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# Re-conceptualizing the Science of Sustainability: A Dynamical Systems Approach to Understanding the Nexus of Conflict, Development and the Environment

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ABSTRACT
The concept of sustainability has come to permeate many spheres of governance, decision-making and scientific inquiry. Although current academic conceptualizations of sustainability often acknowledge the conflicts inherent in the pursuit of sustainable development, the present discourse does not explicitly include the concepts of peace and conflict. This omission has been in error, as the pursuits of sustainable environmental governance and sustainable human development are themselves efforts to manage and resolve conflict. Thus, this article advocates for an expanded framework of sustainability that operates at the nexus of conflict, environment and development by exploring current mainstream conceptualizations of sustainability and illustrating the direct connections between sustainability and the fields of peace studies and conflict resolution. It goes on to discuss the utility of applying a complex systems approach to the expanded conceptualization of sustainability, including aspects of both coupled systems and dynamical systems theory, in order to provide an analytical framework for studying mechanisms that enable sustainable development by dealing explicitly with conflicting needs and interests among actors in social–ecological systems. Copyright © 2016 The Authors Sustainable Development published by ERP Environment and John Wiley & Sons Ltd

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## Introduction

THE PAST DECADE HAS WITNESSED UNPRECEDENTED AND OFTEN UNFORESEEN POLITICAL, ECONOMIC AND ENVIRONMENTAL changes. In an increasingly interconnected world, sudden changes such as the swift rise of the Islamic State (Fisher, 2015), economic volatility in the energy sector (Brewer *et al.*, 2014) or even the reversal of US foreign policy related to US–Cuban relations (Leogrande, 2015) are no longer isolated events, and their impacts are felt at multiple scales of social and political aggregation.

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While there is much heterogeneity in the frequency, intensity, and spatial and temporal reach of the challenges we face, they consistently draw attention to the question of sustainability. We are increasingly faced with the dilemmas of whether and how our actions drive social and environmental change, what actions might serve to mitigate their negative effects and how we can establish resilient and robust political institutions and sustainable economic development trajectories (Hopwood *et al.*, 2005). These questions have produced rich philosophical, moral and scientific debate, as discussed in part by Imran *et al.* (2014), among others. These questions have likewise spurred incredible political, economic and technological experiments. They have also mobilized incredible financial and political resources in international organizations, multilateral and bilateral funders and relief and development service providers. Perhaps the most pertinent recent example of this is the international community's re-envisioning of the development agenda beyond the poverty-focused Millennium Development Goals (MDGs) toward the more broadly applicable Sustainable Development Goals (SDGs), which were ratified in September 2015 by the United Nations General Assembly (Jones and Kweifio-Okai, 2015).

More importantly, while the focus of our development agenda has become more inclusive and is meant to be wider ranging, the SDGs are largely focused on outputs and integrated targets and do little to guide the development of policies, institutions and structures that enable or inhibit sustainability (Le Blanc, 2015). While the new SDGs set forth an ambitious agenda, we are left to ask 'What are the policies, frameworks and institutional arrangements that enable us to make progress toward sustainability?', 'What structures facilitate and support these arrangements?' and finally 'What theoretical and analytical paradigms will aid us in understanding means of resolving the inherent tensions in the pursuit of sustainable development?'. It is on this latter question that the current paper is focused.

The pages that follow explore the current academic conceptualizations of sustainability and advocate for an expanded framework that operates at the nexus of conflict, environment and development. This article argues that our current understanding of sustainability has largely focused on the intersection of ecological and social–economic sustainability, with a focus on outputs to achieve what can be sustained for a reasonably long time period. What have been missing from the sustainability debate until recently are the concepts of peace and conflict. The process of constructive conflict management can provide important insight into processes that can guide the pursuit of sustainability by providing policy guidance to balance the inherent tensions and incompatibilities in sustainable development dilemmas. While current conceptualizations of sustainability imply the presence of conflicting needs across societies and over time (Giddings *et al.*, 2002), few take the necessary step of discussing the pursuit of sustainability itself as a process of conflict management.

This article then discusses the ways in which the complexity of social and natural systems requires new research and practice paradigms to make advances toward real sustainability. The natural sciences, particularly physics and ecology, have made many advances in recent decades to develop methodologies that actively engage complexity from a coupled human–ecological systems perspective. More recently, endeavors in the social sciences have built parallel analytical frameworks that employ concepts from the dynamical systems paradigm. This article merges these literatures and ends by calling for future research at the nexus of conflict, environment and development as a means of enabling further progress toward sustainable development.

## Conceptualizing Sustainable Development

The concept of 'sustainable development' has come to permeate many aspects of political, economic, environmental and corporate governance, as well as scientific inquiry and personal decision-making (Helne and Hirvilammi, 2015). For the sake of brevity, we will hereafter use the term 'sustainability' in place of 'sustainable development', though we acknowledge that the two are not directly synonymous. It is generally understood that sustainability refers to a situation in which 'something related to human welfare is maintained or increased over some temporal scale', and that this welfare should be maintained inter-generationally (Anderies *et al.*, 2013, p. 3). In other words, sustainability involves 'meeting human needs, both now and in the future, without degrading the planet's life support systems' (Miller, 2012, p. 283). However, attempts to define exactly which needs and whose are maintained, how they are met, and for how long, quickly become points of contention.



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## Re-Conceptualizing the Science of Sustainability

In a recent review of the literature on sustainability, Miller describes three broad ways in which sustainability is conceptualized. He calls the first *Universalist sustainability* (2012, p. 283), under which sustainability is a universal constant aimed at stabilizing human population growth, improving quality of life for all humans and maintaining the planet's life-supporting systems for current and future generations. He presents several variations of this conceptualization drawn from prominent scientists and organizations, including the Third World Academy of Sciences, in which sustainability refers to '[m]eeting current human needs while preserving the environment and natural resources needed by future generations' (Miller, 2012, p. 283, quoting Hassan, 2001, p. 70). In each of the specific definitions he provides, the recurrent themes are human development, environmental health and providing for future needs. Universalist sustainability then resembles a utopian conceptualization of human relationships in and with the natural world. In order to be widely applicable, it necessarily provides little guidance on ways to advance toward a sustainable future.

Miller contrasts this with a second conceptualization that he calls *thick sustainability*, by which he means making explicit and concrete choices about exactly which aspects of human welfare to advance, which environmental states and elements are necessary to promote that welfare and on what time scale we expect to sustain these. Building off of Walzer (1994), his thick definition recognizes that sustainability will involve tradeoffs, and with these tradeoffs come compromise, disagreement and complexity (Miller, 2012, p. 285).

He refers to the third conceptualization of sustainability as *procedural sustainability* (Miller, 2012, p. 285). In this notion, sustainability is a process of defining, learning and adapting to changing conditions and uncertainty. Rather than being a stable state toward which we work, the process of adaptation to shifting social and environmental conditions is what defines sustainability, and the degree to which we are sustainable is correlated with our ability to adapt as individuals and societies. He goes on to note that procedural sustainability and Universalist and thick sustainability are not mutually exclusive, but rather can integrate in so far as they advance our ability to adapt in specific contexts (Miller, 2012, p. 286).

From this very cursory discussion of a rich debate, it is clear that any conceptualization of sustainability involves balancing competing needs and interests and adapting to social and environmental changes (Giddings *et al.*, 2002). This is realized through some combination of redistributing material and political allocations throughout society and imposing legal, physical and economic barriers to some set of actions. This prioritization in itself calls into conflict the needs and interests of various groups. These conflicts are amplified when multiple actors, each with their own definition of sustainability, pursue the needs and interests of the groups they have prioritized. Effectively, the pursuit of sustainability then becomes a source of conflict. This conflict, in turn, can lead to systemic marginalization away from sustainability.

## Sustainability as a Form of Conflict Resolution

It is interesting that, while each conceptualization of sustainability acknowledges that there are certain incompatibilities in the social world, most fail to explicitly discuss the associated conflicts and means of resolving them. Rather, the Universalist view emphasizes an ideal state that resembles what Galtung (1969) refers to as a *positive peace*, or a state that is characterized by a lack of sources of somatic marginalization and the promotion of human development. In both the thick and procedural conceptualizations, conflict is explicitly discussed as being a characteristic of the choices we make regarding sustainability, but no mention is made of how to productively manage such conflicts. Instead, the process of resolution is merely implied, presumably as part of the adaptation process.

Rather than assuming that conflict management and conflict resolution will occur in a 'sustainable' world, an operational conceptualization of sustainability should be included in these processes explicitly, along with the institutions and structures required to facilitate them (Russo *et al.*, 2014). The fields of peace studies and conflict resolution have grown in the past decades and have developed a rich body of theory and practice that can inform sustainability science on methods, institutions and structures required to manage the conflicts inherent in balancing social, environmental and trans-generational needs and interests. Before reviewing the close ties between sustainability and conflict studies, however, it is necessary to define several concepts to highlight the direct connections.



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Conflict as a concept can be understood as a situation in which two or more parties (individuals or groups at various levels of social organization) have, or perceive that they have, incompatible needs, interests or positions (Hammill *et al.*, 2009). Conflicts may be latent, with groups not acting on, or not acknowledging, the incompatibilities between them. Active conflicts, however, can be expressed in myriad forms, from political debate to public dialogue or even large-scale violence (Pondy, 1967). Whatever form conflict takes, it is a response to underlying incompatibilities.

When discussing conflict behavior, Morton Deutsch (1969, 1973) makes a distinction between constructive conflicts and destructive conflicts. *Constructive conflicts* involve efforts to solve or resolve incompatibilities between groups (Nowak *et al.*, 2012). While these conflicts may involve intense hostility or negative emotion, groups in conflict tend to seek solutions that are mutually acceptable rather than mutually exclusive. *Destructive conflicts*, in contrast, aim to undermine or otherwise injure the opposing party (Nowak *et al.*, 2012). Destructive conflicts erode or inhibit the wellbeing of individuals, groups and societies through both physical and psychological means.

There is a direct link here between conflict and sustainability. Under the Universalist conceptualization, sustainability seeks to actively promote human wellbeing. Under Miller's (2012) thick conceptualization, sustainability involves making explicit choices about which needs to prioritize and how to pursue them in order to promote wellbeing. In either case, conflicts among groups with competing or incompatible needs, interests or positions are inevitable. Sustainability then, or rather the pursuit of it, is very much akin to the idea of constructive conflict or constructive conflict resolution and positive peace. This idea is reified by examining the relationship between the procedural conceptualization of sustainability discussed by Miller (2012) and Anderies *et al.* (2013), wherein sustainability is a process of constant adaptation to and balancing of changes in biological, geophysical and social contexts. Similarly, constructive conflict is a process of productively managing existing, changing and new tensions that arise from these same biological, geophysical and social changes (Nowak *et al.*, 2012).

A burgeoning literature on *sustainable peace* strengthens the tie between sustainability and conflict (Coleman and Deutsch, 2012). Just as in mainstream sustainability, there is no standard definition of sustainable peace. However, as a concept it might be understood as

> ...a state where the probability of using destructive conflict and violence to solve problems is so low that it does not enter into any party's strategy, while the probability of using cooperation and dialogue to promote social justice and well-being is so high that it governs social organization and life (Coleman, 2012, p. 355).

Under a sustainable peace, environmental considerations and development efforts are important for preventing the erosion of social stability and promoting social justice and wellbeing. This conceptualization of sustainability is parallel to the more traditional views in which peace and conflict resolution are necessary to advance human welfare and provide a physical environment that will promote it.

When viewed on a larger scale, the ideas of prevention and promotion described by Higgins (1998) are key to the sustainable peace concept, and they may also be directly relevant to mainstream sustainability. Prevention is the act of protecting or preserving some baseline standard or status quo on which to build sustainability in the future (Coleman, 2012). Promotion, then, when referring to sustainability, is the act of advancing, implementing or otherwise advocating for specific strategies and policies that will continue the process of building sustainability. According to Coleman, simultaneously serving prevention and promotion functions enables social systems and social actors to constructively engage themselves, other actors and their environment to manage conflict and build sustainable relationships (2012, p. 355). Effectively, sustainability becomes a process of maintaining gains made in desirable systems dynamics, while actively changing, modifying and enhancing other dynamics to move the system closer to the goal of social justice and human wellbeing.

In order to be effective (or perhaps even possible), human action aimed at advancing sustainability must take place in a structure that permits change. The existing social and social–ecological (which, according to Gallopin, 2006, refers to human relationships in and with the natural world) institutions must allow for productive change and constructive conflict resolution. Human history is rife with examples of social systems that are oppressive or otherwise sub-optimal but incredibly resilient (Fry, 2006; Howell and Willis, 1989). Autocracies for instance have proven to be extremely stable, while not providing flexibility for social action and change (Hewitt, 2008). As such, we should distinguish between a social order being sustained and a system being sustainable (Nowak *et al.*, 2012).



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The former relates to something being perpetuated, whereas the latter is understood as movement toward some ideal. In order to move toward this ideal (i.e. in the pursuit of sustainability), the system must be structured in such a way as to allow for movement. Thus, in addition to the ideas of prevention and promotion, constructing sustainability must occur in a structure that permits it.

## Using 'Complex Systems' Paradigms to Synthesize a New Conceptualization of 'Sustainability'

While mainstream sustainability science emphasizes social and economic development and environmental stewardship, sustainable peace research emphasizes constructive conflict management. In spite of these tangential foci, the two conceptual frameworks share the same overarching core concern of advancing the wellbeing of societies and individuals, now and into the future. Environmental quality, ecosystem functioning, economic development, and peace and conflict management are all necessary components of sustainability in so far as they drive human wellbeing. What is needed to advance sustainability, then, is guidance on which changes to the social–ecological order to promote, what sorts of degradation to prevent and how to structure our social systems such that they can be simultaneously durable and flexible to enable positive change (Le Blanc, 2015).

Unfortunately, answers to these questions are elusive due to the complexity of social–ecological systems. We have only cursory understandings of the pathways through which the drivers of any sub-component of sustainability (peace, ecosystem functioning, economic development) function. Further, we know that these sub-components are interconnected in systems such that environmental quality affects development or access to natural resources affects conflict likelihood (Balint *et al.*, 2011), but we lack coherent understanding of these feedback processes within systems. This is illustrated by the lack of social and scientific consensus over the issue of climate change, whether and to what degree it is human caused and what to do to prevent or mitigate it (Nordas and Gleditsch, 2007; Ozawa, 2006). The uncertainty resulting from social–ecological complexity, coupled with the lack of consensus, make any prescription or potential course of action highly contentious. Thus, we need analytical frameworks capable of working with the complexity of the social–ecological world as well as strategies and tools to manage the conflicts that arise from uncertainty and complexity.

The field of complex systems has gained ground over the past decades as an alternative, or perhaps a complement, to the traditional scientific approaches that has direct implications for sustainability (Djuric and Filipovic, 2015). It seeks to explore the complex and emergent dynamics of the social–ecological world rather than to find fundamental laws by studying specific elements of a system discretely (Bar-Yam, 1997; Innes, 1999). Accordingly, a complex system can be understood as a set of elements that interact over time and space in linear and non-linear feedback processes. Those interactions produce emergent properties and dynamics that in turn affect the elements and their interactions (Nowak *el al.*, 2012).

Complex systems approaches have been used to study multiple aspects of the physical and social world. Two sub-disciplines that are particularly useful for the discussion of sustainability here have emerged in parallel. These are the resilience or coupled systems approach (Folke *et al.*, 1996; Holling, 1973), and dynamical systems theory (DST) (Coleman *et al.*, 2007, 2010). While these sub-disciplines are complementary, they have not as yet been brought together. However, a synthesis of the two could provide a useful framework for understanding sustainability at the nexus of conflict, environment and development.

## Resilience and Social–Ecological Systems

As Gallopin (2006) explains, natural and human systems exist in tandem. They are not merely interactional, but rather are interconnected in social–ecological systems (hereafter SESs). An SES includes both human and non-human biological and physical sub-systems in mutual interaction (Gallopin, 2006). Turner *et al.* (2003), among others, refer to this mutual interconnection as coupling, and sustainability science has tended to focus on the coupled systems approach with emphasis placed on the environmental aspect of these systems.



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Resilience theory is one of several intellectual trends that explore coupled systems. The concept emerged in ecology in the early 1970s with the publication of Holling's (1973) innovative paper 'Resilience and stability of ecological systems'. This paper challenged the mainstream view that ecosystems tend toward single static equilibrium. By exploring predator–prey dynamics, Holling demonstrates that natural systems are composed of multiple elements simultaneously acting and interacting. These interactions give rise to emergent relationships, and multiple potential relationships can be formed depending on the elements in the system and the ways in which they interact. The nature and functioning of an observed system at any given temporal and geographic point is only one of the multiple potential expressions of the system, called a *stable state*.

Holling describes the ways in which natural and human disturbance and cross-scale feedback mechanisms affect system states (Folke, 2006; Holling, 1973). The multiple potential stable states are referred to as *basins of attraction*, and *resilience* is the capacity of a system to remain in a single basin despite exogenous and endogenous changes in the components of the system and the relationships among these components (Walker *et al.*, 2004). A related concept is *robustness*, which refers to the ability of the system to continue performing the same functions at approximately the same rate, despite changes in the elements that comprise it (Anderies *et al.*, 2013). Whereas the resilience of a system is the degree to which it can 'absorb changes of state variables, driving variables, and parameters, and still persist' (Holling, 1973, p. 17, cited by Folke, 2006, p. 254), robustness refers to the system's ability to absorb shocks and continue to function. Gallopin conceptualizes basins of attraction as 'the portion of the state space... that contains an 'attractor' toward which the state of the system tends to go, and is therefore one region... where the system would tend to remain in the absence of strong perturbations' (2006, p. 297).

These concepts have important relevance for the field of sustainability science. If it were possible to identify attractors in whose orbits the system elements behave in a sustainability-promoting way, then it would be possible to identify ways in which changes to these elements affect system resilience and robustness. This knowledge could help answer the question posed earlier of how to build durable (i.e. resilient) social structures and institutions that are flexible enough to enable movement toward a more desirable state. Likewise, if we identified the correct parameters and their specifications, then we could explore methods of causing regime shifts away from undesirable (i.e. unsustainable) system states.

## Dynamical Systems Theory

The foundations of dynamical systems can be traced back to the late 19th century mathematician Henri Poincaré, but gained prominence between the late 1960s and 1980s, when mathematicians and physicists demonstrated that simple dynamical laws give rise to complex emergent and chaotic phenomena (Aubin and Dalmedico, 2002). In the vein of Newtonian mathematics, dynamical systems are useful for defining trajectories and orbits in phase space. Indeed, it is from this tradition that resilience and coupled systems approaches derive.

Recently, a number of scholars and researchers have begun applying the dynamical systems approach to study conflict systems, developing what they call *dynamical systems theory* (Bui-Wrzosinska, 2013; Coleman *et al.*, 2010; Nowak *et al.*, 2007; Vallacher *et al.*, 2013). This approach has been particularly effective in describing attractor dynamics in conflict systems. On various scales from interpersonal to international, conflicts tend to follow non-linear trajectories and often become mired in intractable stalemate or negative cycles. In the DST perspective, these enduring conflicts can be characterized as a conflict system orbiting a basin of attraction that contains some attractor for conflict. By understanding the parameters that define the trajectory of this orbit, and further by identifying how the system's trajectory is altered in response to changes in those parameters, it is possible to design peace-building strategies that may be useful in instantiating a regime shift in which the system transitions to a new basin of attraction around a different or more positive attractor (Coleman *et al.*, 2010; Bui-Wrzosinska, 2013). Further, this approach is useful for illuminating the ways in which exogenous actors and processes (social and environmental) affect the dynamics of conflict systems, which is difficult in traditional approaches to studying conflict. From a methodological perspective, the mathematical tools and computational techniques employed in traditional dynamical systems research offer conflict theorists methods capable of incorporating variables and data from multiple temporal and spatial scales in sophisticated ways, and enable feedback processes from multiple levels of social organization. Further,



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these methods allow conflict theorists to explore the emergent and non-linear dynamics observed in many intractable conflicts.

## Conclusion: Toward a Complex Systems View of the Conflict–Environment–Development Nexus

Whereas coupled systems approaches have tended to emphasize the natural world and social impact on it, the emerging DST field has focused almost exclusively on the social world. However, as Gallopin (2006) adeptly notes, the world exists as nested social–ecological systems (SESs). When exploring something like sustainability, which is necessarily driven by the interaction of societies, environments, institutions and structures, we need an approach capable of engaging the complexity of social–ecological systems to enable us to find solutions to the conflicts that are inevitable among the needs and interests of so many disparate actors.

The field of sustainability science has made great strides in these terms, seeking to understand the interactions between humans and societies, with a real focus on what Carpenter *et al*. (2009) refer to as compelling or urgent human and social needs. Miller (2012) notes that, while complex systems thinking has made many advances in understanding human–environment interaction, there is still a great need for more knowledge on behavioral dynamics. He suggests that one of the goals of sustainability science should be to understand human decision-making and perceptions, because many of the knowledge gaps in the field result from poor understanding of these factors and the influence they exert on the system.

It is precisely here that a merger of the coupled systems and DST paradigms would enable us to begin to fill the knowledge gaps in sustainability science. In its current state, the coupled systems paradigm has made greater strides in refining theory and developing a corpus of research, owing to the long history of the field and the direct tie with natural systems that lend themselves more readily to dynamical systems modeling. DST, however, has the pursuit of knowledge and insight into behavior and decision-making, particularly in a conflict context, as its explicit focus.

If we accept that pursuing sustainability involves identifying and productively managing the conflicts that will arise from decisions made about how to engage each other in and around the natural world (i.e. conflicts over resource access and use, constraints of specific actions, redistribution of political and economic power etc.), then capitalizing on DST's insights into conflict drivers, behavior and trajectories could augment the knowledge from coupled systems approaches such that we develop clearer understandings of how specific policies and environmental changes will affect overall system functioning. Likewise, we could begin to understand how resilience and robustness are affected by changes in the social and environmental parameters of the system, thereby identifying how to build durable yet flexible systems or experiment with ways of instantiating change in undesirable system states.

When peace is understood in its complete form, the pursuit of peace is the pursuit of a state in which social and social–ecological relationships permit and promote the realization of individuals' potential. As long as there exist barriers that prevent human development, we will be unable to achieve sustainable peace. However, institutions and relationships that encourage human development will serve to erase the barriers that do exist as well as providing the support structures necessary to realize our potential. Thus, real or positive peace is dynamic.

While there will inevitably be divergent needs, interests and positions in any society, a state of peace is a state in which the resulting conflicts are managed in productive ways that do not marginalize the groups involved. In much the same way, the pursuit of sustainability is the pursuit of a state of equilibrium, where components of the system interact dynamically without jeopardizing system integrity or constraining interaction. In other words, a sustainable system both permits and promotes interaction and individual development. If there are barriers to development, be they biological, physical, social, legal or economic, the system will ultimately prove untenable as competition turns virulent. Likewise, if the system is forced to be static, it will stagnate.

Once we expand the conceptualization of sustainability to include actively and explicitly managing conflicts that arise over governance, economics, social institutions and the natural world to promote human development in systems free of barriers, we are confronted with the challenge of identifying strategies for conflict management via the institutions and structures that enable the process of sustainability. That challenge becomes evident when we begin to explore the multiple levels of social and ecological complexity of the world. The challenge is made even greater by



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our limited understanding of the processes that drive social and social–ecological interaction. If we take seriously the challenge issued here of working at the nexus of conflict, environment and development, then it is clear that we need new intellectual paradigms to provide insight into the behaviors, parameters and interactions that drive us toward and away from sustainability.

It is here that merging the theoretical traditions of dynamical systems theory and coupled systems would provide real utility. Despite having developed in parallel to each other, they share the same fundamental assumptions regarding complexity, non-linearity and attractors in system space. Rather than imposing artificial structures and static processes on systems, these paradigms explore the richness and emergences of social and social–ecological interaction to understand what drives system dynamics toward equilibrium around specific attractors. By employing a complex systems approach to the expanded conceptualization of sustainability advocated here, a new line of research could investigate the attractors around which a social–ecological system would exist in a truly sustainable state. What are the drivers that bring the system closer to this state? What parameters make the system robust in this state? Likewise, this new paradigm could explore the drivers that could push the system away from attractors around which the system exists in an unsustainable state, and the parameter changes that could lead the system to shift from a marginal to a sustainable regime.

The real utility of the complex systems perspective is that it enables us to better and more fully understand how we affect and are affected by the system. By acknowledging that conflicts are inevitable among the needs, interests and positions of social actors in and with the natural world, we can understand that true sustainability depends on seeking means to productively manage these conflicts in ways that will both permit and promote human development.

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