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Feedback enhances greening during disaster recovery: A model of social and ecological processes in neighborhood scale investment

Keith G. Tidball[a,*], Athena Aktipis[b]

[a] 118 Fernow Hall, Department of Natural Resources, Cornell University, Ithaca NY, 14853, USA
[b] Department of Psychology, Arizona State University, PO Box 871104 Tempe, AZ, 85287, USA

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ABSTRACT

In disaster recovery situations, including the post-Katrina recovery in New Orleans, greening behavior (i.e., the planting of trees, flowers and other plants) is thought to play an important role in social, ecological and economic recovery. In this paper, we use agent-based modeling to investigate and understand the roles of green attachment (which encompasses place attachment and biophilia), engagement in local ecological investment (i.e., greening), and social feedback (where individuals who observe greening become more likely to engage in it). We model this social-ecological feedback process, basing our parameters and assumptions on real-world data and grounding our model in the Tremé neighborhood of New Orleans. We find that social-ecological feedback enhances greening overall and leads to larger spatially continuous regions with high rates of greening. We also find that social-ecological feedback leads to tipping points in neighborhood greening, with approximately 30% of households needing to engage in greening for it to reach asymptotically high levels. In addition, when green attachment is high, this leads to more widespread greening behavior. We conclude that social-ecological feedback processes such as those modeled here may play important roles in neighborhood recovery after disasters such as Hurricane Katrina.

1. Introduction

After hurricane Katrina, many residents in New Orleans banded together to restore the green infrastructure in their neighborhoods. For example, in the Tremé neighborhood, people participated in greening activities that ranged from individuals planting trees in front of their homes to collective participation in larger scale efforts like the establishment of gardens and resurrection of parks that had been destroyed in the disaster. Both ecological and social feedback can contribute to the emergence of such a movement, with individuals becoming more willing to engage in greening as a result of observing greened environments (ecological feedback) and observing individuals engaging in greening behavior (social feedback). In this model we engage in initial inquiry into the role of social-ecological feedback, at the neighborhood scale, in shaping this transition and the recovery of neighborhoods after disaster. We find that social feedback – where individuals can observe the greening behavior of others – generally enhances greening. However, it can be a double-edged sword, sometimes enhancing recovery but other times dampening it. We found that greening is enhances above a tipping point of approximately 20% of households engaging in greening behavior. We also found that, when households have higher green attachment, this leads to more rapid greening in the neighborhood overall. We discuss the implication of this model for understanding the dynamics of green infrastructure in the Tremé neighborhood, including the initiation of a social movement which linked greening behavior to the restoration of neighborhood history and pre-disturbance culture. Agent-based models like the present one can help us understand the emergence of the greening social movement and the implications of it for the resilience of communities to disasters.

1.1. Why greening?

The value of green places, or restorative environments (Hartig and Staats, 2003) for easing trauma or discomfort (Kaplan and Kaplan, 1989; Ulrich, 1993) is a topic of great interest among researchers and practitioners. Many researchers have identified benefits to greening generally (Markee and Janick, 1979; People Plant Council, 1993; Relf and Dorn, 1995; Relf, 2005), as well as in more specific contexts such as among returning war veterans (Helphand, 2013; Krasny et al., 2013), in refugee contexts (Moore, 2013), and in prisons (Lindemuth, 2013) to name a few (for an interdisciplinary literature review of the concepts of Green Infrastructure, ecosystem health, and human health and well-

* Corresponding author.
E-mail addresses: kgtidball@cornell.edu (K.G. Tidball), athena.aktipis@asu.edu (A. Aktipis).

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being, see Tzoulas et al., 2007).

Recent studies (Hartig and Staats, 2006; Van Den Berg et al., 2007; Bell et al., 2008) have shown that the ability to see or actively experience green spaces can reduce domestic violence, quicken healing times, reduce stress, improve physical health, and bring about cognitive and psychological benefits in individuals (Ulrich, 1984; Kaplan and Kaplan, 1989; Hartig, Mang et al., 1991; Sullivan and Kuo, 1996; Faber Taylor et al. 1998; Wells, 2000; Wells and Evans, 2003) and populations as a whole (Hartig et al., 1991; Branas et al., 2011). For example, a 10 year study indicated that greening may reduce certain crimes while promoting some aspects of health (Branas et al., 2011). Despite some claims that green spaces can be perceived as dangerous (Herzog and Flynn-Smith, 2001; VanWinsum-Westra and Boer, 2004), Maas et al. (2009) concluded that green space in people's living environment is generally associated with enhanced feelings of safety. Kuo et al. (1998) and Kuo and Sullivan (2001) demonstrated that exposure to trees in urban settings can foster a sense of safety and reduce crime rates, thus contributing to social well-being (see also (Salick, 1995; Elings, 2006; Relf, 2006).

Given these many benefits of community greening efforts, here we further arguments that they contribute importantly to post-disaster recovery and resilience. Tidball and colleagues (2013) have documented greening as an important contributor to resilience in the face of catastrophic change. The act of coming together around the renewal and stewardship of nature appears to enhance individual and community resilience, including that associated with chaotic post-disaster and post-conflict contexts (Tidball and Krasny, 2013b). Our use of the term resilience refers to the capacity of linked social-ecological systems to absorb disturbances to retain essential structures, properties, and feedbacks and continue to develop and innovate (Holling, 1973; Walker et al., 2004; Adger et al., 2005). Resilience reflects the degree to which a complex adaptive system is capable of self-organization and building capacity for learning and adaptation (Carpenter et al., 2001; Folke et al., 2002). We view humans as integral to the ecosystem and one of the main "inter-actors" that shape the system's self-organization. Consequently, ecosystem services in the urban landscape are generated by interacting social-ecological systems and not by ecosystems alone (Niemelä et al., 2011).

Social-ecological feedback in greening includes the interaction between environmental quality, individual behavior, and social information. *Tight* feedbacks, which illustrate how quickly and strongly the impacts of a system change are felt, are an important quality in resilience thinking because they enable actors to take actions and response steps before ecological and other thresholds are crossed (Beatley, 2012). An example of such a "tight feedback" can be found among individuals who increase greening behavior as a result of inhabiting an environment with green infrastructure, by watching others engage in greening, or to fill a perceived deficit (Tidball et al., 2017). The presence of tight feedbacks indicates resilience (Levin, 1999; Levin and Lubchenco, 2008), because they index the capacity of a system to learn from itself and adapt to and recover from perturbations and recalibrate to transform in response. Though there are many examples of the importance of tight feedback in purely ecological systems, there are relatively few social-ecological examples, especially in peopled landscapes/urban contexts.

In response to this gap, we present a model grounded in reasonable (and substantiated, see appendix) assumptions about social-ecological interactions that can shed light on the nature of these processes and outcomes. We use agent-based modeling to study the social-ecological feedback processes underlying greening behavior, basing our parameters and assumptions on real-world qualitative data and grounding our model in the Tremé neighborhood of New Orleans.

2. Background

Within the general field of systems theory, complex systems are described as process dependent organic systems with feedbacks among multiple scales that allow self-organization (Holland, 1995; Levin, 1999, 2005; Folke, 2006). Virtuous and vicious cycles or feedback loops are important to social-ecological systems resilience approaches (Gallopin, 2002; Powell et al., 2002; Matthews and Selman, 2006; Selman, 2006; Selman and Knight, 2006), and represent interactions that are typically self-sustaining and reinforcing; if their influence is negative, they are considered "vicious" cycles, and if their direction is positive, they are "virtuous" Varis (1999), p. 599). These virtuous and vicious cycles provide a means to visualize how greening can interact with other processes to help transform a social-ecological system. Tidball (2012a,b); Tidball et al., 2017) identified "greening feedbacks" as a possible mechanism at work in disaster contexts but more work is needed to fully understand the emergence of these greening feedbacks and their expansion.

One way to begin to understand these greening feedbacks and virtuous cycles is through the use of agent-based modeling (ABM). In recent years, ABM is increasingly being considered a promising quantitative methodology for social science research (Janssen, 2002; Parker et al., 2003; Janssen and Ostrom, 2006). In agent-based modeling, heterogeneous individuals interact with their local environments and with each other. Individual decisions about whether or not to engage in greening after disaster are likely to be very complex, involving individual, environmental, and social factors. Agent-based modeling allows for the investigation of greening in light of these factors and allows us to isolate the role of social feedback in influencing greening behavior and aggregate neighborhood outcomes.

Agent-based models explicitly model individuals and environmental patches which allows for a more specific and realistic simulation of the kinds of interactions that underlie complex social-ecological processes especially at the level of individual decision making (Magliocca and Ellis, 2016). This can provide an advantage over analytic models and simulation models that do not explicitly represent individuals and local environmental patches. However, there are also challenges with agent-based models including deciding on the appropriate level of specificity for the model in order to address the question at hand. Models that are too complicated often lack transparency, making them hard to interpret and models that are too simple are often criticized for not including enough detail or real-world parameterization (Sun et al., 2016).

In this paper we explore the dynamics of greening in response to disaster, using the events in the Tremé neighborhood of New Orleans as a starting point for understanding more general processes. We model the effects of green attachment (which represents a combination of place attachment/topophilia and affinity for other life/biophilia) as well the effects of social contagion of greening behavior in order to better understand how these processes contribute to greening after disaster. In so doing we translate an observed greening process to a formal model and utilize agent-based modeling in order to create a model that captures certain components of the ecological and social processes underlying greening.

2.1. Site description

The Tremé neighborhood is a historically African-American neighborhood with a legacy of lost green space. In the 1960s, an elevated highway was constructed above the oldest section of Claiborne Avenue, a central avenue lined with old and stately live oak trees that had provided a community gathering space for neighbors. After construction, poorly lit asphalt parking lots under the freeway replaced the green grounds, and concrete supports for the highway replaced stately oak trees. Construction of the overpass contributed to the overall decline of the Tremé neighborhood in the 60's and 70's (Rogers, 2009). After Katrina, the social-ecological memories (Barthel et al., 2010; Nykvist and von Heland, 2014) of the green infrastructure that had characterized the Clairborne Avenue and Tremé neighborhood were slowly reawakened, which appears to have contributed to the

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