF fire-fighters, commanders of the Fire Department, and researchers on wildfire risk management. The sample also included different positions within the Fire Department's command hierarchy; institutions working at the municipal-, provincial-, and Catalan level; positive as well as negative views of wildfire as perturbation; and diverse territorial backgrounds ranging from metropolitan Barcelona to the rural southern region. Some of the GRAF firefighters with whom we regularly interacted were included in the sample. The sample also included key actors in the process of development of GRAF such as the head of the Fire Department and the Minister of the Interior when it was established, as well as GRAF's head.

An interview guide was used. This included five groups of questions: (1) Personal background, (2) Current job, (3) Experience in (large) wildfires, (4) Fire and wildfire, and (5) Ideal society. Group #1 included biographical information that could be used as a spatial and temporal frame to interpret the data collected from the informant. Group #2 explored in detail his/her job or activity of wildfire prevention/extinction. Group #3 asked the informant to talk about particular wildfire events that he or she had experienced, with a focus on the positive and negative interactions with other actors. Group #4 asked what fire is and what wildfire is. Group #5 related the visions of informants about (wild)fire to their visions of the ideal society, and asked about the role of (wild)fire in that society. The guide was adapted to the informant's profile and the information that we intended to retrieve from him/her. Informants that did not belong to GRAF, for instance, were asked about their opinions on the positive and negative contributions of GRAF to the Catalan wildfire management system. All interviews were conducted in Catalan by the first author during the summer of 2014 ($n = 31$), spring 2015 ($n = 1$), and summer 2015 ($n = 3$). They lasted from 0.5 to 2.2 h. All but one were recorded and transcribed. The non-recorded interview was synthesized drawing on extensive notes taken during it.

Participant observation notes and interview transcriptions were coded in NVivo 10 for Windows. Coding aimed at structuring the qualitative data by highlighting key themes and looking at their relationships. Codes were created for (1) institutions and actors in the wildfire management system, (2) conflicting and synergistic interactions between them, (3) processes and topics of particular interest, (4) experience in large wildfires; (5) visions of (wild)fire; and (6) an ideal society and envisioned social-ecological transformation. In the paper, we refer to data from interviews with the number of the informant in brackets, together with the informant's profile the first time he/she is mentioned. For those informants whose identity could be revealed by

the information given, we sent individual emails with all excerpts attributed to them in the text, and obtained written permission to publish them. Data from participant observation is integrated into the narrative.

Secondary data were collected from several public administrations working on wildfire prevention and extinction and forest management, including wildfire statistics, legislation, lawsuits, internal documents and a selection of relevant newspaper articles. Secondary data is referred to in the text as footnotes.

4. Achievements: reshaping the wildfire management system

4.1. A new way of dealing with wildfires: the creation of GRAF

In July 1998 a fast moving wildfire once again surpassed the capacity of the Fire Department and burned 27,274 ha.⁴ "Catalonia burns again", the press informed, stressing that the "fire nightmare" of 1994 was happening all over again (see Section 3.1.2).⁵ The Minister of the Interior and the politician responsible for the Fire Department at that time told us in an interview that "after that wildfire there was a political fuss" resulting in the left opposition attacking the conservative government for their incompetence (#35). After the fires in 1986 and 1994, the subsequent reorganization of the Fire Department and the improved firefighting capacity, ordinary explanations and solutions to the wildfire problem no longer seemed tenable. Some weeks after the 1998 wildfire, an extraordinary plenary session in the Catalan Parliament was thus held, forcing the government to commit to a revision of its policy on wildfire extinction.⁶ Meanwhile, some commanders within the Fire Department realized that putting out some wildfires in the past had contributed to the accumulation of fuel and even larger wildfires (#24, head of the Fire Department ca. 1992–2001). New knowledge on wildfire prevention and extinction was therefore greatly needed by both politicians and techno-managerial staff.

A set of alternative ideas and practices on wildfire fighting and prevention had already been underway in the years prior to the 1998 wildfire. In the Fire Department's school, where firefighters are trained, a group of instructors incorporated the use of cartography and the analysis of wildfire behaviour into the curriculum (#22, instructor of the Fire Department's school at that time). Researchers at the Forest Sciences Centre of Catalonia were now viewing wildfires as having predictable patterns rather than being unpredictable or circumstantial events, and conceptualized large wildfires as symptoms of unbalanced social-environmental relationships (#33, researcher at the Forest Sciences Centre of Catalonia). According to several of our sources, many of the new ideas on fire ecology, management and behaviour were introduced from the US by a professor from the Lleida University, where forest engineers were trained. A network of people was formed from the Lleida University, the Fire Department's school, and the Forest Sciences Centre of Catalonia, and through joint activities and shared ideas, the need to go beyond the predominant suppression paradigm emerged. One such activity was a prescribed burning⁷ in March 1998. This was organized to illustrate the prevention potential of prescribed burnings and to show a new way of managing forests (#9, GRAF technician). The organizer of the burning was the current head of GRAF Marc Castellnou, a forest engineer of the Forest Sciences Centre, trained at the Lleida University, and volunteer firefighter for the Fire Department. During our fieldwork he explained that as a consequence of the

⁴ Wildfire database, 1800–2013, GRAF, Fire Department, Ministry of the Interior. The area reported for this wildfire by the Fire Department is larger than the area reported by the Wildfire Prevention Service (see discrepancy with Fig. 2).

⁵ La Vanguardia, 21 July 1998, pages 1 and 24.

⁶ La Vanguardia, 6 August 1998, page 15.

⁷ In the paper, "prescribed burning" refers to the planned use of fire under specific environmental conditions for fuel load reduction (wildfire prevention) as well as for ecosystem and landscape management objectives.

burning he was expelled from the Fire Department: “A firefighter must extinguish and not set fire”, he was told.

Things did however change after the 1998 wildfire. The Minister of the Interior and the head of the Fire Department agreed to create a group of wildfire fighting specialists that would extend the range of firefighting techniques by incorporating the use of fire and that would bring new scientific and technical knowledge for wildfire analysis (#24; #35). The head of the Fire Department had heard of Castellnou and realized that, unlike many other forest engineers, he was not only familiar with forestry and fire ecology but also with extinguishing systems being a firefighter himself (#24). Castellnou was consequently reinstated by the Fire Department, and in 1999 he started to train a selection of firefighters on wildfire analysis and on the use of fire as a prevention and suppression tool (#22). In our interviews, these firefighters stressed the change of approach that they witnessed. The training allowed them, according to one interviewee, to understand the reasons behind wildfire behaviour, something he contrasted with the traditional visceral way of fighting fires (#17, GRAF fire-fighter). The press followed suit, informing of “a 180 degree turn in the strategy of the government against wildfires” as “fire went from being an enemy to an ally”.⁸

The new group was named GRAF after the Catalan acronym for Support Group for Forest Interventions. It was launched on May 28, 1999 (Savalls, 2009b). The following year, young forest engineers trained at the Lleida University or working in the Forest Sciences Centre joined GRAF as temporary employees during the wildfire season. They were hired to come up with a new type of cartography for the Fire Department but soon started to participate in prescribed burnings and to support the firefighters in wildfire analysis (#26; #28, GRAF technicians). The minister told us in an interview that those youngsters, working in a room with their computers, “looked like a cyst” in the Fire Department. They “slept in sleeping-bags” in the office which “looked like a commune” (#35). For him, and for many other informants, it was apparent that an alternative way of dealing with wildfires had entered the Fire Department.

4.2. Reorganizing the Fire Department

The creation and integration of GRAF into the Fire Department was not smooth however. Some sectors, including trade unions, rejected the idea of allowing outsider forest engineers to define how to fight wildfires (#12, ex-GRAF fire-fighter; #24). Two of the first young forest engineers enrolled in GRAF told us that they were regarded as “the minister’s kids” and that telling experienced firefighters what to do was not easy (#26; #28). The then head of the Fire Department told us that an integrative strategy was implemented to appease such tensions. Since 1999 intermediate commanders were enrolled in GRAF and trained on wildfire analysis and fire use, while the novice forest engineers entered the Fire Department as commanders through public examination (#24). Still, as GRAF started to put its ideas into practice, some of the regional commanders saw their authority and exclusive rights to decision-making threatened and were strongly opposed to GRAF (#12; #14, GRAF’s head; #22; #35). The rapid promotion of GRAF members also created jealousy among non-GRAF firefighters (#6, fire-fighter). Non-GRAF firefighters accused GRAF of acting outside the commanders’ orders, misusing suppression fire⁹ and putting firefighters

at risk (#2, auxiliary GRAF fire-fighter; #6; #7, fire-fighter; #12; #24). The incorporation of suppression fire indeed questioned the dominance of water (#12; #22), but clearly the conflict was not only a matter of methods. According to the Minister of the Interior at that time, the creation of GRAF came with “strong resistance within the Fire Department because it meant changing its organizational structure” (#35).

GRAF grew in spite of such tensions. It is currently made up of 84 firefighters (36 initially) and it is now an essential component of the Fire Department. The reasons for this are clearly related to its success in predicting, preventing, explaining, managing and ultimately extinguishing wildfires. These abilities are closely linked to two sub-units of GRAF. GRAF-01 sits in the Fire Department’s central control room located just outside Barcelona. It forecasts wildfire risk and monitors and coordinates GRAF regional units on the ground. Risk forecast combines weather, topographic, and fuel conditions, recently observed fire behaviour and past wildfire events to predict expected wildfire types and come up with a strategy¹⁰ to fight or manage them. As observed in the field, GRAF-01’s forecast shapes crucial decisions of the Fire Department such as resource allocation. GRAF-00 on the other hand analyses the wildfire in situ and suggests appropriate strategies for the current situation to the emergency’s head, who is a non-GRAF high ranked commander of the Fire Department. Strategies generally involve identifying suppression opportunities (i.e. areas with lower fire spreading rates, deriving from fuel discontinuities related to topography, vegetation heterogeneity or fire scars), prioritizing intervention areas, and determining the techniques that can be used for each of them. With the consolidation of these two sub-units, GRAF’s wildfire analysis and methods became an integral part of the Fire Department’s operations (#12, head of the Fire Department’s Division of Special Groups; #14). This was clearly evident in the field, where we observed that even if GRAF’s positions are intended to provide decision support to the emergency’s head, they had de facto a key role in how wildfires were managed. This situation has led to an ongoing and still incomplete reorganization of the Fire Department, as revealed by several discussions between GRAF and the commanders of the Fire Department that we observed in the field. Key discussions revolved around how to implement GRAF methods in non-GRAF units as well as how to reorganize the command system to move from a reactive wildfire fighting decision-making system to a proactive and anticipatory one.

Such reorganization in the Fire Department has been clearly enhanced by GRAF’s prominent role in the training of fire-fighters. Since its inception, GRAF has taken charge of the compulsory training on wildfires in the Fire Department school (#12; #32, ex-GRAF assistant). Knowledge transfer to non-GRAF firefighters and commanders also occurs in formal and informal activities or through ad hoc exercises on prescribed burning or pro-active wildfire management that we could observe in the field. Up to 345 former GRAF members now carry out different roles in the Fire Department, often as ranking commanders. Moreover, many pre-GRAF commanders have either retired or will retire soon, thus further facilitating the growing dominance of the new vision of wildfires in the Fire Department (#22).

⁸ La Vanguardia, 22 April 1999, page 1, Tarragona supplement.

⁹ In the paper, “suppression fire” refers to “any fire used as a suppression technique during uncontrolled fires” (Castellnou et al., 2010, p. 190). It includes different techniques such as burn out and backfire, both used by GRAF. “Burn out” means setting fire inside a control line to consume fuel between the edge of the fire and the control line. It is often done at the back or in the flanks of the wildfire along with the construction of the control line. “Backfire” is similar to burn out except it is ignited to take advantage of the convective indraft directly ahead of an intense wildfire in order to change the direction of its convective column (National Wildfire Coordinating Group, 2015; Miralles et al., 2010).

¹⁰ In GRAF’s terminology, “strategy” is the set of response actions applied to reduce the uncertainty created by the wildfire down to an acceptable level. It involves a plan to achieve an objective and prioritizes and times the interventions. The objective relates to the desired result guiding the response to uncertainty, for instance confining the wildfire in a perimeter of 150 ha. The strategy requires considering the wildfire potential, its suppression opportunities and the land-uses, properties and people at risk. According to GRAF, a strategic vision of the wildfire allows them to make pro-active decisions to minimize the hazard (Castellnou, M., Miralles, M., Estrategia en incendios forestales, GRAF, Fire Department, Ministry of the Interior, 17 pp.).

4.3. Changing the philosophy of the wildfire prevention services

The new GRAF practices were not limited to suppression. The identification of “critical points” where wildfires change behaviour was often mentioned as crucial in interviews with GRAF fire-fighters. Such points provide suppression opportunities, particularly if a forest structure with lower fuel continuity has been implemented in advance (#9). GRAF’s firefighting practices thus began to revolve around identifying such critical points in non-burnt areas and the concept of Strategic Management Points (SMP) emerged (#5, ex-GRAF auxiliary fire-fighter; #9). As the strategy of wildfire confinement in critical points proved successful in limiting the size of the first large wildfire that GRAF faced (Sant Llorenç in 2003), the SMP method expanded in the following years (#14). GRAF fire-fighters hence drafted or supervised wildfire prevention plans for several regions and protected areas throughout Catalonia where SMP were identified to guarantee the effectiveness of prevention works at different scales (#5; #9). Forest engineers in charge of forest management schemes in the public administration (e.g. Ministry of Agriculture) thus learned from GRAF how to plan prevention works according to the expected wildfire patterns and ensuing SMP (#4; #19, public administration’s engineers). In essence, preventive interventions in SMP facilitate the extinction and limit the potential of future wildfires. During our fieldwork we observed SMP developed through these inter-agency collaborative networks in areas ranging from Southwestern to Northeastern Catalonia. These were often pastures growing after prescribed burnings¹¹, thinned forests, and croplands, all of which create low fuel areas halting the speed of a fire.

However, planning to deal better with future wildfires contrasted markedly with the dominant vision of the wildfire prevention services, mostly aimed at avoiding all wildfires. Resistance to GRAF’s new preventive practices was especially strong in the Barcelona Province Authority, where a wildfire prevention office had been created with the specific function of drafting prevention schemes for the province’s municipalities. The founder of this office told us in an interview that their prevention schemes were based on developing a network of tracks and water infrastructure to ensure that wildfires could be put out quickly (#25). According to him, a quick intervention is key to prevent a wildfire from escalating (#25). In contrast, GRAF considered this policy to be nonsense because in particularly adverse conditions wildfires become large even when firefighters arrive quickly at the scene, and rather stressed the need to reduce wildfires’ potential intensity through preventive measures such as SMP (#9). Disagreements surfaced in debates at the Lleida University (#23, ex-GRAF auxiliary fire-fighter; #27, GRAF auxiliary fire-fighter) and tensions were high in the committee in charge of drafting a state of the art paper on wildfires for the Catalan Forest Congress in 2007, where members of both institutions had to agree on a common text (#9; #25; #26). Later on, the two positions came closer. A GRAF technician explained that after the founder retired, the provincial wildfire prevention office started to incorporate GRAF’s input in its prevention and forest management schemes (#9). Indeed, the office’s current head of prevention schemes told us that now they incorporate SMP as advised by GRAF (#20). Even

¹¹ In the period 1998–2015, ca. 460 prescribed burnings were conducted by the Fire Department covering an area of ca. 1600 ha throughout Catalonia. About half of this area was burnt with the objective of improving pastures, while the creation of Strategic Management Points was the objective in 25% of it. Other objectives included the protection of houses and industries, the training of fire-fighters in fire use, forest management, habitat management, and scientific research. Prescribed burnings were conducted in plots with different vegetation structures, mostly shrub land (42%) and tree-covered shrub land (24%). Other structures managed through prescribed burning included grassland, tree-covered grassland, and stubble fields (Database on prescribed burning, 1998–2015, GRAF, Fire Department, Ministry of the Interior). Besides the Fire Department, the Ministry of Agriculture has its own prescribed burning program to manage pasturelands in high mountain areas and to improve wildlife habitats (#9, GRAF technician; #13 and #30, public workers at the Wildfire Prevention Service, Ministry of Agriculture).

in formerly antagonist, *wildfire avoider* institutions, prevention started to be designed according to the wildfires that *will occur*. A new vision of wildfire prevention and forest management adapted to wildfire patterns was consolidated (Costa et al., 2011; Piqué et al., 2011).

4.4. Challenging the power of forest owners

73% of the forests in Catalonia are privately owned (Fletas et al., 2012). While forest owners in our sample acknowledged the fact that GRAF has provided some very valuable knowledge on wildfires, they were still very critical regarding some of their methods (#10; #21; #29; #30). The use of suppression fire was a particularly conflicting issue. After the large wildfire of 1998 some forest owners supported the creation of a group of wildfire fighting specialists that would use suppression fire.¹² But as GRAF consolidated its position and suppression fire became an integral part of the Fire Department’s extinction system, conflicts with forest owners arose. After the Sant Llorenç large wildfire in 2003 two forest owners sued the Fire Department and claimed compensation for burnt property allegedly caused by GRAF’s fire suppression interventions. The Fire Department objected, arguing that those interventions had been necessary to stop the wildfire from spreading and that the affected properties would have burned anyway. The owners lost the lawsuit.¹³ A neighbouring forest owner and head of the local volunteer prevention groups (forest defence association) whose property also burned during that wildfire acted as the plaintiffs’ legal expert in the lawsuit. In our interview he told us that “GRAF is a flock of arsonists” who “set fire to everything” during that wildfire (#29). He stressed that “they [GRAF] don’t burn their pines, their forest and their landscape” but that of others instead. According to him GRAF was responsible for half of the size of that wildfire. GRAF’s head instead stressed that GRAF’s interventions, including not only suppression fire but the strategy of proactive wildfire confinement at critical points, reduced the size of that wildfire from 30,000 ha to 4600 ha, and regretted that this success had not been acknowledged by some forest owners (#14).

Importantly, the forest owners affected by that wildfire were not against the use of suppression fire (the forest owners that we interviewed explained that fire had actually been used to suppress wildfires by their ancestors [#10; #12; #21; #29; #30], and even if this practice had receded with time, it was still used by some forest owners in the early 2000s [#21; #24; #26]), and yet they were still critical towards how suppression fire was used by GRAF. In our interviews, they compared GRAF’s suppression fires with the ones they made in the past which, unlike GRAF’s, were necessary, small in size, and successful (#21; #29; #30). The landowners that we interviewed explained this and other conflicts in the Sant Llorenç wildfire as examples of how GRAF and the Fire Department did not always acknowledge the knowledge on wildfire fighting accumulated by locals (#21; #29). Indeed, the head of GRAF explained that, in comparison with a GRAF analyst who has experienced thousands of wildfires across Catalonia, a landowner cannot be considered as an expert because he has experienced only a handful of wildfires, i.e. only those happening in his area throughout his lifetime (#14).

Collaboration between land owners and GRAF also existed however. In the Sant Llorenç wildfire, GRAF firefighters worked together with local groups of forest owners and volunteers (forest defence associations), who were included by GRAF staff as support for their suppression fire interventions when there were not enough resources from the Fire Department (#14; #26). According to a GRAF technician, the creation of GRAF allowed forest owners to recover some of their traditional wildfire fighting tools, which they had abandoned with the

¹² La Vanguardia, 22 July 1998, page 25.

¹³ Documentation of the lawsuit against the Fire Department regarding the 2003 Sant Llorenç wildfire, 2003–2009.

consolidation of water as the dominant extinguishing tool in the 1980s (#26). Indeed, according to the then head of the Fire Department, one of the premises of the creation of GRAF was a reconciliation between the Fire Department and forest owners, whose relationship had been damaged after the tensions of the 1998 wildfire (#24).

5. The unsuccessful success of a “better” wildfire management system: reinforcing the extinction paradox

The extinction paradox or the positive feedback between extinction efficiency and risk is at the heart of GRAF discourse. Under a general trend of forest expansion and fuel accumulation, greater extinction efficiency and a lower area burnt today means more fuel and larger or more intense wildfires for tomorrow, GRAF argues. In actual fact though, GRAF’s knowledge has made the extinction system more efficient. As we observed in the field, GRAF uses a wide range of methods to forecast risk, anticipate what might happen, focus on those wildfires that might become large, allocate more or less resources according to potential damage, use suppression opportunities to contain wildfires, and prioritize strategic interventions. As a result, the Fire Department can contain potentially large wildfires even in very high risk seasons such as that of 2015. GRAF’s head told us that by limiting the size of wildfires, GRAF actually reinforced the extinction paradox, especially as a preventive forest management strategy is not yet sufficiently developed in Catalonia. This is an insight shared by the other GRAF firefighters that we interviewed (#17; #26; #28). A GRAF technician indeed told us that by reducing burnt area, they are in fact “filling the storehouse” with fuel and increasing the probability of large wildfires (#28).

GRAF’s understanding of how wildfires evolved as a result of changes in both the extinction system and landscape in Catalonia is captured in their concept of “generations of large wildfires”, describing the emergence of ever more intense and hazardous wildfire types (“generations”) as agricultural landscapes were abandoned and urbanized, and as extinction pressure increased from the 1950s (Costa et al., 2011, pp. 52–57). “Fifth generation” events are now expected where “simultaneous large wildfires crossing the wildland-urban interface” with “extremely rapid [and] virulent fire behaviour” might cause large civil emergencies (Costa et al., 2011, p. 57). Echoing these insights, the head of the Fire Department during the creation of GRAF, currently head of the Central Control Division, told us in an interview that the Fire Department has not yet been able to exit the extinction paradox because the new generations of wildfires are increasingly difficult to fight (#24). This perception of increased wildfire risk was captured in the field during the first weeks of July 2015, when extreme weather and fuel conditions made GRAF forecast simultaneous convective wildfires in residential areas of metropolitan Barcelona, creating great expectancy and tension in the Fire Department’s central control room.

Indeed, a central concern that we identified in the discourse of GRAF’s head is that the wildfires able to escape an ever stronger and more efficient extinction system could be devastating. When we asked a GRAF technician whether she thinks that GRAF reinforced the extinction paradox, she responded affirmatively and added that by limiting the size of wildfires “we are buying time but we do next to nothing with the time that we buy” (#26). In the next section we show GRAF’s attempts to make the most of this “bought time” in terms of wildfire prevention and how they go beyond fire-fighting to encompass a transformation in dominant social-ecological values and relationships underlying risk.

6. Challenges: from fire-fighting to the production of alternative values and landscapes

6.1. “Wildfire is not an enemy!” Changing dominant social values

The dominant message sent to society by authorities through the

media is exemplified by the “zero fire” and the “no fire in the forest” summer publicity campaigns of the government and the Barcelona Province Authority in the last years (González-Hidalgo et al., 2014). These campaigns suggest that wildfire is something to be avoided and eliminated from forests. GRAF sends out a substantially different message. As observed in the field, GRAF actively collaborates with the Fire Department’s press office to spread a message on the limits of extinction, the importance of prevention and the need to learn how to coexist with wildfire. Wildfires are not to be suppressed but understood and integrated into landscapes, GRAF publicly argues. The head of the press office explained in an interview that during the press conference of GRAF’s public presentation in 1999 the key message was that from then on, wildfires would not only be extinguished but also managed (#31). The press office is instrumental in the dissemination of GRAF’s practices and it informs about preventive prescribed burnings and about innovative strategies applied in large wildfires (#31). On some occasions the media (partially) echoes the original message. For instance, one week after the 2014 Tivissa large wildfire, the widely read newspaper *La Vanguardia* highlighted as a positive novelty the strategic decision, driven by GRAF, to letting it burn in a pre-defined area instead of choosing a direct attack.¹⁴ That decision was acclaimed by GRAF members and sympathizers as a first step towards using unplanned wildfires to break fuel build-up and to find a way out of the extinction paradox. According to our observations, the social pressure on the Fire Department to immediately extinguish a wildfire is considered as a major obstacle to implement this management option on a broader scale, especially near densely-populated areas. Through the Fire Department’s press office, GRAF thus attempts to create a more favourable public opinion that supports their alternative wildfire management options. Another example is the appearance of GRAF’s head in a Catalan public TV program on wildfires that was shown at the beginning of 2014 wildfire season. Dressed in his firefighter uniform, he stated that wildfires cannot be eliminated and that society should learn how to coexist with them. As wildfire intensity is determined by landscape features, he argued that society can choose to have low intensity wildfires by actively managing landscapes.¹⁵

Besides the press office, GRAF has also expanded its vision through the activities of the Pau Costa Foundation. Founded in 2011 by GRAF firefighters and sympathizers, and chaired by GRAF’s head, the Foundation aims at promoting a deep change in the social perception of fire by disseminating expert knowledge on fire ecology and management. According to one of its technicians, the Foundation is trying to communicate that fire is not an enemy but an ecological factor and a useful tool, and that society needs to become more resilient to wildfires by managing forests (#32). Several of our interviewees referred to the Foundation as an exemplary platform for the dissemination of a new wildfire culture through the training of national and international firefighters, workshops, conferences, research projects and educational activities for children (#16, GRAF fire-fighter; #19; #23; #31; #32).

However, the media pressure during a wildfire and the sometimes sensationalist coverage of events were mentioned by our interviewees as barriers for the transfer of GRAF’s insights and innovative strategies to the general public (#24; #27; #31).

6.2. Moving towards alternative economies and landscapes that burn at lower intensity

In our conversations and field trips with GRAF firefighters, the enhancement of local economic activities linked to a sustainable use of forests emerged as a key pathway towards reducing wildfire risk. Material appropriation of forest resources is intended to break fuel

¹⁴ *La Vanguardia*, 23 June 2014, page 2. *La Vanguardia*, 23 June 2014, page 5, *Vivir* supplement.

¹⁵ *Espai Terra*, TV3, 25 June 2014, min. 16:38.

continuity, reduce the potential spread rate of wildfire and avoid high intensity wildfires. Some GRAF members decided to actively engage in such activities beyond their main job as firefighters. In 2012 some of them founded *Les Atxes* in Southern Catalonia, a cooperative that sells biomass and provides technical service for biomass boilers. As its technician explained to us, biomass is first sold to customers through heating contracts and then bought from forest owners or managers at a fair price. Biomass often comes from Strategic Management Points (SMP, see Section 4.3) of a protected area in the region. This area is managed by a consortium of six municipalities where two ex-GRAF firefighters work. One of them explained in an interview that their management integrates wildfire prevention by means of SMP with the recovery of open habitats of conservation interest and the enhancement of local economic activities such as silvopasture or wine production (#5). In that protected area, prescribed burning, carried out by GRAF, is used to prevent wildfires, to create new pastures and to recover natural habitats (#5). Sharing the philosophy of *Les Atxes*, another GRAF firefighter founded the cooperative *Piro_NEGAWATT* in the Pyrenees region, to facilitate the energetic transition from fossil fuels to local renewable energy sources and to create a demand that makes sustainable forest management viable (#16). The cooperative provides consultancy to improve the energy performance of buildings by prescribing construction and refurbishment techniques and materials entailing positive feedbacks on local forests, e.g. sheep wool as insulation or timber for construction. In so doing, their services contribute to create a demand for the recovery of tree-covered pasturelands in the region, which can be done via prescribed burning or coppicing (#16).

These cooperatives set up by GRAF members and sympathizers can be added to other embryonic initiatives throughout Catalonia where the planning of wildfire prevention is linked to the enhancement of local economies, namely initiatives of silvopasture which control shrub growth while producing organic meat (e.g. Otero, 2011). Efforts towards producing wildfire resilient landscapes also include the integration of SMP into legally binding forest and land-use planning schemes (#33; #34, researchers at the Forest Sciences Centre of Catalonia; Plana, 2011). However, the effects of all these attempts to produce alternative, less vulnerable landscapes through the sustainable use of forests are not yet visible on the ground. During our numerous trips to Southern Catalonia, for instance, large expanses of fuel accumulating ranges, the Tarragona metropolitan area, two nuclear power plants and a petrochemical industry reminded us of the current social-ecological and energetic model underlying high wildfire risk.

7. Discussion

Various papers have shown how traditional ways of fighting wildfires are losing their relevance across the globe as climate and land use changes, changing settlement patterns, and increased extinction efficiency create environments in which wildfires can get out of control and threaten human lives and key economic and ecological values (Moritz et al., 2014; Fischer et al., 2016; Donovan and Brown, 2007; Calkin et al., 2015). The need to learn how to coexist with wildfire is therefore increasingly emphasized, and various options have been discussed in the literature. These include enhancing community cohesion, fuel treatments, promoting collaborative planning networks at multiple scales, providing incentives for alternatives to suppression, and facilitating societal dialogue about alternative adaptation options. The data presented in this paper illustrate the relevance of some of these options in the particular context of Catalonia, the pace at which these might develop as well as the main political, administrative and social challenges they may face. The results presented also emphasize the conflicting nature of wildfire risk policies, as shown elsewhere in the “Global North” and the “Global South” (Carroll et al., 2005, 2006; Eriksen, 2007; Kull, 2002; Sletto, 2008). By demonstrating how conflicts arise from alternative prevention and extinguishment policies stemming from heterogeneous visions and interests of different social

actors (see also González-Hidalgo et al., 2014) a central finding was, however, that a better coexistence with wildfires not only entails but also can emerge from such conflicts. GRAF’s re-shaping of fire-fighting procedures entailed for example a structural and functional re-organization of the Fire Department that met the resistance of trade unionists, commanders and rank and file fire-fighters. Still, the conflicts in the wildfire management system were shown to co-occur with cooperation among actors, as it has been also observed elsewhere (Carroll et al., 2005), and to produce transformative practices along the way. The Fire Department incorporated GRAF’s wildfire analysis in its functional organization, the wildfire prevention services integrated wildfires as expected perturbations in their planning schemes, and forest owners recovered some of their traditional wildfire fighting tools. Our results therefore suggest that social conflict and cooperation should be explored as key processes at play in efforts to achieve a better coexistence with wildfire. This insight complements institutional accounts on wildfire resilience (Abrams et al., 2015) and case studies on wildfire management agencies (Neale, 2017, 2016) by illustrating how the conflicting or cooperative interaction among different institutional and social actors enhances or hinders resilience.

Our findings also illustrate the limited and potentially counter-productive effects of implementing innovative techno-managerial solutions to emerging global environmental problems within current social-ecological systems’ constraints. Our data suggests that applying better knowledge about wildfires to a social milieu that is still in favour of suppression in an increasingly forested landscape, reinforced the extinction paradox. Models confirm that annual area burnt decreased in the period 2000–2010 as a consequence of the changes brought by GRAF to the Fire Department’s suppression practices (Brotons et al., 2013; see also Fig. 2). These authors however offered a more nuanced perspective on the extinction paradox as they modelled the effects of GRAF’s use of suppression opportunities in Catalonia’s fire regime. As shown in our results, suppression opportunities are areas with lower fire spreading rates due to topography, vegetation heterogeneity or fire scars which are identified by the analysis of GRAF-00 and used by the Fire Department to contain the wildfire. Models suggest that the use of suppression opportunities which are not related to fire scars but to other sources of fuel discontinuity have had a major role in the reduction of total area burnt in the region of Catalonia, but those related to fire scars have also played a role in some sub-regions (Brotons et al., 2013). As these authors argue, while this entails that more effective fire suppression today may lead to fewer opportunities related to fire scars in the future, the final outcome in terms of area burnt will also depend on the relative contributions of those opportunities which are not related to fire scars, as well as climate variability and landscape patterns, on the fire regime (Brotons et al., 2013). It is also worth noting that wildfires in Catalonia have been shown to create a positive feedback on fire propagation as they increase landscape homogeneity (Loepfe et al., 2010).

While these insights nuance the expert perception on the enhanced extinction paradox presented in our results, they nevertheless stress the relevance of a new landscape configuration based on fuel discontinuities such as Strategic Management Points for a more sustainable fire regime. Thus in any case, a more sustainable coexistence with wildfire appears to be strongly dependent on fundamental landscape transformations. GRAF is fully aware of this, as illustrated by our results, and is actively involved in processes that attempt to produce changes beyond the wildfire management system to reshape broader social-ecological relationships and values underlying risk. Examples of this are the territorial management around silvopasture, nature conservation, and biomass and wine production observed in southern Catalonia; the embryonic efforts towards an energetic transition in the Pyrenees; or the dissemination of the “fire-ally message” – all of which have been triggered by GRAF knowledge. Re-configured local-regional economies where fire is both a useful management tool and a potentially desirable ecosystem perturbation which is able to manage fuel

Table 1

Variables shaping wildfire regimes and risk, underlying social-ecological trajectories and how these trajectories are challenged by attempts to coexist with wildfire in Catalonia.

Variables shaping wildfire regimes and risk ^a	Underlying social-ecological trajectories	Attempts to coexist with wildfire that challenge underlying social-ecological trajectories ^g
Climate and weather	Increasing greenhouse gas emissions from fossil-fuel dependent growth economies causing global climate change ^b	Facilitating an energy transition from fossil fuels to renewable energy sources
Land uses Fuel accumulation Land use management	Industrialization that led to rural–urban migration, cropland abandonment, forest encroachment, fuel accumulation and urban expansion. Actively managed traditional rural mosaics were abandoned ^c	Conservation of cropland through high value products that stabilize the population in rural areas (e.g. wine production) Re-using forests to supply biomass for heating at the local-regional level Integrated agro-silvo-pastoral management to control shrub growth and produce organic meat Fragmentation of the landscape through strategic management points integrated in local economic activities
Firefighting	Increase in extinction efficiency to protect people and assets from wildfire ^d	Allowing some wildfires to burn under monitored conditions to break fuel accumulation
Awareness-raising campaigns	Prevention of wildfires starting under the “no fire in the forest” logic ^e	Reshaping the message: from “no fire in the forest” to “fire as an ally”
Wildland-urban interface Infrastructures	Formation of metropolitan Barcelona, urbanization of coastal areas and counter-urbanization in forestlands. Development of highways, electric lines, power plants and industrial areas ^f	Enhancement of self-protection culture Integration of wildfire risk into legally binding land-use planning schemes

^a Climate and weather, land uses, fuel accumulation, land use management, firefighting, and awareness-raising campaigns are some of the variables shaping wildfire regimes according to the models developed for Catalonia by Piñol et al. (2005), Loepfe et al. (2011) and Brotons et al. (2013). Wildland-urban interface and infrastructures were added as proxies for wildfire impacts, an essential component of risk assessment.

^b IPCC (2014) and Llebó (2010).

^c Vidal (1979), Parcerisas et al. (2012), Otero et al. (2013, 2015), Marull et al. (2014), Cervera et al. (2016), and Vayreda et al. (2016).

^d Brotons et al. (2013). See also text.

^e González-Hidalgo et al. (2014).

^f Dura-Guimera (2003), Catalán et al. (2008), and Otero (2010).

^g From our own data (see text).

illustrate how wildfire management in Catalonia is moving beyond mere suppression or classic prevention. Our results indicate that only the production of an alternative landscape which burns at lower intensity will actually lead to a better coexistence with wildfires. This is in agreement with models suggesting that in Catalonia high intensity fires can be avoided by prescribed burning, grazing or mechanical cutting, while fire suppression enhances fire intensity (Piñol et al., 2007, 2005). As in other Mediterranean countries facing high wildfire risk, a more sustainable coexistence with wildfire in Catalonia seems thus related to the recovery of the traditional rural mosaic (Loepfe et al., 2010). This policy becomes especially relevant to reduce climate change induced increases in burnt area and large wildfires (Loepfe et al., 2012). However, fire suppression can also substantially contribute to compensate the predicted effects of climate change in Catalonia's fire regime (Loepfe et al., 2012; Brotons et al., 2013). Therefore a better coexistence with wildfires under climate change also seems to require strategic decisions about which wildfires should be suppressed and which let burn, under what conditions, and according to whose values (Regos et al., 2014; Otero et al., submitted for publication).

The literature on the wildfire problem across the world does not discuss the social-ecological and political-economic implications of moving towards a new rural mosaic and other proposed management options to coexist with wildfire. Table 1 highlights how these options, implemented in Catalonia, challenge the underlying social-ecological trajectories which in turn shape wildfire regimes and risk. Such trajectories include processes, relationships and values that are constitutive of Catalonia's current social-ecological configuration (Table 1; second column). They encompass the structure of its energy sector, the spatiotemporal distribution of land uses and associated historical rural-urban migration fluxes, the metropolitan condition of its settlements, as well as the dominant perception that wildfire must be prevented or immediately suppressed to protect people and assets. The attempts to better coexist with wildfire reported in our case study seem to operate in the opposite direction of these core social-ecological trajectories that

unfolded with industrialization, urbanization and development since, at least, the 1960s (Table 1; third column). In other words, facilitating energy transitions, stabilizing rural populations, managing the land to supply local-regional consumption networks, integrating wildfire risk into land planning and allowing some wildfires to burn all point to a radical social-ecological transformation of the current (post-)industrial configuration. Inspired by political ecology, our research thus shifts its attention from wildfire management aspects to the political-ecological conditions through which an alternative, less flammable landscape, can be produced (González-Hidalgo et al., 2014; Buizer and Kurz, 2016). In Catalonia, current efforts towards this endeavour are limited, insufficiently connected and essentially unable to reverse the general historical trajectories underlying wildfire risk. An example of this is the fact that in spite of all the efforts reported in our case study, tree-covered land increased at a rate of ca. 8100 ha/year due to succession in scrublands and abandoned cropland over the period 1993–2009; while cropland decreased at 10,400 ha/year and urban areas and infrastructures increased at 4900 ha/year (Vayreda et al., 2016). This is only the last phase of a long-term process of forest transition associated with socioeconomic development and urbanization (Otero et al., 2015) the inertia of which is not easily reversed. Therefore, both in theory and in practice, wildfire researchers and practitioners should link the proposed management options for a better coexistence with wildfire to a deeper debate on how to redirect and reshape such pervading trajectories, including the necessary political strategies and alliances.

Coexisting with wildfires in a rapidly changing Earth is thus a matter of initiating fundamental social-ecological transformations (O'Neill and Handmer, 2012). As the case of GRAF exemplifies, more and better knowledge helps to fight fires, but this is not necessarily enough. The wildfire case presented here is exemplary in this respect and strongly supports the need highlighted in the literature for a “transformation science” when exploring the causes and consequences of global environmental change (e.g. O'Brien, 2011; Moser, 2016). To date, this literature has mainly described transformations in institutions

and governance, social and ecological systems, communities and landscapes, energy use and farming systems at different scales, but a multidimensional and historic perspective on transformations is largely absent (Brown et al., 2013). Our case shows precisely how transformations to sustainability might develop historically as multiple institutions, landscapes and sectors are strategically intertwined at different scales when learning how to coexist with wildfire. Therefore, wildfire practitioners working to achieve a better coexistence with wildfires across the western fire-prone regions should be considered as potentially powerful transformative agents (Neale, 2016). Our case also shows how as these transformations unfold, social-ecological and power relationships constitutive of a western society are challenged at ever deeper levels. While in the first phase the attempt to coexist with wildfire reshaped the wildfire management system and met the resistance of status quo in public agencies and local power arrangements, in the second – incipient – phase it was shown to potentially challenge deeply entrenched societal values (humans can and should dominate “natural” forces), as well as global fossil-fuel based food and energy systems and the ensuing landscape structures shaping wildfire risk. In line with other authors pointing out the need for radical transformations (e.g. D’Alisa et al., 2015; Asara et al., 2015; Escobar, 2015) our paper thus shows how the attempt to live sustainably puts the essence of the “modern subject”, the industrial system and capitalism at stake.

8. Conclusions

In this paper we described the emergence and consolidation of GRAF, an internationally renowned group of wildfire fighting specialists in the Catalan Fire Department, to explore the social-ecological transformations that a better coexistence with wildfire entails for western societies of fire-prone regions. Drawing on qualitative data, we showed how the GRAF-led attempt to coexist with wildfire triggered a set of transformative processes that challenge social-ecological and power relationships highly constitutive of these societies. Our case study also suggested that unless these transformative processes reach sufficient rate and reach, techno-managerial solutions might actually end up reinforcing the wildfire problem they were meant to address. Thus, a priority for wildfire practitioners and researchers should be to explore the conditions, strategies and pathways that might accelerate these necessary transformations. Given that the latter touch upon deeply rooted social-ecological entanglements, channelling otherwise inevitable social conflict in productive directions seems crucial to coexist with wildfire in the context of rapidly changing fire patterns across the Earth. By using wildfires as symptoms of the profound changes needed to effectively address sustainability challenges, our paper stressed the need for the global change research community to deliberately insert the development of knowledge-based and techno-managerial solutions into political processes aimed at reorganizing social-ecological relationships towards new social-ecological orders.

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