Resilience as a systems concept, with an application to the American West

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[Abstract] What is resilience, and why has it emerged as an important concept in environmental science and governance? One answer is that the common prerogative of sustainable management that requires us to meet our own needs while respecting the needs of future generations has become unsatisfactory as a guiding principle, prompting a new strategy that better aligns with the challenges of the wicked problems we face. Resilience, as a governance strategy, promises a more refined approach to environmental governance by recognizing the relationships between disparate characteristics of complex systems, understanding that it is insufficient to manage parts of a system without recognizing the impacts on the whole system. Resilience, therefore, prompts us to govern our environments in ways that respects the diverse values, needs, and relationships that communities have with their environments. This chapter builds a systems-approach to environmental governance from the work of the oft neglected pragmatist philosopher, C. West Churchman. A systems-approach, as described by Churchman, allows environmental governance to anticipate a broader range of consequences to management actions while providing a framework that allows managers to incorporate the social, ethical, and cultural dimensions of management that so often catalyze wicked problems. This approach is briefly illustrated through consideration of the governance of the Sagebrush Steppe of the Intermountain West in the American West. A systems-approach, we argue, is better able to conceptualize the obstacles to management in the American West offering a robust management strategy that can help demystify complex environmental concerns.

What is resilience, and why has it emerged as an important concept in environmental science and governance? In this paper, we provide an alternative answer to this framing question, and present an application that illustrates one problematic dimension to recent thought trends in environmental studies. In fact, a detailed development of the argument we will make in this paper would exceed the limits of a single essay. We thus beg our readers' indulgence as provide the sketch of an argument that leaves out too many steps. The argument sketch begins with a brief discussion of the sense in which we think of our approach as an alternative, and then traces a line of thought that connects recent thinking on resilience to the pragmatist tradition in philosophy of science. We conclude with an example that is illustrative of the current shape in policy thinking on resilience.

An Alternative to What?

The intellectual history of sustainability and resilience is only now being written, and it will, without doubt, undergo a period of contestation with numerous revisions. One version of this narrative is that the idea of sustainability is introduced at a United Nations sponsored conference in 1972, and that it matures as a somewhat well-formed idea with the main publication of the World Commission on Environment and Development (WECD) in 1987. The WECD was chaired by Gro Haarlem Brundtland and its report pioneered the language on sustainable development that is often said to capture the essential elements of sustainability itself: development that “meets the needs of the present, while allowing future generations to meet their needs.” (WCED, 1987, p. 43). For many current scholars of sustainability, the Brundtland report is the single most important document in the history of sustainability (see Dresner, 2003).

The Brundtland report took an approach to sustainability that was deeply dependent on then-current ideas of the role that economic development would necessarily play in addressing large discrepancies in the quality of life between the industrialized nations and those that do not have access to the same resources as the industrialized nations. Aiden Davison’s detailed review of the sustainability literature argues that this emphasis on development was distorting the discourse on sustainability as such (Davison,2001). However, there were other approaches to sustainability that were being argued even as the Brundtland Commission was undertaking its work. Within ecology, Brian Walker and C. S. Holling had long been developing models for understanding sources of stability within complex ecosystems. in agriculture, sustainability had emerged as a contested discourse in the early 1980s, with some focused on the integrity of soil and water ecosystems, some focused on the economic viability of smaller farms and still others defining the concept in terms of agricultural science’s traditional focus on increasing yields (Thompson, 2010).

For reasons that will be left to future historians, some of the scientists who were exploring alternatives to the development-oriented thinking of the Brundtland report united in a loose-knit confederation called “the Resilience Alliance” in 1999. By the 2010s, dissatisfaction with the development-oriented focus of those who were continuing a discourse launched by the Brundtland report began to congeal. Publications began to appear that issued a call to move “beyond sustainability.” But what did that mean? The answer: Resilience, (see Zolli and Healy, 2013; Benson and Craig, 2014; Orr, 2014). In ecology, resilience refers to an ecosystem’s ability to recover key functions following a period of disturbance. In the literature that is emerging in the wake of this shift from sustainability to resilience, writers draw upon much more prosaic metaphors, such as an individual’s ability to maintain composure following periods of personal loss or physical and psychological abuse. In either case, the thought that resilience might serve as a fundamental organizing principle in policy-making can be seen as a riposte to conceptualizations of sustainability that emphasize resource deficits or limits to the potential for global economic growth. In this narrative, resilience is a successor to sustainability, and an idea that involves a substantial deviation from the theoretical underpinnings of sustainable development.

Sustainability, Pragmatism and Systems

There are reasons to contest this narrative. One of us (Thompson) has argued that two paradigms for conceptualizing sustainability had emerged even in the 1980s. While the Brundtland paradigm stressing resource availability compiled the largest literature, an alternative paradigm focusing on the robustness and adaptive capacity of complex systems (as well as their resilience) was also accumulating a significant amount of scholarship (Thompson, 2010, 2016a). When the ecological conceptualization of resilience is in the foreground, the resilience paradigm represents a return to the systems thinking that lay behind the original *Limits to Growth* (1972), attributed to the Club of Rome. In the Club of Rome models, feedback embedded within biological, economic or social systems can alternatively regulate systems in a sustainable manner, or it can lead to overshoot, oscillation and collapse. Systems that have the capacity to resist disturbances are robust, while those that can rebound to a stable equilibrium after disruption are said to be resilient. In this sense, much of the recent interest in resilience reflects a call to reinvigorate the systems perspective that was motivating key thinkers in the 1970s.

Pragmatist philosophers can play a constructive role in this turn toward resilience by rediscovering one of their neglected figures. C. West Churchman (1913-2004) was a philosopher of science working in the pragmatist tradition who began to experiment with systems-thinking approaches after World War II. Churchman's initial foray into systems thinking began during his service to the Office of Strategic Services in World War II. Charged with evaluating testing protocols for ordinance, Churchman recognized that statistical methods for testing the reliability of ammunition to be used by soldiers in the field presuppose a normative judgment of acceptable failure rates. While the obvious norm might be a failure rate of zero, testing to assure zero failures is both conceptually incoherent but more importantly, so costly that it would impair delivery of ordinance to the place it was needed. The problem was thus one of multiple value judgments that were essential for framing what was, once those judgments were made, a complex and highly technical problem. This experience underlined the importance of a pragmatic distrust in the positivist program for value free science (to which Churchman was already inclined by his philosophical commitments).

After the war, Churchman returned to the philosophy Department at the University of Pennsylvania and assumed the editorship of *Philosophy of Science.* However, his philosophical colleagues shared little enthusiasm for framing highly technical issues in science as questions that could not avoid values. Churchman gravitated toward operations research, left his philosophy appointment at Penn and assumed positions at Wayne State and then Case in Cleveland. After 1957 Churchman spent the balance of his career in business administration at the University of California-Berkeley. From this post, Churchman made fundamental contributions to systems theory and articulated a vision for the integration of ethics into systems thinking (Mason and Mitroff, 2015).

The Systems Approach (1968) was Churchman's most influential book. Non-technical language is used to illustrate how a number of different situations can be described in terms of quantities that rise and fall when material comes in and goes out, much like the level of water in a bathtub. These quantities are called stocks. Inflow makes them to go up, outflow makes them go down. One can model systematic interaction among stocks through feedbacks that are initiated by the tracking of the level of a certain stock and by controlling the rates of inflow and outflow from that stock. This systems approach allows one to recognize formal similarities that hold among very diverse entities. Churchman describes the operations at an airport as feedbacks between the stock of airplanes waiting to land or take-off and the amount of time available on runways. Other examples include the inventory of goods on a store shelf. This is depleted (e.g. the outflow) when goods are purchased, while store managers watch the inventory to place new orders (the inflow). Another system might be the temperature in your living room, which goes up when the heat comes on (the inflow) and goes down as heat is lost to the outdoors (the outflow). All of these systems can be stable: the inflows and outflows can balance out. But they can also experience overshoot and oscillations due to delays in the feedback. A store manager may order too much or too little if he or she is simply watching the level of goods on the shelf and failing to take into account the length of time that it takes for the order to be filled.

The systems approach consists in being mindful of the interaction between stocks, flows, feedbacks and delays. More significantly is recognizing how quantification and data collection can improve system performance. But there are many systems that are quite difficult to manage. Populations can be modeled as stocks with births and deaths as the respective flows. Births will, of course, increase as the total population stock increases, but as the population increases so will deaths. Although there is the potential for counteracting feedbacks to keep a population stock balanced, there is, in this instance, an important delay built into the system that allows the inflow to outpace the outflow leading to constant growth in the population. Additionally, there are other stocks – such as the food supply – that initiate feedback to the outflow (i.e. the death rate). The early 19th century work of Thomas Malthus (1766-1834) was, in this respect, an instance of the systems approach.

Although the word “sustainability” does not appear in *The Systems Approach,* Churchman was quite influential in showing a very diverse audience how systems thinking could give insight into the stability of stocks and flows, as well as their vulnerability to various perturbations among the various feedbacks that control overall system behavior. As noted already, the pioneering use of computers to model complex stock and flow relationships gave us *Limits to Growth* in 1972. Churchman should not be seen as having invented “the systems approach,” but rather as a highly influential figure in communicating its applicability across different spheres of application. Indeed, one of his objectives was simply to argue for greater penetration of scientific methods, including quantification and data collection, in policy making and practical problem solving. In this respect, Churchman was following the advice of John Dewey (1859-1952).

However, Churchman was also intent on communicating the ineliminable role of ethics in applications of the systems approach. His little book emphasizes the importance of human judgment in defining which stocks and flows are worth modeling, and he stresses the way that systems thinking presupposes a shared understanding of the problem that needs to be solved. Churchman emphatically rejects the notion that science can produce a valid system model through value-free collection of data and statistical correlation. Furthermore, he recognizes that there will be many areas where defining the system at hand will generate deep disagreements. In this respect, Churchman's approach to ethics was closely tied to the concept of "wicked problems," as introduced by his Berkeley colleagues, Horst Rittel and Melvin Webber (Churchman, 1967; Rittel and Webber, 1973). Although a more extensive treatment of wicked problems lies beyond the scope of the present treatment, we note that the concept implicitly endorses democratic engagement of multiple perspectives in response to the uncertainties and contested nature of most contemporary environmental problems (Thompson and Whyte, 2012)

In all the above respects, Churchman exemplifies a pragmatic approach. His dissatisfaction with the sterility of mid-20th century philosophy was one of the key factors that led him to resign his position at the University of Pennsylvania in 1948 and launch himself on a career in operations research and systems thinking,. Even before that he recognized the role of values in scientific activity at the same time that he realizes the promise of data collection, quantification and rigorous scientific approaches in addressing the problems of everyday life. (Mason and Mittroff, 2015). His approach to ethics is inherently democratic, requiring planners, managers and environmental scientists to be working *with* stakeholders, rather than imposing technically induced solutions upon them. The systems approach goes beyond some contemporary models for public engagement by illustrating how conceptualizing the interaction of stocks and flows can help a community achieve greater (not necessarily complete) mutuality in conceptualizing their situation. Finally, the systems approach promoted by Churchman provides a paradigmatic way of understanding sustainability that includes resilience as one of several desiderata for systems we hope to preserve. Rather than seeing resilience as an alternative that supersedes sustainability, It is, along with robustness, adaptive capacity and general resistance to perturbance or collapse, a fundamental feature of what we hope to achieve when we promote sustainability, (Thompson, 2016b).

Sustainability and Resilience in the American West

Also like a dedicated pragmatist, Churchman was committed to a philosophical approach that was capable of addressing the real problems of ordinary people. In this spirit, we conclude the chapter by considering how Churchman's notion of pragmatic systems thinking – including the resilience of systems –might inform current dilemmas of environmental governance in the American West.

For this paper we specifically focus on the management regimes of the Intermountain West, comprised of portions of those states that lie between the Rocky, Cascade, and Sierra Mountains (portions of Washington, Oregon, Idaho, Arizona, New Mexico, Colorado, Wyoming, and Montana as well as the majority of both Nevada and Utah). The region ranges from the lowest elevation on the North American continent – Death Valley at 282 feet below sea level – to many of the highest mountain peaks. Along with a wide range of topography the region varies between dry desert ecosystems, such as the sagebrush steppe, to high alpine forests and lakes that support a broad array of wildlife and critical wildlife corridors. The Intermountain West is predominantly under federal or tribal management with nearly 70% of the region being managed by federal agencies (colloquially referred to as *public lands*), while the remainder is split between state and local management and private commercial interests. The region's population is divided between scattered rural communities and the growing urban centers, each with an array of demands on the lands including opportunities for recreation and support for agricultural economies. The diversity of the Intermountain West – from its ecology and topography to its socio-demographics and management regimes – provides a salient example of how a systems approach with a specific focus on system resilience can help us to navigate complexity in environmental governance in the face of competing demands and the diversity of community values on the landscape.

The Federal Land Policy and Management Act (FLPMA) was enacted in 1976, providing the framework with which the U.S. Department of the Interior Bureau of Land Management (BLM) must use to manage the federal lands of the Intermountain West (a large portion of the 70% federal lands). FLPMA explicitly demands that these federal lands be managed on a multiple use doctrine which underwrites all BLM action on the landscape. "Multiple use", in this instance, is explicitly defined as managing public lands to recognize

> "various resource values so that they are utilized in the combination that will best meet the *present and future needs* of the American people; …a combination of balanced and diverse resource uses that takes into account the long-term needs of future generations for renewable and nonrenewable resources, including, but not limited to, recreation, range, timber, minerals, watershed, wildlife and fish, and natural scenic, scientific and historical values" (Federal Land Policy and Management Act of 1976, p. 2, italics added).

As defined in FLPMA, the multiple use doctrine should remind us of the tenets of sustainable management described above. First, there is an explicit demand to meet "present and future needs of the American people", tracking the Brundtland report's recommendation for meeting "the needs of the present, while allowing future generations to meet their needs" (ibid). Furthermore – and consistent with the criticisms that the Brundtland report focused sustainability too narrowly on economic development – is FLPMA's definitions of 'sustained yield': "the achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources of the public lands *consistent with multiple use*" (ibid, p. 2, italics added). FLPMA, it seems, demands that the vast public lands of the Intermountain West be managed via a sustainability paradigm. We do not presume to give a historical account of the evolution of public land management here, but it suffices to recognize that FLPMA demanded a new paradigm for environmental management centered around sustainability that required the consideration of a broad array of environmental values over long periods of time.

While FLPMA was a clear achievement for responsible environmental management, the intellectual foundation of sustainability does not provide the resources for disentangling the complexity of management in the Intermountain West. Although consistent with predominant conceptions of sustainability, FLPMA's demands for "the achievement and maintenance…of various renewable resources" while managing for a "combination that will best meet the present and future needs of the American people" (ibid) does not, in and of itself, recognize the dynamism of the system. An explicit requirement to manage for resource production, recreation opportunities, historical and cultural preservation, habitat for fish and wildlife, et al is, in essence, a demand to recognize that each value is in itself a stock with its own inputs, outputs, feedbacks, and delays. We would be remiss to imagine that a management action taken to increase the stock of one resource – for example, a restoration project being done to develop riparian habitat – would not impact, in some way, the stock of another resource. Perhaps the riparian restoration limits the ability for the land to be used for livestock grazing. When managing for a diverse set of values on a landscape, it is not sufficient to silo each resource or environmental value in order to manage it independently of the other resources and values. Thus, a recognition of the *system* is helpful to begin understanding the complex interplays between the different stocks. A turn from sustainability toward a systems approach, as described by Churchman, can help to better integrate diverse values in environmental governance in the Intermountain West.

The discussion thus far has served to provide the environmental management context of the Intermountain West, but it is helpful to describe how a systems approach is being developed in current practice. Despite the vast array of environmental values that the BLM must manage for, current priorities in the West can generally be categorized as either: [1] Managing for invasive species and their impacts on the landscape, [2] Managing for wildfire, including the benefits and detriments of fire regimes, [3] Managing for the health and proliferation of threatened and endangered species, specifically the Greater Sage Grouse, and [4] Understanding and anticipating the impacts of changing grazing regimes on the local communities and economies. These priorities are foregrounded worries that rural communities are disproportionately impacted by management decisions and ideological divisions regarding development and conservation. The remainder of this discussion will outline the role that each of these priorities – together with their management actions – play in the land management system of the Intermountain West.

Invasive species threaten many ecosystems, worldwide. In the Intermountain west, the largest concern is the introduction of nonnative annual grasses in ecosystems that are historically dominated by herbaceous native perennials. The nonnative plants thrive in the semi-arid west and dramatically alter the landscape. The largest culprit – cheatgrass – has thrived across the Intermountain West, especially in those areas that were damaged by overgrazing cattle, wildfires, or development as cheatgrass has a competitive advantage over native species given its prolific seeding and ability to germinate in seasons that native species cannot (Pellant 1996). It is important to recognize that the sagebrush steppe ecosystem is a *sub-system* of the environmental governance system in the Intermountain west, meaning that it consists of stocks, feedbacks, and delays that properly balanced render the system resilient to external perturbations. In areas that cheatgrass is prolific, this sub-system is dominated by imbalancing feedbacks between native species and the cheatgrass. For example, cheatgrass is able to germinate before the native species and so takes root in areas that would have been populated by native species, which not only proliferates the cheat grass but negatively impacts the numbers of reproducing native plants. As the cycle continues annually, cheatgrass can eventually dominate the ecosystem making the sub-system less resilient overall. From the perspective of the larger environmental governance system, the external perturbations that cheatgrass ecosystems are susceptible to are wildfire and livestock grazing. Signaling the complexity of systems-level management is the fact that although cheatgrass ecosystems are vulnerable to fire and grazing, fire and grazing are also tested methods of removing cheat grass from a landscape as described below. Managing for invasive species from a sustainability perspective amounts to doing what is necessary to minimize and/or eradicate the nonnatives from the landscape in order to promote overall ecosystem health. From a systems perspective, though, the role that invasive species plays in the larger system is not so neatly cleaved and must be balanced against other concerns.

Wildland fire has always been present on the western landscape, but it is getting more common and more destructive (Brown et al. 2004). Simply, wildland fires are becoming more commonplace and burning more acres then they previously did. A multitude of factors account for this – fire suppression management leaves too much fuel on the ground for future fire, a changing biotic community (i.e. nonnative replacement of native vegetation) is more conducive to fire, and changing climatic conditions leave these semi-arid landscapes vulnerable. We do not intend to fully analyze wildland fire management, but to show how it’s consideration plays into a systems approach to governance. First, the proliferation of cheatgrass provides a large amount of fuel for wildfire, so as the ecosystems change as a result of nonnative proliferation they become more vulnerable to wildfire. Sagebrush is easily killed by fire, so as more/larger fires are present because of a proliferation of cheatgrass, the native plant species are killed leaving nonnatives to easily populate an ecosystem. Coincidentally, sagebrush fires burn hotter than cheatgrass fires and are hot enough to burn cheatgrass seeds. Therefore, wildland fire can be used to eliminate cheatgrass if the fire burns hot enough to destroy the cheatgrass seeds and the area is replanted and otherwise restored before the nonnatives can repopulate it. This balance is hard to achieve given the veracity of nonnatives, the unpredictability of wildland fire, and the damage to non-plant species habitats that results from both wildland fire and invasive species proliferation.

The third priority for management in the Intermountain west is the health and proliferation of threatened and endangered species, specifically the Greater Sage Grouse. Although the sage grouse is not the only species managed for, it is perhaps most salient to this discussion as it heavily impacts the environmental governance system in the Intermountain west. The issues surrounding the Greater Sage Grouse are broad and have been heavily studied elsewhere (see Crawford et al. 2004, Duvall et al., Wambolt 2002). Generally speaking, though, the impact of the Greater Sage Grouse has been due to the potential listing of it as an endangered species and the ensuing changes to management regimes on the landscape to prevent its listing. To do this, management agencies and community stakeholders (e.g. ranchers, non-profits organizations, university researchers) have worked to change how the land is managed in order for the sage grouse populations to increase. The Greater Sage Grouse's native habitat extends across the Intermountain west, affecting nearly every management decision. In line with this discussion, wildland fire destroys sage grouse habitat and therefore gives motivation to decrease wildfire. Ideal sage grouse habitat combines perennial grasses and shrubs meaning that the nonnative annual grass replacement of native perennial shrublands is, in effect, a reduction of potential sage grouse habitat. Therefore, the management agencies must reduce nonnative plant species – which are pushing out native species – while maintaining the health of the ecosystems while balancing concerns for wildland fire, both in its use to control the proliferation of nonnative species and its potential to destroy native ecosystems that leads to more proliferation of nonnatives. These three concerns – habitat health, invasive species, and wildland fire – are inherently and ultimately intertwined and must be understood in terms of a systems approach. Any management decision in regards to one will directly impact another and it is only as these decisions are taken together can we understand how best to manage the lands of the Intermountain west.

The fourth priority is to better understand and anticipate the impacts of changing cattle grazing regimes on the local communities and economies. The public lands of the Intermountain west have long been used by local communities to graze their cattle as the lands are rich in forage that are able to sustain large herds of cattle. Historically, communities would remove sagebrush in order for perennial grasses to proliferate increasing the feed for cattle. These changes to the ecosystem set the stage for invasive species to dominate these landscapes and, as described, these changes alter the wildland fire regimes of the landscape. Prior to the passing of FLPMA in 1976 which demanded that management take into account a broad array of interests on the land, land management agencies were constrained by the economic valuing of the land resources (e.g. sub-surface mining, rangeland for grazing) (Skillen 2009). Although the land management agencies have broadened the scope of their efforts in light of FLPMA, the communities in the Intermountain west have developed a rich culture centered around the prominence of cattle in their own livelihoods. Current management decisions, therefore, are entrenched within a complex narrative of cultural well-being on a land that is, itself, threatened by many changes to the ecosystem. This complexity is magnified by the fact that although cattle have historically damaged the ecosystem, cattle can also be used to help the ecosystem.

Large herbivores – such as bison, elk, and deer – have historically operated in the western landscape as grazers that help to keep native grasses at levels that deter large fires. With the settlement of the American west, many of these herbivores have been either eradicated or displaced and the ecological niche they filled left void. Cattle grazing stands to fill this ecological niche, but it is insufficient to manage the land for sustainable grazing apart from understanding the overarching system that grazing takes place in. Cattle will graze on cheatgrass which will reduce both the proliferation of cheatgrass as well as the fuel loads for wildland fire. Since cattle will also graze on the native perennial plant stock, cattle management requires rotating pastures throughout the season to keep the herds in the landscapes that need grazing the most. Given the variability of growing seasons in light of changing climatic conditions, the unpredictability of wildland fire, and the motivation to promote healthy habitats for threatened species, cattle grazing becomes a beneficial tool when given the flexibility to move the herds around the landscape. Yet current permit requirements rarely provide ranchers this flexibility and so current cattle management can reflect the historical trends that led to ecosystem degradation. Given this impact of cattle on the landscape, many environmental groups call for the removal of cattle from the landscape. The communities that have developed rich cultural traditions alongside cattle ranching will understandably recoil from management strategies that undercut their well-being. Although too brief, this discussion should reveal much of the conflict that surrounds land management in the Intermountain west. It is our argument that a systems understanding and approach to management can help to better understand these landscapes and guide decision making.

If western management agencies wish to manage the land from paradigm of the sustainability of its resources, consistent with the multiple use doctrine, then they need to track which of the resources are threatened and put effort into developing strategies that can sustain that resource. However, this brief discussion should highlight the ways in which it is insufficient to focus on the sustainability of individual resources. Each management priority is fundamentally interconnected with the others (and, to be sure, the management of these lands must take into account much more than the four priorities listed here including wild horse management, recreation opportunities, energy development, and more). Viewing management as a system with stocks, feedbacks, and delays allows management actions to be weighed against all of the priorities simultaneously. The resilience of the system to outside perturbations including an increase in invasive species proliferation, increasingly devastating wildland fires, changing climactic conditions, etc. recognizes the inherent connectedness of the uses of western lands. Resilience, in this context, suggests that the system is strong enough to withstand devastation in any of its components in a way that can recover much quicker than if each component was managed individually. The systems approach to environmental governance highlights the role of resilience in environmental governance and demands a shift from a sustainability paradigm to a systems paradigm. The management priorities of the Intermountain west highlights the importance of systems thinking and the need to shift to a systems approach and resilient management of natural landscapes.

The systems approach developed by Churchman and taken up in environmental management promises to shift management strategies from a focus on sustainability to a focus on resiliency. Furthermore, Churchman’s systems approach highlights belies a pragmatist philosophy that does well to recognize and respond to a multitude of values that need to be considered in management actions. This brief chapter seeks to reinvigorate Churchman's thought and show how our contemporary world can be reimagined in light of the systems approach and the concept of resiliency inherent in these systems.

References

Benson, MH, Craig RK. (2014) The End of Sustainability, Society and Natural Resources, 27:777–782

Brown, T. J., Hall, B. L., & Westerling, A. L. (2004). The impact of twenty-first century climate change on wildland fire danger in the western United States: an applications perspective. *Climatic change*, *62*(1), 365-388.

Churchman, C. West. 1968. *The Systems Approach.* New York: Delacorte Press.

Churchman, W. C. (1967). Wicked problems. *Management Science*, 14(4), B141–B142.
Davison, A., 2001. *Technology and the contested meanings of sustainability*. Suny Press.

Crawford, J. A., Olson, R. A., West, N. E., Mosley, J. C., Schroeder, M. A., Whitson, T. D., ... & Boyd, C. S. (2004). Ecology and management of sage-grouse and sage-grouse habitat. *Journal of Range Management*, *57*(1), 2-19.

Dresner, Simon. 2008. *The Principles of Sustainability.* 2nd Ed. London: Earthscan.

Duvall, A. L., Metcalf, A. L., & Coates, P. S. (2017). Conserving the Greater Sage-Grouse: A Social-Ecological Systems Case Study from the California-Nevada Region. *Rangeland Ecology & Management*, *70*(1), 129-140.

Mason, R.O. and Mitroff, I.I., 2015. Charles West Churchman—Philosopher of Management: An Interview With Richard O. Mason Conducted by Ian I. Mitroff. *Journal of Management Inquiry*, *24*(1), pp.37-46.

Meadows, Donella, Dennis Meadows Jorgen Randers, William W. Behrens III. 1972. The Limits to growth ; a report for the Club of Rome's project on the predicament of mankind. New York: Universe Books.

Orr, D.W., 2014. Reflections on Resilience in a" Black Swan" World. *Resilience: A Journal of the Environmental Humanities*, *1*(1).

Pellant, M. (1996). *Cheatgrass: the invader that won the west* (p. 22). US Department of the Interior, Bureau of Land Management.

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, 4: 155–169.

Skillen, J. R. (2009). *The nation's largest landlord: The Bureau of Land Management in the American West*. University Press of Kansas.

Thompson, Paul B. 2010. *The Agrarian Vision: Sustainability and Environmental Ethics*. Lexington: University Press of Kentucky.

Thompson, Paul B. 2016a. “The Many Meanings of Sustainability: A Competing Paradigms Approach,” in *Pragmatic Sustainability: Dispositions for Critical Adaptation*, 2nd Ed. Steven A. Moore, Ed. Abingdon, Oxon UK and New York: 2016, Routledge, pp. 16-28.

Thompson, Paul B. 2016b. “Machines, Watersheds and Sustainability,” *The Pluralist* 11 (2016): 110-116.

Thompson, Paul B. and Kyle Powys Whyte. 2012. “What Happens to Environmental Philosophy in a Wicked World,” *Journal of Agricultural and Environmental Ethics* 25:485–498.

WCED (World Commission on Environment and Development. 1987. *Our Common Future:* New York: Oxford University Press.

Wambolt, C. L., Harp, A. J., Welch, B. L., Shaw, N., Connelly, J. W., Reese, K. P., ... & Torell, L. A. (2002). Conservation of greater sage-grouse on public lands in the western US: implications of recovery and management policies.

Zolli, A. and Healy, A.M., 2013. Resilience: Why things bounce back. New York: Simon and Schuster.