Content analysis of resilience in forest fire science and management

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**ABSTRACT**

To better understand the implications of the word resilience for western forest and fire management, this study explores its emerging use in a large body of policy and management documents produced between 1980 and 2016. We performed a computer-aided content analysis on 1487 scientific journal articles and 139 western U.S. Forest Service USFS planning documents to answer three questions: 1) how has the use-rate of the word resilience changed over time? 2) are changes in the use-rate of the word resilience associated with shifts in terminology associated with environmental values, complex systems theory, or environmental change? and, (3) how does the use of the word resilience compare between science and management documents? To ground our interpretations in the context of the word’s technical use, we conducted 25 semi-structured interviews with scientists and managers working across the region. We found that the word resilience has been used in these documents since the 1980s but that its use sharply increased in both contexts between 2009 and 2011. The use-rate trends differ between science and management documents and do not appear to be associated with complex systems terms but do seem associated with increases in the use of terms “climate change” and “adapt” and biocentric values. Finally, although there are differences in how resilience is used between science and management documents, the shared meaning of the term is a hopeful framing for adapting forests to changing conditions. Understanding the emerging use of the word resilience is of critical importance for land use policies that rely on it to signify a central concept, strategy or goal.

1. Introduction

When new scientific terms emerge and gain prominence in land use policy and scientific writing, the social and historical contexts of their use become critical for their interpretation (Skillen, 2015; Norton, 2005; Klyza, 2000). There are significant policy debates around the choice of language for defining management strategies on public lands as well as frequent disagreements among scientists and managers about the definitions of new terminology, such as keystone species, sustainability, ecosystem management, forest integrity and new forestry (Wright, 2010; Hays, 2006; Davic, 2003; Grumbine, 1994; Gillis, 1990). Underlying these disagreements are often conflicting scientific conceptions, environmental values, beliefs about the purpose of public land, and views of the role of cross-boundary disturbances like fire. This study examines the context of the use of resilience: a word with multiple interpretations and increasing importance for land management science and policy. Rather than offering a new technical definition of resilience, we perform a content analysis of its emerging use in the documents of forest and fire management and science in the western United States (US) to better understand the underlying social factors driving its increased use and varied meanings.

In recent years, the word resilience has proliferated across academic disciplines and policy sectors concerned with the stated concern of adapting social-ecological systems to change, but how it will be operationalized for land management remains uncertain (Walker and Cooper, 2011; Brand and Jax, 2007). Land use policy discussions about the word often draw from an interdisciplinary scientific literature on the management of social-ecological systems, and in these documents, it is usually associated with a concept developed in systems ecology in 1970s that has been called a “metaphor” and a “way of thinking” by its primary theorists (Folke et al., 2010; Carpenter et al., 2001). Buzz Holling, who is credited with introducing the concept to ecology, was also the first to define it in multiple ways: engineering resilience and ecosystem resilience (Holling, 1973, 2001). Rather than solidifying into a unified definition over time, the word resilience has acquired new definitions (Brand and Jax, 2007; Davidson et al., 2016). Uncertainty about its technical definition and application to management persists in recent land management policy briefs and reports (Timberlake et al., 2017). Advocates and critics of applying the word resilience in land management policy both believe that the way it is defined will have “major consequences for policy” (Holling and Meffe, 1996; Newton and Cantarello, 2015).

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Previous studies of the use of the word resilience in United States Forest Service (USFS) documents have found it increasingly used in relation to fire and climate change adaptation policy but in various and sometimes contradictory ways (Benson and Gar mestani, 2011; Bone et al., 2016). For example, the word has been used to describe a management strategy for adapting forests to climate change, a national goal of learning to adapt and “live with wildland fire,” and alternatively, in a recently passed law (H.R. 1625), a goal for expedited timber harvests for fuel reduction with reduced regulation (Millar et al., 2017; Moritz et al., 2014; U.S. Department of Agriculture and Interior, 2011). In discussions about climate adaptation strategies, some scientists and managers, frustrated with the ambiguity of the word resilience, have even suggested that its use is “maladaptive” because it can simultaneously imply “diametrically opposed” management strategies ranging from historical ecosystem restoration to a guided transition to ecosystem novelty (Fisichelli, Schuurman, and Hoffman, 2015; Newton, 2016; Rissman et al., 2018). These alternative uses of the word resilience in discussions about the contentious issues of fire management and climate change adaptation—as well as the persistent difficulty in formally defining it—call for a further investigation into the social factors behind its increased use and varied meanings, factors which bear on how the word resilience will be operationalized and interpreted on public lands in the coming decades.

In this study, we take a social-scientific approach to examine the academic and technical uses of the word resilience in the documents of USFS management and forest and fire science in the western US. The evolving languages of science and policy cannot be isolated from their social contexts: institutional norms, environmental values, scientific conceptions, and management priorities all underlie changes in the language of land use policy. Our aim is not to define the word resilience but to provide a timeline of its adoption and use, and to explore how social factors may be influencing its increased use and varied use. We apply the methods of computer-aided content analysis, structural topic modeling, and semi-structured interviews to take a broad look at the use of the word resilience (i.e. resilience, resilient, and resiliency) in the documents of western US forest and fire science and management to answer three questions:

1. How has the use-rate of the word resilience changed over time, and did its use-rate first increase in science or in management documents?
2. Are changes in the use-rate of the word resilience associated with shifts in other terminology related to environmental values, complex systems theory, or environmental change?
3. How do uses of the word resilience vary between the scientific literature and USFS planning documents?

2. Language in science, management, and policy

2.1. Studying language: social-scientific approaches

Social-scientific analyses of terminology in science, management, and policy seek to explore the relationships between technical terms and the dynamic social processes in which they are used. Social scientists generally favor a ‘conventionalist’ view of language, where meaning is dynamic, evolving and based on social convention and context, over an ‘essentialist’ view, where language represents an external structure of the world and scientific terminology represent unchanging, objective categories of meaning that can accurately represent it (Norton, 2005; see Moon and Blackman, 2014). Social scientists usually conduct conventionalist analyses of language using either qualitative methods, like discourse analysis, or quantitative methods, like computer-aided content analysis. These social-scientific approaches differ from efforts to define or operationalize terms, which seek to bring scientific or management communities into agreement about their use.

The call to operationalize resilience for management has led to many efforts to define and apply the word. In an effort to avoid confusion about the meaning of the word resilience, many scientists have supplied typologies (e.g. Brand and Jax, 2007) or operationalization strategies (e.g. Carpenter et al., 2001). These approaches (like Brand and Jax, 2007) typically demarcate discrete, relatively stable meanings of the word resilience by their academic and technical definitions and are indispensable for effective and transparent land management policy. However, if the meaning of the word resilience is understood to be social—something dynamic that emerges by convention in the process of communication—then a conventionalist approach, using either qualitative or quantitative methods, must also be helpful for understanding the various meanings, uses, and contexts of the word resilience.

Discourse analysis is a qualitative, conventionalist approach to studying language that places the use of environmental policy terminology in its social and political context. A discourse is defined as a particular “ensemble of ideas, concepts and categories through which meaning is given to social and physical phenomena,” and a central premise of discourse analysis is that the meanings of words and scientific concepts “are not and cannot be imposed in a top-down way … but are continually contested in a struggle about their meaning and interpretation” (Hajer and Versteeg, 2005). For example, Vaughn and Cortner analyzed forest policy discourses to reveal how the Bush Administration advanced and framed its western US land use policies in the Healthy Forests Initiative (HFI). Using a variety of policy tools, the administration framed events (western wildfires) and scientific concepts (in this case forest “health”) to influence public perceptions of federal forest policy and achieve its particular policy goals (2005).

Recent studies have applied discourse analysis to understand the increasing use of the word resilience in the context of forests, fire, and natural resource policy. For example, Walker and Cooper examine how, in the discourse of natural resource management, the word resilience has become a “pervasive idiom of global governance” and is tied to “logistics of crisis management, financial (de)regulation and development economics” (Walker and Cooper, 2011). Similarly, McGreavy’s study of the word resilience as a discourse of land use policy explores how the word expresses and advances “specific ways of understanding, measuring, visualizing, and otherwise ordering reality.” It is developed by “discourse societies”—groups of academics like the Resilience Alliance—and then used by organizations and governments to advocate “resistance, control, and attempts to return to normalcy” (McGreavy, 2016).

Social scientists studying language and management with a conventionalist epistemology and qualitative methodology have also identified resilience as a management buzzword and boundary object. Management buzzwords are ambiguous but optimistic words or phrases that managers and policy-makers may use to establish authority, conceal sensitive issues, and displace responsibility (Cornwall, 2007; Cluley, 2013). If ambiguous words or phrases can obscure controversial intentions, they will also be useful in the polarized context of environmental policy (Edelman, 1977; Burke, 1969). In a recent content analysis of the word resilience in high-level USFS policy documents, Bone et al. found that the word still “begg[s] for conceptual clarity” when used it define policy goals, and in conclusion, question if it is simply “the latest in a string of similar terms” reframed to give the agency “the political space to act” (Bone et al., 2016). The malleability of the word resilience has led others to call it a boundary object—an idea or concept that can be shared across disciplines and stakeholders. Brand and Jax argue that the word resilience serves as a boundary concept, which makes its use in land use policy both advantageous and risky (Brand and Jax, 2007). Its polysemous nature may make it “politically successful,” but it could also hamper transparent communication by obscuring divergent interests and values.

Qualitative discourse analyses are usually conducted through careful readings of primary documents, but the ability of computers to detect and quantify patterns allows for the examination of specific
words or phrases across much larger bodies of text. Computer-aided content analysis is an established methodology for systematically drawing inferences from texts that can vastly increase the number of documents examined, track patterns over time, and evaluate small but important differences between contexts (Krippendorff, 2012). In the field of natural resources, computer-aided content analysis like this has been applied in variety of ways including an overview of emerging research topics and an analysis of changing environmental values in the US (Nunez-Mir et al., 2017; Bengston and Xu, 1995; Bengston, 2000).

A major challenge of applying computer-aided content analysis to study language is the implicit assumption that meaning can be measured without interpretation and without readers—an assumption at odds with most methodological traditions concerned with meaning and text, including the conventionalist approach to language discussed above (Herrera, 2004). However, the methodology of content analysis as articulated by Klaus Krippendorff offers a methodological framework for analyzing texts that addresses this challenge. Krippendorff defines content analysis as “a research technique for making replicable and valid inferences from texts to the contexts of their use” (2012). In this framework, the meaning of “content” is never inherent to the signifier nor is it an attribute of its source—words and texts cannot speak for themselves and meaning cannot be measured. Instead, the meaning of content is what emerges from the “process of a researcher analyzing text relative to particular context.” Therefore, this approach requires the researcher to constantly move between the text under analysis—the “data,” and the context of its use. This implies that meaning can never be measured or obtained from a text but must emerge from the “process of a researcher analyzing text relative to its particular context” (Krippendorff, 2012). We adopted this methodological framework for content analysis that considers meaning as distinct from both a text and its source. Therefore, to ground our computer-aided content analysis of the use of the word resilience in the lived contexts of western US forest and fire science and management, we interviewed managers and scientists across the western United States region—those who are writing and using the word—about their own interpretations of its meaning and use.

2.2. Important contexts for resilience use

Applying the conventionalist perspective of language to understand the word resilience means recognizing that its meaning is imbedded in the social process of its use. Changes in language use over time and space, by context or by document, may in fact reflect—and re-inforce—alternative values, priorities or policy positions. We believe that developing a better understanding of how the word resilience’s use differs between contexts—particularly between those of research scientists, policy-makers and managers—is critical for the ongoing land use policy discussions that rely on the word to represent a fundamental concept or strategy. By examining the relationships between the word resilience and the textual contexts of its use, we seek to facilitate the land use policy discussions between citizens, scientists, managers, and stakeholders.

We hypothesize that the adoption and increased use of the word resilience in the documents of forest and fire science and USFS management is connected to underlying social and environmental factors. Shifts that take place in the terminology of science and USFS management do not occur in isolation but may reflect broader shifts in the dominant environmental values, scientific conceptions, and policy priorities (Rosenbaum, 2016; Kennedy and Thomas, 1995). Below, we review the historical and social contexts of USFS policy and planning to identify and then highlight how three factors—environmental values, complex systems theory, and environmental change—may be associated, or driving, the increased use of the word resilience. We also discuss factors that may influence the variation in meaning of the word resilience between science and policy documents.

2.3. USFS planning

The USFS, which manages land in units called national forests and grasslands, was originally directed by the Organic Act of 1897 to focus on supplying a sustainable source of timber and water. Conflicts between competing public interests, particularly grazing, and the growing demand for recreation in the 1950s, led Congress to pass the Multiple-Use and Sustained Yield Act (MUSYA) in 1960. MUSYA formally mandated that the USFS manage its land by balancing public interests—timber, recreation, mining, and grazing—in a “harmonious and coordinated” manner while simultaneously extracting resources at the highest level possible for a “sustained yield”—a paradox central to the contentious nature of USFS management since (Dana and Fairfax, 1980; Hirt, 1996). However, changing attitudes toward the responsibility of government and the growing power of the environmental movement during the 1960s and 1970s brought new laws and significant changes to how public lands were managed.

The National Environmental Policy Act (NEPA) of 1969 required all federal agencies, including the USFS, to produce Environmental Impact Statements (EIS) before significant actions and important plans. The National Forest Management Act of 1976 (NFMA), passed following controversy and lawsuits around clear-cutting on national forests, required every USFS unit to develop regulated Forest Plans (FP) for guiding management. Finally, the 1982 Planning Rule stipulated that the development of these plans would require an interdisciplinary and collaborative planning process. The combined result of NEPA (1969), NFMA (1976) and the 1982 Planning Rule was that USFS land management was required to be evidence-based—utilizing a systematic and interdisciplinary approach—while simultaneously including public participation and a process for appeals. Between the early 1980s and 1995, every national forest unit prepared an FP under the process defined in the 1982 Planning Rule and a corresponding EIS document as recommended by NEPA.

Since the 1980s, changes in USFS land management policy have been driven by the appeals process and frequent litigation but also by the environmental values advanced by presidential administrations, which have the power to hire staff and set agendas. In the 1990s, a new management paradigm called “ecosystem management” emerged that promised to bring together utilitarianism and biocentrism, important US ethical frameworks that are typically at odds with each other (discussed more below). This paradigm was quickly adopted, however, the Clinton administration (1993–2001) used it to promote policies with biocentric leanings, like the Northwest Forest Plan (NWFP) of 1994, which contains a single use of the word ‘resiliency’ in relation to “riparian and aquatic ecosystems” (Skillen, 2015). The Bush administration (2001–2009), on the other hand, re-framed the existing paradigms and scientific language of ecosystem management to advance utilitarian interests, notably in the Healthy Forests Initiative (HRI), which was modified and passed by congress as the Healthy Forest Restoration Act (HFRA) of 2003. The word resilience is used in HFRA seven times in relation to “wildfire-resilient stands” and resilience to insects (Vaughn and Cortner, 2005).

During the early years of the Obama administration, the word resilience appears to have become increasingly used in key policy documents like the major revision to the 1982 Planning Rule, which developed and promulgated in 2012. In the initial draft of the document, the word resilience appeared frequently often paired with “ecosystem health” and was used in the context of wildlife, wildlife habitat, viable populations, watersheds, and aquatic ecosystems. In the final version of the document, however, the word only appears twice. As the agency explained in its response to public comments, it was removed due to “public concern about how to define and measure” it. In the revised 2012 Planning Rule, it still appears twice: once in the definition of the term “restoration” and later in the definition of “viable populations.”
2.4. Environmental values

Human values shape natural resources policy and management (Kennedy and Thomas, 1995). Social scientists who study environmental values often refer to two value orientations or “philosophical and normative views of forests”: a utilitarian view and a biocentric view (Steel et al., 1994; Vaske et al., 2001; Cubbage, O’Laughlin, and Peterson, 2016; Layzer, 2015). Although their motivations may vary, those who hold a more biocentric view typically see the environment as holding intrinsic or life-sustaining value and emphasize the interconnectedness of human society with the environment. Those who hold a utilitarian view tend to emphasize the importance of economic development for human well-being through timber harvest, grazing livestock, or recreation. Since USFS lands are publicly owned, changes in the value orientations of stakeholders and the US public have a significant influence on USFS management policy. During the 1960s and 1970s, US environmental values shifted from a more economic or utilitarian orientation toward a more intrinsic and biocentric orientation, which contributed to the frequent clashes between environmentalists (biocentric view) and those with economic interests (utilitarian view) over the management of public lands (Hays, 2006; Nash, 2001; Skillen, 2015).

We hypothesized that the increasing use of the word resilience would be associated with a shift toward biocentric values. The word resilience is often used in an ecosystem context, and its use has been advanced by an ecological value-oriented organization, the Resilience Alliance. Discussions of ecosystem resilience often use biocentric terminology and describe the intrinsic value of nature (B. Walker et al., 2004). However, because it can also describe resource harvest and use, the word resilience could potentially be associated with language that reflects either biocentric or utilitarian values. As ecologists have noted, specifying the resilience of “what” and “to what” does matter (Newton, 2016; Carpenter et al., 2001). Those with a biocentric view might aim for the resilience of ecosystems, diverse species, or ecosystem processes, while those with a more utilitarian view might focus on the resilience of timber stands, markets, and jobs. For these reasons, we expect to find the use of biocentric value terms associated with the use of the word resilience over time, but we would not be surprised if it is occasionally linked to utilitarian values or even to an entirely new normative perspective of forests.

2.5. Complex systems science

The legal framework for USFS management (i.e., NEPA, NFMA, and both Planning Rules) mandates a systematic and interdisciplinary (physical, biological, economic, and social) evaluation process for land management planning, and therefore, USFS planning relies on evolving scientific conceptions of physical, natural, and social systems. We hypothesize that the increased use of the word resilience in the context of western forest and fire management and science may be associated with an increase in the use of complex adaptive systems terminology.

Prior to the 1950s, the predominant view of natural systems among ecologists in the US was one of balance and predictability—a view informed by the theory of succession and well-expressed by the phrase ‘balance of nature.’ In the 1960s, however, ecological theory followed in the wake of a broader economic and cultural shift in postwar science toward interdisciplinary research, computer simulation and the use of complex systems theory with the latter ascending to become a unifying paradigm for a wide range of academic fields including psychology, sociology, biology, physics, and ecology (Grauwin et al., 2012; Worster, 1994). Those who applied complex systems theory to ecology challenged the traditional view of ecosystems and re-conceptualized them as being complex, dynamic, non-linear, and characterized by multiple equilibriums, self-organization, networks, and adaptive learning (Barbour, 1996; Turner, 2014). Furthermore, the postwar increase in computing power equipped ecologists with the tools to study what might have been impenetrable complexity by allowing them to simulate and model ecosystems to identify emergent properties across space and time (Levin, 1998; May, 2001).

The development of resilience theory in ecology, beginning in 1973 with the work of C.S. Holling, is characteristic of the shift toward complex systems theory that occurred across social and natural sciences. In the early 1990s, a group of scientists (including C.S. Holling, Elinor Ostrom, Steve Carpenter, Lance Gunderson, Carl Folke and Fikret Berkes) developed a conceptual framework around the word resilience based on the idea that reducing the hierarchical control of complex social-ecological systems might allow for the self-organization of “polycentric systems of governance” that are diverse, sustainable, and resilient to unexpected changes (Folke, 2006; Ostrom, 2009; Gunderson and Holling, 2002; Berkes et al., 2000). Against traditional natural resource management, guided by what they called a “command and control pathology,” they argued for a “resilience approach” that would place more emphasis on the “flexibility of institutions, and incentives in economics” to encourage more sustainable resource management (Holling and Meffe, 1996; Gunderson and Holling, 2002). In 1999, this group of scientists founded the Resilience Alliance (www.resalliance.org), and in the last decade, their conceptual apparatus, centered around a concept called “social-ecological resilience,” has become a “dominant discourse in natural resource management” (Walker and Cooper, 2011; Parker and Hackett, 2012). Recent reviews and applications of social-ecological resilience continue to emphasize the importance of complex systems theory and ecological resilience (Messier et al., 2015; Lindemayer et al., 2016).

2.6. Environmental change

Due to its central place in discussions about climate change adaptation, we hypothesize that the use of the word resilience is associated with the terms “climate change” and “adapt.” Historians and policy scholars have shown how concerns about forests have a significant influence on federal forest management goals and practices (M. Williams, 1992; Dana and Fairfax, 1980; Steen, 2004). The use of the word resilience began, and has increased, as scientists, managers and the public have become increasingly concerned about the direction and magnitude of environmental change and instability. An important theme of the Resilience Alliance’s work, for example, is to show how managing for the resilience rather than the stability of natural resources may help societies circumvent ecological collapses caused by misguided management and the increasing human demands on ecosystems (Holling and Meffe, 1996; Folke et al., 2004).

In the western US today, climate change and human development (e.g. the expansion of the wildland-urban interface) are the primary drivers of ecological novelty, catastrophic environmental changes, and ecosystem collapse (Radeloff et al., 2015, 2005; Folke et al., 2004). Discussions using the word resilience in this region are often focused on understanding the relationship between climate change, the increasing frequency and severity of wildfire, and the ability of policy and management paradigms to help ecosystems and rural communities adapt to social-ecological change (Moritz et al., 2014; Stephens et al., 2013). Key studies have linked the warming climate to the increasing frequency of high-severity fires in the western United States, which could have “profound consequences for many species and for ecosystem services including aesthetics, hydrology, and carbon storage” (Westerling et al., 2006, 2011; Abatzoglou and Williams, 2016; Harvey, 2016). Some scientists have proposed a “resilience approach” to management in the face of climate change that looks to the past and prepares for the future (Miller et al., 2007; Adger et al., 2011; Nelson, Adger, and Brown, 2007; McWethy et al., 2019). However, critics of this resilience approach argue that its ambiguous combination of historic restoration and climate change adaptation make it potentially more “maladaptive” than helpful for planning for environmental change (Fischelli, Schurman, and Hoffman, 2015). Furthermore, social scientists have critiqued the
resilience approach for being incommensurable with contemporary social theory because of its “lack of attention to agency, conflict, knowledge, and power” (Olsson et al., 2015).

Our review of the USFS policy and planning context demonstrates that changing national environmental values, spreading scientific conceptions of natural systems, and new concerns about environmental changes, are all important factors that may influence the use and meaning of the word resilience in the context of forest and fire management policy in the western United States. Our study attempts to identify and compare the relationships between the use of the word resilience and changes in the use of collections of words that capture these contextual factors. We also compare these relationships between the contexts of science and management.

3. Methods

3.1. Data collection

To gather the body of documents representative of USFS management, we downloaded PDFs of all available FPs and FEIS documents from the websites of all national forests and grasslands located in the western US (Arizona, California, Colorado, Idaho, Nevada, New Mexico, Montana, Oregon, Utah, Washington, and Wyoming). Units that have updated or revised their original FPs may have up to two of each document type. We identified a total of 78 units in these states and 75 had at least one document available for download. Documents were occasionally missing or failed to download. The final number of PDFs collected was 1072, which represents 98 FPs and 51 FEIS documents because a single FP or EIS could be composed of multiple PDFs. To gather the corpus representative of forest and fire management science, we collected scientific journal articles by querying the Web of Science database for journal articles published between 1980 and 2016 that included the terms forest* AND fire* AND manage* (non-case sensitive and the asterisk representing a wildcard) in their title or abstract. Only results with at least one U.S. affiliated author were kept. This query returned 3225 references including 41 book chapters that were removed leaving a total of 3184 articles. To limit these articles to the western US, we removed articles that did not contain the name of a western state or USFS unit in the abstract or title, which left a total of 1527 articles. Using EndNote’s “find full-text” feature we downloaded 672 of these documents as PDFs. The remaining 824 articles were downloaded manually and could not be found online. The final count of journal articles was 1496 (Table 1).

PDF documents from each body of text were converted into raw text data and pre-processed using open-source tools for text analysis. Scientific journal articles, which have a relatively predictable text structure, were converted into raw text using GROBID, a tool developed explicitly for this purpose (Lopez, 2009). Nine journal articles failed to convert leaving a total of 1487 documents for analysis. FPs and FEIS documents were converted into raw text using Python’s PDFminer 1.3.1. package. Ten complete USFS management documents failed to convert leaving a total of 91 FPs and 48 FEIS documents for analysis. We used Python’s Natural Language Toolkit 3.2.1 package (NLTK) to remove common words, i.e. stopwords (“and”, “the”, “or”, etc.), and singularize words (e.g. “trees” converted to “tree”) (Bird et al., 2009). Words were not stemmed or lemmatized, other common normalization methods for reducing inflected words to their stem, to improve the interpretability the results.

3.2. Semi-structured interviews

To ground our interpretations in the context of the publication and technical use of these texts, we conducted semi-structured interviews with scientists and USFS managers. We selected and emailed thirty-five scientists working in the western US who had authored the highest number journal articles in a Web of Science search that included the terms “forest”, “fire”, AND “resilience.” We emailed 104 USFS employees working in Western regions in positions relevant to planning and management (i.e. Forester, Fire Ecologist, NEPA Planner, etc.) listed in the USFS employee database. Semi-structured interviews were conducted over the phone using a dramaturgical approach, which emphasizes the performative and reflexive aspects of the interviewee’s role (Berg and Lune, 2011). We continued scheduling interviews until saturation, and in total we conducted 25 interviews: 11 with university and USFS scientists and 14 with USFS managers. Example questions include:

1) When and in what setting do you first remember hearing the word resilience used in forest and fire management?
2) Do you think that the increasing use of the word resilience is associated with changes in how forests and fires are managed?
3) From your perspective, what makes for a resilient landscape?

Interviews were recorded with the permission of participants, transcribed and then reread for key themes. We did not code the interviews systematically. In each section of the results, we provide summaries and relevant quotes from the interviews to provide a qualitative and interpretive context for our quantitative results. The final sample included university scientists, fire ecologists, forest supervisors, foresters, natural resource planners, NEPA planners and one vegetation ecologist. The managers and scientists we talked to work across the west, which includes the Pacific Northwest, Southwest, Rocky Mountain, and Intermountain regions.

3.3. Quantitative analyses

3.3.1. Question 1: Resilience use over time

To answer Q1, we compared the use-rate trend of the word resilience by body of text (i.e. scientific journal articles and USFS management documents) and year of publication. This rate was calculated by dividing the total number of instances of the word resilience (i.e. resilience, resilient, resiliency) that occurred in a body of text each year by the total number of words for that body of text and year. We compared the use-rate of the word resilience to the use rate of the words “health” and “integrity,” which are common and similar terminology used to describe forest conditions in the field of forestry (Helms, 1998).

3.3.2. Question 2: Association of environmental values, complex systems theory, and environmental change with resilience use-rate

To answer Q2, we compared the use-rate trend of the word resilience to trends in the rate of terms derived from coding dictionaries that represent the contextual categories of meaning we hypothesized as important factors of increasing resilience use: environmental values, complexity science, and environmental change (for an explanation of coding dictionaries see Krippendorff, 2012). The dictionaries for utilitarian and biocentric environmental values were drawn from a previous content analysis of US forest values (Bengston, Webb, and Fan, 2004; Appendix B). Because the number of terms in these two coding dictionaries differ, their rates were weighted as a proportion of the combined count of terms in both dictionaries. The dictionary for complex system theory terminology was derived from a list of terms used in a bibliometric study of complex system research (Grauwin et al., 2012;
Appendix B). The dictionary for environmental change focused on climate change adaptation and therefore only included the words “climate change” and “adapt.” We plotted all use-rate trends on over time and created a correlation matrix for both contexts.

3.3.3. Question 3: Structural topic model of scientific literature and USFS planning

To answer Q3, we fit and evaluated a structural topic model (STM) on all instances of the word resilience (i.e. resilience, resiliency and resilient) extracted from the documents using a 10-word context window (10 words to the left and 10 words to the right). A STM is an unsupervised, machine-learning algorithm used for inferring and comparing themes, or “topics,” in large collections of documents (Roberts et al., 2017). This approach is useful for comparing the language between groups (e.g. political parties, newspapers) and has been applied in a wide variety of comparative studies of text (Lucas et al., 2015; Bohr and Dunlap, 2018; Chandelier et al., 2018; Rothschild et al., 2018). The contextual words around each use of resilience (10-words on both sides) were converted into a numerical feature vector so that in our final dataset each instance of resilience was a row and for each word in the entire corpus there was a binary column: equal to one if the word was within the context window and zero if not (Bird et al., 2009). Prior to fitting the model, we also computed phrases—two words that frequently co-occur together across instances, like “climate change” or “insect outbreak”—to include as unique terms using the phrase collocation detection class in Python’s gensim package (Rehůřek and Sojka, 2010). Rather than providing a prior number of topics to discover, as topic models usually require, we used a model initialization method for inferring the optimal number of topics (Lee and Mimno, 2017). The results of the structural topic model are algorithmically inferred collections of words around uses of the word resilience that are both shared and distinctive to scientific journal articles and USFS planning documents (Blei et al., 2003).

4. Results

4.1. Question 1: Resilience use over time

The word resilience was minimally present in both USFS planning documents and scientific journal articles for most of the period between January 1980 and December 2010, but its use increased rapidly in 2011 (Fig. 1). The earliest two uses of the word resilience in USFS planning documents were in the early 1980s and are not related to fire management but to (1) the response of streams and vegetation to recreation impacts and (2) the positive effects of economic diversification. The first occurrence of the word resilience in the scientific literature of western forest and fire management in this dataset appeared in 1993 in an economic analysis of ungulate herbivory (Weigand et al., 1993). After 1993, the use-rate of the word resilience remained relatively flat until 2011 when its use simultaneously increased in USFS planning documents and scientific journal articles. The word resilience does not appear to have replaced other important stability terminology, like health or integrity (see Grimm and Wissel, 1997), but has become part of a collection of terms used to describe the characteristics of natural resources.

In interviews, USFS managers told us that they have heard the word used for a long time but that its use has become more frequent in the last 5–10 years. Most USFS managers were first exposed to the word resilience though training, project work, grant writing, or a supervisor. Explanations for the recent increase in the use of the word resilience varied, but many managers believed that it was connected to a direct policy action, like the development and implementation of the Northwest Forest Plan in the early 1990s, the Healthy Forest Initiative in the mid-2000s, the 2012 Planning Rule, or Executive Order 13653 signed by President Obama in 2013 directing federal agencies to plan for climate change. Unlike USFS managers, scientists did not see the recent increase as having a policy origin but generally described the use of the word resilience as beginning in theoretical discussions in the early 1990s and growing through recent efforts to formalize the concept for management. The increase in the use of the word resilience in USFS management was described by many scientists as a “bubbling up” from science into policy. Millar et al. was frequently mentioned as a key scientific paper, and several scientists mentioned the work of C.S. Holling and the role of the Resilience Alliance in promoting use of the word Millar et al., 2007).

4.2. Question 2: Resilience, environmental values, complex systems theory, and environmental change

The rates of environmental value terms (utilitarian and biocentric) have changed over time in both USFS planning documents and scientific journal articles (Fig. 2). In scientific journal articles, both value rates show a high degree of variability between 1980 and 1994 because there are few documents in our dataset from this period. By 1998, and

![Fig. 1. Rate of resilience (i.e. resilience, resilient, and resiliency) by corpus and year compared to the rate of the terms health and integrity.](image-url)
from then on, the value term rates are relatively consistent and when
the use of word resilience increased around 2011, they both remained
level. In USFS planning documents (FEISs and FPs), however, there do
appear to be meaningful shifts in the rates of value terms. In USFS
documents, utilitarian terms occurred at a higher weighted rate than
biocentric terms between 1980 and 1995 with a relatively wide gap
between them. In 1994, the weighted rate of utilitarian value terms
decreased and the weighted rate of biocentric value terms increased, so
that the gap between the two rates narrowed to become almost non-
existent. By 2011, the gap between the weighted term rates widened
again, but this time with the biocentric term rate much higher than the
utilitarian term rate. Complex systems terms have been used in both
bodies of text since the 1980s, but its use trend shows relatively little
change between 1980 and 2016. The terms “climate change” and
“adapt” have also been used in both bodies of text for most of the
period, but in both USFS planning documents and scientific journal
articles their use increased sharply between 2009 and 2011 (Fig. 3).

A simple matrix of Spearman’s rank correlation coefficients of these
data reveals associations between the use of the word resilience and the
use of terms in our hypothesized contextual categories (Fig. 4). In USFS
planning documents, the use-rate of the word resilience was highly
positively correlated with the use-rate of the terms “climate change”
and “adapt” ($r_s = 0.85$) and highly positively correlated with the bio-
centric value use-rate ($r_s = 0.87$). In scientific journal articles, the use-
rate of the word resilience was weakly positively correlated with the
use-rate of previous years ($r_s = 0.67$), weakly positively correlated with
“climate change” and “adapt” ($r_s = 0.51$), and weakly negatively cor-
related with the utilitarian value use-rate ($r_s = 0.58$). A vector auto-
regressive (VAR) correlation matrix, a method used for analyzing the
relationships between multiple time-series, selected by minimizing the
AIC also suggests an association between biocentric terms, climate
change adaption, and resilience use (Figure S1 in online supplement).

In interviews, many managers and scientists associated the in-
creased use of the word resilience with a shift from production, or
output-oriented management that was dominant in the 1980s, to a
more ecological and holistic approach to management (e.g. longer-term

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**Fig. 2.** Rate of resilience and biocentric and utilitarian values by corpus and year.

**Fig. 3.** Rate of resilience and complex system terms and climate change adaptation (climate change and adapt) by corpus and year.
planning, considering broader scales, and ecosystem process and function rather than composition and structure). Managers and scientists also described the shift as much broader than the context of western forest science and management but rather, as one agency scientist said, as the result of an “evolution of societal values.” Most managers and scientists described the awareness of climate change as playing an important role in the increased use of the word resilience, and many explained how the goals and terminology of restoration, another important management concept, are no longer reasonable. A few saw the word resilience as a safe alternative to the goal of historical restoration because it skirts the challenge of establishing a baseline (i.e. pre-European) and one manager saw the word resilience as a helpful way discussing environmental change while avoiding the acquired political connotation of the term “climate change.” Neither managers nor scientists mentioned the role of complex systems theory directly, but some scientists mentioned the importance of associated concepts like the shift to understanding ecosystems as having multiple equilibria or being dynamic, complex, and unpredictable.

4.3. Question 3: Comparison of use between scientific literature and USFS planning documents

The word resilience (i.e. resilience, resiliency, and resilient) was found in these documents a total of 5484 times, 3898 of those instances in USFS planning documents and 1586 of those instances in scientific journal articles. The form of the word (i.e. resilience, resiliency, and resilient) varies between scientific journal articles and USFS planning documents: a higher proportion of the instances found in scientific documents are in the form “resilience,” whereas in USFS planning documents there are higher proportions of “resiliency” and “resilient.”

The structural topic model fit to 5484 instances of resilience inferred 39 topics. The twenty most commonly expected topics of the structural topic model demonstrate similarities and differences in the use of the word resilience between USFS planning documents and scientific journal articles (Table 2). The topics we called “climate change adaptation,” “maintaining ecosystems” and “system ability to absorb” were common and shared between scientific journal articles and USFS planning documents. On the other hand, USFS planning documents were more likely to contain instances of resilience with a higher estimated proportion of the topics: “desired conditions,” “invasive species,” “watersheds and water quality,” “impacts of grazing on riparian areas and soil,” “insects and disease,” and “high intensity landscape fires.” In scientific articles, the word resilience was more commonly used with the topics of “fuel reduction by thinning and prescribed fire,” “old growth forest resistance and recovery,” “restoring wildland fire regimes,” and the “risks and benefits of promoting wildfire.”

In interviews, both scientists and USFS managers described the word resilience as an ecosystem or landscape’s positive response to environmental change. Some USFS managers offered highly specific interpretations of resilience: one manager told us, “I would define resilience as … if our stands, under our management, are free to grow in the absence of fire, if they’re free to grow in a manner that benefits the suite of resources that utilize those habitats, including wildlife.” Another manager suggested that “maybe resiliency is the ability of the landscape to repel non-native invasives.” Scientists, on the other hand, usually offered more general, or theoretical interpretations of the word: one scientist told us “[resilience] is the capacity of the system to regain its characteristic processes and to reorganize following a disturbance.” Almost all respondents—even the few scientists who saw the word as value-neutral and dependent on the desired ecosystem state—perceived the word resilience as representing a desirable goal for forest management. Few managers and scientists directly connected ecological resilience to social resilience or mentioned social-ecological systems.

All respondents were aware of the difficulty of defining and operationalizing the word resilience. Many respondents called it context-dependent, and a few called it subjective. One scientist told us that “a lot of us have pretty different ideas in our minds of what we mean by resilience.” An idea we heard repeatedly was, as what one manager said, “[resilience] depends on where you’re talking about.” A scientist told us that “the literature is awash with a pretty vague conflation of resistance and resilience.” In addition to resistance, resilience was often directly associated with, or explained using, other terminology, particularly health, restoration, and sustainability. Despite these challenges, even the most skeptical of those we talked to expressed hope that the increased use of the word resilience signifies a positive change in the ideas and practices of forest and fire science in the United States. One NEPA planner told us “I don’t think that we’re just putting these buzzwords out and then going back to our normal way of doing business. I really think that we are changing what we do.” A USFS employed scientist told us “the cynic in me, who’s worked for the Forest Service too long goes, ‘Well, it’s a lot of language that may not amount to anything.’” but then expressed hope that the term would still lead to improvements in management and long-term planning.
Table 2

The top twenty topics surrounding instances of resilience use. Words with an underscore (“_”) are common phrases computed using Python’s genism package.

<table>
<thead>
<tr>
<th>Corpus</th>
<th>Topic Name</th>
<th>Most Common Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both</td>
<td>climate change adaptation</td>
<td>adaptive, change, strategies, climate_change, climate</td>
</tr>
<tr>
<td></td>
<td>maintain ecosystems</td>
<td>ecosystem, future, maintain, restore, maintain, persist</td>
</tr>
<tr>
<td></td>
<td>system ability to absorb</td>
<td>ability, system, state, absorb, return</td>
</tr>
<tr>
<td>USFS</td>
<td>desired conditions</td>
<td>desired_conditions, towards, desired, condition, de-veg.</td>
</tr>
<tr>
<td></td>
<td>invasive species</td>
<td>species, long term, term, short, years, invasive, species</td>
</tr>
<tr>
<td></td>
<td>alternatives</td>
<td>action, better, alternatives, alternative, proposed</td>
</tr>
<tr>
<td></td>
<td>plan direction</td>
<td>plan, direction, plan_components, revised, plan_direction</td>
</tr>
<tr>
<td></td>
<td>watersheds and water quality</td>
<td>watersheds, natural, disturbances, quality, water, quality, water</td>
</tr>
<tr>
<td></td>
<td>sustaining processes</td>
<td>sustainability, current, ecological, processes, integrity, facilitate</td>
</tr>
<tr>
<td></td>
<td>impacts of grazing on riparian areas and</td>
<td>riparian, areas, areas, grazing, soil, riparian</td>
</tr>
<tr>
<td></td>
<td>soil</td>
<td>insects, disease, large-scale, historic, disease, large-scale, disturbance</td>
</tr>
<tr>
<td></td>
<td>high intensity landscapes fires</td>
<td>high_intensity, landscape, large_intensity, high_intensity, scale, landscape_scale</td>
</tr>
<tr>
<td></td>
<td>fuel reduction treatments</td>
<td>reduction, thinning, fuel, fuel_reduction, treatments</td>
</tr>
<tr>
<td>Journal</td>
<td>old growth, resistance</td>
<td>old_growth, growth, old, resistance, relative_resilience</td>
</tr>
<tr>
<td>articles</td>
<td>restoring wildland fire regimes</td>
<td>wildland, wildland, fire, maintaining, restoring, maintaining, fire_regimes</td>
</tr>
<tr>
<td></td>
<td>pine trees</td>
<td>ponderosa, pine, ponderosa, pine, tree, lodgepole</td>
</tr>
<tr>
<td></td>
<td>mixed terms</td>
<td>may, highly, found, levels, environments</td>
</tr>
<tr>
<td></td>
<td>risks and benefits of promoting wildfire</td>
<td>risk, benefits, reduce, wildfire, goal</td>
</tr>
<tr>
<td></td>
<td>research</td>
<td>forest_service, service, research, science, response,</td>
</tr>
<tr>
<td></td>
<td>forest management</td>
<td>national_forests, managers, forests, mixed-conifer, burned</td>
</tr>
</tbody>
</table>

5. Discussion

The word resilience has proliferated rapidly throughout a wide range of academic fields (Brand and Jax, 2007; Xu and Marinova, 2013). In scientific journal articles published in the last decade, the word resilience has been described as a measurable characteristic that emerges from ecosystem structure (Carpenter et al., 2001); a framework associated with concepts like ecosystem integrity, health, and degradation (Ghazoul et al., 2015); and a strategy for forest management in the face of unprecedented change (Millar et al., 2007). It has become common in high-level planning documents about managing fire such as The National Cohesive Wildland Fire Management Strategy, which sets a goal to “restore and maintain landscapes… [that] are resilient to fire-related disturbances in accordance with management objectives” (U.S. Department of Agriculture and Interior, 2011; Gissel and Jenison, 2015). It is also increasingly used by federal land management agencies in the US. A recent analysis of its use in USFS documents suggests that it is increasing but requires conceptual clarification (Bone et al., 2016). Our analysis provides a detailed timeline of resilience use in the documents of forest and fire science in the western United States and reveals some of the broader factors that may be influencing the use of the word.

Our analysis reveals that the word resilience has been used in western USFS planning documents and scientific journal articles on western U.S. forest and fire management since 1980 but that its use in these contexts increased rapidly and simultaneously between 2010 and 2016. This parallel increase in the use of the word resilience is evidence for a shared social driver. It also suggests that there may be a tight linkage between the language of USFS management and the language of science. Determining the exact origin of the increased use-rate of the word resilience and the social drivers behind its use is complicated by the incremental nature of the production of policy and science and would require a much more in-depth historical analysis (Lindblom, 1959; Hess, 1997). Shifts that occurred at smaller temporal scales may reflect transitions between U.S. White House administrations—a process that has played an important role in the language and priorities of federal land management between 1980 and 2016 (Vaughn and Cortner, 2005). The timing of the marked increase in the use of the word resilience (around 2011) does appear to be later than the timing found in other broader bibliometric studies of the word resilience, which suggests that resilience may have entered the language of western forest fire management and science later than it did in other academic and technical spheres (Xu and Marinova, 2013).

In USFS documents, the use-rate of the word resilience appears to be associated with the use-rate of “climate change,” “adapt,” and biocentric value terms. However, in science documents, the use-rate of the word resilience is moderately associated with “climate change” and “adapt” but no other terms. Still, we expect that, as time passes, the groupings of words once associated with the use of the word resilience will evolve and become more variable in both contexts, which makes this a time-sensitive interpretation.

These data reveal other interesting patterns. USFS planning documents show a long-term decline in the use-rate of utilitarian value terms and a similar long-term increase in use-rate of biocentric value terms (Fig. 2). This reflects the shift in USFS management from the economic-focused management priorities of the 1980s to the more biocentric, or ecosystem-focused, management priorities adopted following the 1994 Northwest Forest Plan, federal ecosystem management in the 1990s, and the decline of timber markets in many regions (Skillen, 2015; Hays, 2006). After 2011, the use-rate of resilience in USFS documents rapidly increased with a simultaneous increase in the use of “climate change” and “adapt” and biocentric value terms. These patterns and key informant interviews suggest that the USFS may be using the word resilience in a time of uncertainty about how to maintain biocentric values by adapting forests to climate change. Resilience use increased concurrently in USFS and management-oriented forest fire science, reflecting connections between scientists and managers who are responding to the dramatic increase in wildfires in the western U.S., and events which have been interpreted as driven by climate change.

The data derived from interviews and the structural topic model also suggest that, despite differences, there is a high-level of consensus among managers and scientists that the word resilience is associated with adapting and maintaining ecosystems under changing environmental conditions. In USFS management documents, the word resilience is often part of a desired condition (e.g. “a resilient forest”), which suggests that managers are grappling with achieving desired conditions under increasingly novel conditions. What we learned in interviews was that some scientists and managers believe that the use of the word resilience could also be emblematic of an increasing recognition of the limits of human control over ecosystems—a notion found in Holling’s original work on resilience and much of the seminal resilience-thinking literature (Gunderson and Holling, 2002; Holling, 1973). USFS managers and scientists both expressed concern about the ambiguity of the word resilience, but its ambiguous, yet holistic resonance may also be helpful for managers working to balance multiple and sometimes conflicting interests under changing conditions. As a few
managers and scientists suggested, the word resilience may indeed be a helpful stand-in for more polarizing terms like climate change or historically-oriented strategies like restoration. These factors provide further evidence that the increased use of the word resilience in management is driven by its usefulness in boundary crossing contexts—like public lands management—rather than an emerging scientific consensus around a new scientific conception of nature. Indeed, our interviews suggest that the word resilience has a hopeful resonance helpful for framing land management policy and science to a diverse group of policy-makers, interest groups, and citizens.

Understanding language as dynamic yet dependent on changing social conditions involves recognizing that the meaning of the word resilience is continually evolving—it may change as its implementation begins. In fact, recent events offer clues about how the meaning of the word may already be changing. The fact that the word resilience was removed from the final 2012 Planning Rule and replaced with the word integrity due to public concern over its meaning reflects discomfort with the adoption of the word resilience in articulating federal land policy goals. In USFS budget justifications, high level policy documents prepared by the agency, resilience use increased sharply from 11 to 193 instances between 2009 and 2016 in the Obama administration, and then declined in the Trump administration from 74 to 42 instances between 2017 and 2019, although it remained above levels from prior administrations. This could indicate that the word resilience was perceived as less salient or persuasive for justifying the agency’s expenditures.

Perhaps the most significant recent example of the use of the word resilience in forest and fire management policy is one that suggests the term is being used to reframe timber management. A new categorical exclusion described as “wildfire resilience projects” is included in the U.S. Consolidated Appropriations Act of 2018 (also known as the FY 2018 Omnibus Spending Package). This bipartisan law amended the Healthy Forests Restoration Act of 2003 to allow hazardous fuel reduction projects under 3000 acres to proceed with a reduced or expedited review under the National Environmental Policy Act. In the law’s text, and the public communication about the law, the word resilience appears to have replaced older terms, like health and restoration. The law also states that when applying this categorical exclusion, projects must maximize retention of old-growth or large trees “to the extent that the trees promote stands that are resilient to insects and disease, and reduce the risk or extent of, or increase the resilience to, wildfires” (16 U.S.C. 6511). These specific uses of the word resilience, as a standard in a law intended to expedite the NEPA review process and as a characteristic of tree stands rather than ecosystems, suggests that as the word resilience becomes institutionalized it’s dominant use is shifting away from a systems-oriented stability concept toward a positive frame for advancing utilitarian as well as biocentric values.

As scientists, policy-makers, managers, and stakeholders work to operationalize goals around the concept of ecosystem resilience for federal wildfire management, considering the word resilience itself and the social context of its emergence and increasing use can add to our understanding of the word’s implications for forest and fire policy. The medium of language is dynamic, and the meanings of new scientific and management terminology cannot be isolated from broader social and ecological changes—particularly dominant environmental values, scientific conceptions of nature, and societal concerns (R. Williams, 1985; Worster, 1994; Merchant, 1990). Past disputes over public land policy demonstrate that land use policy is ultimately about competing interpretations of scientific or technical information and the underlying environmental values that inform them (Layzer, 2011; Skillen, 2015; Steel et al., 1994; Kennedy and Thomas, 1995). Successful attempts to operationalize resilience goals for land use policy and management will recognize that the meaning of the word resilience cannot be established decisively, but is the result of ongoing social processes, including scientific measurement, policy development, and communication within political contexts.

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