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RESEARCH ARTICLE

Exploring the potential of food forestry to assist in ecological restoration in North America and beyond

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Food forests—edible, perennial, polyculture systems—are of increasing interest in North America and the United Kingdom, as reflected in projects ranging from urban food initiatives to integrated conservation and restoration planning. To examine emerging food forestry (FF) against the backdrop of ecological restoration (ER), we conducted semi-structured interviews with eight experts each from the fields of FF and ER in conjunction with observations of food forests in Canada, the United States, and the United Kingdom. Using content analysis, our study builds a FF model that encompasses the underlying goals of emerging FF—forest function; diversity of yields; education and culture sharing; healthy habitats for people and other species; and sustainability. We argue that FF has potential as an urban restoration tool in terms of enhancing the multifunctionality of heterogeneous landscapes undergoing significant changes. This will require meaningful consideration of ethical issues (e.g. commodification of nature), landscape contexts, ecological integrity, integration of historical knowledge, and resilience for interdependent, dynamic social and ecological systems. Moreover, systematic, long-term monitoring of different types of food forests will be crucial in order to mindfully apply FF in ER. This research provides one of the first in-depth analyses of how emerging FF might contribute to restoration in the time of the Anthropocene, especially outside traditional tropic regions where most FF has been practiced.

Key words: forest garden, North America, Social-ecological system, sustainability, United Kingdom, urban restoration

Implications for Practice

- We recognize that there are differences between food forestry and ecological restoration, including different priorities placed on social benefits and native species, differing management intensities, and the extent to which wildlife habitat is supported. These differences are context-specific and can be variable.
- Urban food forestry may serve as an innovative restoration model to help restore forest functions and to improve biodiversity, quality of human life, and human-nature connections in urban landscapes that have undergone significant change. Comprehensive restoration principles (Suding et al. 2015) and resilience thinking may provide conceptual guidelines for restorative food forestry.
- A thorough assessment and long-term monitoring will be essential to evaluate and improve the contributions of food forests to restoration practice.

Introduction

Opportunities and Challenges for Ecological Restoration

Ecological restoration (ER) is facing enormous opportunities and challenges. An estimated 2 billion hectares of degraded forestlands worldwide have the potential for different types of ER (Minnemeyer et al. 2011). At the same time, restoration is becoming more conceptually and practically complex due to rapid and significant environmental, ecological, and social changes (Hobbs et al. 2013), coupled with the emergence of an "increasingly human-dominated Earth system" (Alberti et al. 2003). Of the degraded forestlands globally, 1.5 billion hectares might still integrate with other land uses such as agroforestry, agriculture, and/or grazing during and following restoration (Minnemeyer et al. 2011). As a result, a growing body of ER literature asks: How can we build sustainability and resilience of ecosystems that are dynamic and complex while restoring biodiversity and improving the quality of human life and ecosystem services? (Hobbs et al. 2014; Suding et al. 2015). Choi et al. (2008) propose that "future-aimed restoration" should: consider changing and uncertain future environments; use historical information as a guideline; set multiple, realistic goals and trajectories; and explore various restoration techniques.

Food Forestry

A food forest is an edible, perennial, polyculture system that is designed and managed to mimic multistorey forest structures

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and to function like a natural, self-sustaining forest (Jacke & Toensmeier 2005; Walker 2015). Design, techniques, and goals vary depending on ecological, environmental, and socioeconomic conditions. Yet, food forests are generally planted with a high diversity of canopy and small trees, shrubs and herbaceous, root, and/or vine species in a way that maximizes beneficial plant interactions. Most food forest plants have direct uses such as for food, medicine, and building and art materials, as well as indirect functions such as nitrogen-fixing and pollination (Hills 1988).

Food forestry, a type of agroforestry, has long developed as a traditional means for people to adapt and transform lands in response to changing environmental and socioeconomic conditions such as migration. At the same time, it has contributed to biodiversity and cultural traditions (Hills 1988). Food forestry encompasses myriad forms of ancient knowledge and skills from traditional homegardens, forest gardens, and multistorey tree gardens largely in tropical, rural regions. For example, homegardening in Kerala, India is thought to be over 4,000 years old (Kumar & Nair 2004), and the origin of the Javanese homegardens is associated with fishing villages existing from 13,000 to 9,000 BC (Kumar & Nair 2006).

At the time of writing, there are no universally accepted boundaries about what is and what is not a food forest (Kumar & Nair 2004; Crawford 2010), and existing definitions cover a wide continuum of human intervention and intention (Jacke & Toensmeier 2005; Wiersum 2006). This article refers to food forests that are prescribed, intensive systems and that differ from forage forests, where people marginally modify certain elements of an existing forest and simply collect mushrooms, firewood, berries, or herbs (Crawford 2010). Also, food forests in this article are intended as permanent systems, which differ from shifting cultivation systems (Belcher et al. 2005).

Exploring Emerging Food Forestry in the Context of ER

Inspired by traditional food forests in tropical regions, food forestry (FF) is being increasingly adapted to nontraditional regions, such as temperate parts of Canada, the United States, and the United Kingdom (Crawford 2010; Clark & Nicholas 2013), as reflected in diverse projects, from urban food initiatives (e.g. Beacon Food Forest, U.S.A.) to integrated conservation and restoration planning (e.g. Galiano Community Food Forest, Canada). A wide range of values and needs motivate such projects, including food production, biodiversity conservation, and provision of ecosystem services (e.g. carbon sequestration and flood control), education, wildlife habitat, and places for (re)connecting with nature (McLain et al. 2012; Clark & Nicholas 2013). Such emerging FF crosses over contemporary science and environmental movements (e.g. permaculture) to address emerging social and environmental issues (Mollison 1988; Clark & Nicholas 2013).

Agroforestry has been used as a restoration tool to enhance multifunctionality of landscapes and to provide a balanced compromise among diverse values (Belcher et al. 2005; Montagnini et al. 2011). Yet, most studies in English have focused on traditional food forests in South Asia, Africa, and Central America and in rural settings (e.g. Jose & Shanmugaratnam 1993; McNeely & Schroth 2006), aside from limited literature that indicates possible traditional food forest systems in temperate regions in China (Wenhua 2001). In any case, there are very few studies that examine emerging FF in relation to ER.

In this article, we present key goals and attributes of emerging FF in North America and the United Kingdom and a FF model that encapsulates them. Then, we discuss similarities and differences between FF and ER and argue for key elements that must be in place for a food forest to contribute in any significant way to restoration efforts, using four restoration principles developed by Suding et al. (2015). Last, we suggest best possible applications of FF as a tool for ER. Nevertheless, our goal is not so much to conclusively demonstrate propositions around emerging FF but rather to make suggestions, which we hope other researchers and practitioners will draw on for further research and practice.

Methods

In this study, we conducted comparative assessments of literature, semi-structured interviews with 16 ER and FF specialists, conventional content analysis of transcribed interviews in conjunction with participation/observation at food forest projects in Canada, the United States, and the United Kingdom. The processes of interviewing and data collection followed the Ethics Protocol (No. 15-233) approved by the University of Victoria (consistent with Canada's Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans).

Semi-structured Interviews

A total of 16 experts from the fields of FF ($n = 8$) and ER ($n = 8$) were recruited through a purposive, snowball sampling method (Cohen & Arieli 2011) for semi-structured interviews. The experts are practitioners, researchers, or both, and they have professional experience of between 6 years and over 40 years in their field (averaging 27.5 years in ER and 24.5 years in FF) (Table S1). The 16 semi-structured interviews were small in number but were in-depth, systematic, and equipped with prescribed, tested, open-ended questions and a FF diagram (Fig. 1) that we developed based on literature review as a response instrument. The diagram was designed to help to lay a common understanding of key elements of FF among the interview participants and received as "very good baseline model" and "good foundation of thinking about food forestry." Also it allowed us to uncover a range of attributes of complex food forest systems and to facilitate a comprehensive comparison between FF and ER.

The interviews took place from August 2015 to August 2016 through in-person, telephone, or online video. We asked the interviewees the following open-ended questions: (1) what are the goals of food forests? (2) what differences and similarities characterize FF and ER? and (3) what are the potential benefits and challenges of incorporating FF in ER? Arising

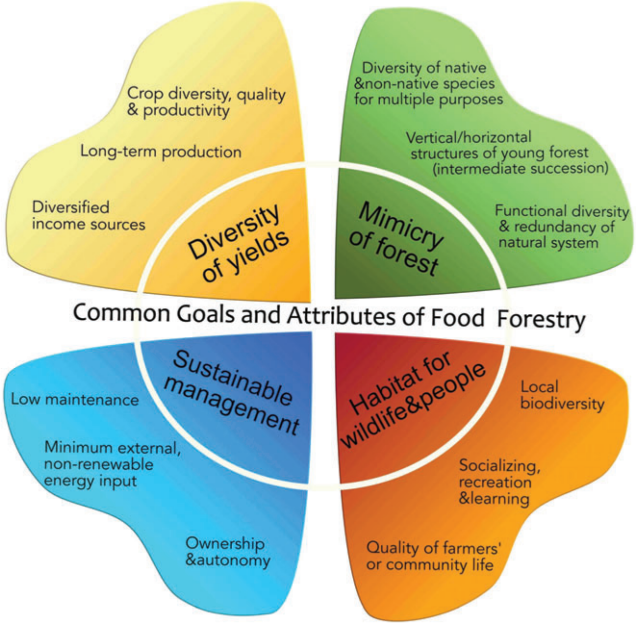

Figure 1. Common elements of food forestry described in Wiersum (2004, 2006), Belcher et al. (2005), Jacke and Toensmeier (2005), Vieira et al. (2009), and Crawford (2010) were compared, using conventional content analysis (Hsieh & Shannon 2005). This diagram was used as a response instrument for semi-structured interviews.

from these main questions, new questions emerged, and participants were free to explore them. The interviews ranged from a minimum of 40 minutes up to 120 minutes (averaging 75 minutes) and were audio-recorded and transcribed in full. Based on feedback from the interviews, the FF diagram evolved into a more complex model encapsulating a wide range of goals from multiple food forest projects, and then reviewed by the participants.

Conventional Content Analysis

Using Atlas.ti qualitative data analysis software, we conducted conventional content analysis of each interview transcript: an inductive, iterative, and systematic process of coding and identifying themes or patterns grounded in the data collected (Hsieh & Shannon 2005). This approach enables researchers to "immerse themselves in the data to allow new insights to emerge" (Hsieh & Shannon 2005) and to develop a rich understanding of the phenomenon.

We conducted transcribing and initial-coding of the interview transcripts concurrently with the interview process. This enabled us to subsequently ask about emerging theory, themes, or questions drawn from the initial analysis of previous interviews. After all the interviews were completed, we closely reviewed the interview transcripts (four times each) and then merged and partitioned the initial codes based on their properties and dimensions, while defining relationships (e.g. opposite, similar) among the codes until no new definite themes or properties were detected. We grouped the final set of codes into question code groups (e.g. what are the goals of food forests?) and thematic code groups to capture key themes that emerged during the interviews (e.g. ecological succession; best applications of FF; and native vs non-native species). Then, we organized the codes within each code group to compare different responses and to analyze the codes and their association or relative congruence with other codes by using a visualization tool "network analysis" in Atlas.ti. Last, we cross-checked and compared the interview data with scientific literature and our site observations for discussion.

Observation and Participation

One of us (H.P.) visited nine food forests, including ones operated by interview participants in Canada, the United States, and the United Kingdom, in the period from August 2015 to August 2016 (Fig. 2 & Table S2). In addition, we participated in site assessment, planting, and/or a public design charrette of a food forest project developed by the Galiano Conservancy Association, which took place in their conservation land on Galiano Island, British Columbia, on the west coast of Canada.

Results

Food Forestry Model

The food foresters identified a total of 5 goals and 19 essential attributes of their food forests (Table S3), which manifest multifunctionality and underlying interwoven relationships between people and nature anchored at the heart of the FF model (Fig. 3). The key goals are described in the following sections.

Forest Functions. A food forest is a "multistorey, perennial polyculture" system (FF-5), which is designed and managed to function like a self-sustaining natural forest. A high diversity of native and/or non-native plants and structural diversity were key ecological components of the food forests. In particular, all food foresters placed emphasis on building healthy soil and promoting diversity of soil biota. One food forest (of FF-6) initially showed 2.4% of soil organic matter, and after 12 years, this increased to 9.0%. A food forester believes that healthy soil is "a legacy that can be left for future generations. It's a major goal here … to leave in a much-improved condition for the next citizens to work with" (FF-7).

Diversity of Yields. FF aims for production of diverse, high-quality yields (e.g. food, medicinal products, art craft, and building materials) over the longest season possible, sustained over an extended time. It also aims to generate supplementary income from diverse sources (e.g. herbal products, nursery, vacation home, tours, and workshops). Yet, the food foresters have had different experiences with productivity depending on management intensity, the level of input, and the purposes of their food forest.

Figure 2. (A) Cottonwood Community Garden in Vancouver, Canada (June 2016); (B) Means of Production Garden in Vancouver, Canada (June 2016); (C) Galiano Community Food Forest on Galiano Island, Canada (August 2016); (D) Beacon Food Forest in Seattle, U.S.A (April 2016); (E) Forest Garden at Dartington in Devon, England (August 2015); (F) Garden Cottage in Coldstream, Scotland (September 2015).

Education and Culture Sharing. The participants underscored the value of their food forests for learning, culture-sharing, and/or demonstrating of different designs (e.g. maintaining native food species; integrated housing and community design; and creating ecocultural edges). All of the food foresters engage in different forms of education, in particular experimental and social learning. The food foresters plant diverse species that are adapted to multiple possible trajectories of the current climate conditions, testing how these plants respond and interact with other plants (FF-1), and/or facilitating exchange of genetic materials across the globe (FF-7). Social learning was identified by both expert groups as a strength of public FF, as "It [food forestry] brings people together with common goals of looking after the places and learning together about how to do that the best way possible" (ER-8). Social learning includes not only ecological and botanical knowledge, but also management and social skills and capacities to share knowledge and responsibilities, which are essential for the long-term success of FF (FF-6).

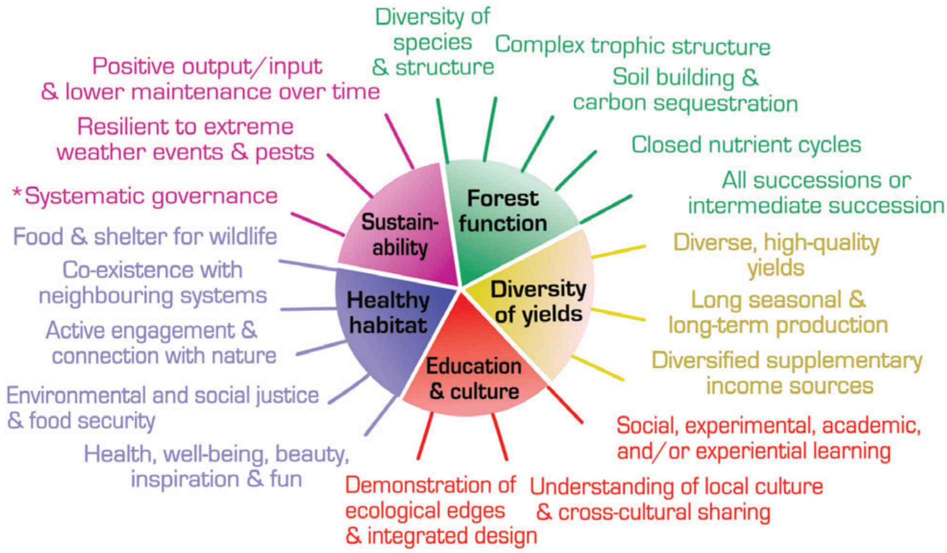

Figure 3. Food forestry model: key 5 goals and 19 essential attributes of food forestry identified by the food foresters in Canada, the United States, and the United Kingdom.

Healthy Habitats. One of the underlying values of the food forests is to create healthy habitats for both people and other species and to strengthen human-nature connections and communities within. One interviewee (FF-1) emphasized, "Food forestry is not only about feeding us. All living things are people. Birds and earthworms are people. They are just different people from us. So, how can we use this food forest in a way that allows everyone to live?"

A food forest supports health and well-being for people, especially urban communities, providing green, functional space for growing food, for those who otherwise have little or none of their own (FF-4). The Cottonwood Community Garden was transformed from an illegal waste dump site in a low-income, industrial neighborhood in East Vancouver into one of the first public food forests of Canada, providing environmental and social justice benefits simultaneously. In addition, food forests invite people to be more active, integral parts of the landscape and to (re)connect to landscapes where they live, distinguishing them from areas simply providing exercise such as jogging or walking, by creating a "social-ecological connection" (FF-4).

Sustainability. One of the most important goals is to maximize "ecological processes to support a sustainable system" which becomes "self-regulating, self-propagating and self-fertilizing" (FF-7). Over time, food forests should be sustained with lower maintenance and external input than other food production systems, and be able to withstand stresses such as extreme weather events, outbreaks of pest and disease, and temporary absence of maintenance. Yet, the more input that goes into a food forest, the more yields the system is likely to produce (FF-5).

Sustainability is also about socioeconomic management, as many food forest projects require continuous maintenance and monetary input. Both restoration and FF experts emphasize the importance of continuity in ownership and/or systematic governance (including stewardship) (ER-6; ER-7; FF-4). Ideally, a project should be financially viable and/or able to operate over time without relying on external funds (ER-6).

Overall, each goal and attribute was cross-linked to other goals and attributes, and some experts found it hard to prioritize one from another. Nevertheless, some of the goals and the attributes were more important to each food forest than the others, depending on size, landscape context (e.g. urban, protected areas), type of entitlement (private, commercial, and public), personal values, and temporal scales. Figure 4 shows a snapshot of what the Cottonwood Community Garden (urban/public) is currently intended to achieve and its priorities. It was noted that as a food forest evolves, the goals and their importance may change over time (FF-4).

Comparing FF and ER

FF aims to create a food system that is as close to a self-sustaining forest as possible through creating the compositional, structural, and functional diversity of the system (FF-7). One interviewee (ER-8) suggested, "Both food forestry and restoration are premised on restoring sustainable systems, using natural processes, that benefit people and other species. And, both are very complementary." Yet, differences between two practices were identified as well as similarities (Table S4).

Working With Ecological Succession. Both practices (FF and ER) manage succession. A restoration expert (ER-3) stated, "People who are restorationists are successionists because we are all changing something and setting it on a new path. Invasive species moving in is a disturbance event, and you are removing it and you are influencing succession." A food forester (FF-7) manages succession by mulching, irrigation, and removal of

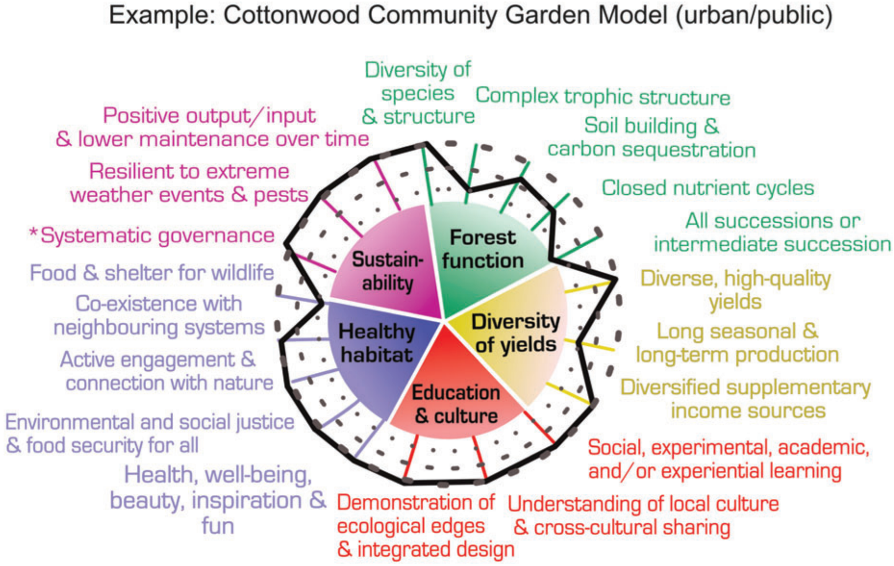

Figure 4. Cottonwood Community Garden Model. This is a snapshot of what the Cottonwood Community Garden (urban/public) is currently intended to achieve, and the outer line implies the highest priority of the garden. As a food forest evolves, the goals and their importance may change over time (FF-4).

weeds and grass from desired young plants. He said, "[Food foresters] We are trying to bypass all—a lot of things that nature takes a lot of time to do." However, the food foresters expressed that there are not many mature, traditional food forests in temperate and cold climates studied to use as a reference, potentially except some homegardens in China (FF-6; FF-7). Also, the restoration experts identified differences in management goals, ideal successional state, introduction of successional species, and climax species.

Attention to Historical Fidelity. Historical fidelity is "loyalty to predisturbance conditions" (Higgs 2003). ER primarily aims to reinstate native biodiversity. "In North America," an interviewee (EF-6) commented, "We often talk about historical baselines and … this idea that we can come back to baselines and that we should be restoring baselines." Another expert argued, "Historical fidelity will separate out restoration from food forestry" (ER-4). Historical fidelity may play a different role, depending on a social and ecological context: "Not all restoration is historically reflective, especially in urban areas, and the choice of restoring historical fidelity becomes site-dependent" (ER-5). In the meantime, historical fidelity might be an important part of FF if it is embedded in traditional management systems and knowledge. Yet, FF may not necessarily restore a forest back to what it was before and more readily accepts novel ecosystems and non-native species (ER-8).

Reflecting Nature by Design. Both practices are "intentional and nature by design" (ER-8). The food foresters underlined "thoughtful design" (FF-4) and "purposeful design" (FF-8), "replicating principles of a forest" or using nature as a model or (FF-7). FF and ER share common design elements such as soil, water sources, sun aspect, site history, slope, plants, and succession. Further, the food foresters highlighted the importance of considering, in design, different values and potential sources of conflict among people who live in the land.

Involving Continuous Management. Both practices generally require higher intervention at an initial stage, ongoing observation, and often adaptation in management, while aiming to create a self-sustaining system. One food forester (FF-7) experienced that 90% of his labor and resources were invested in the first 5 years over the last 30 years. Nevertheless, emerging FF underscores and maybe emphasizes more the value of reconnecting people to landscapes through continuous, active interaction with the system. For example, a food forester (FF-4) described the Cottonwood Community Garden as an "open source landscape": "The idea of a landscape that people actively design, redesign, and constantly adapt to their needs. I would restore it as a process. Soon, other people will come, participate and ultimately change it to what they want. It became a living thing. This landscape never stayed the same."

Considering Livelihoods and Economic Benefits. Most restoration expert interviewees thought that producing yields and/or generating income is still considered less relevant in restoration. Native species will be planted for wildlife but not necessarily for people's use (ER-1). Also, restoration experts warned of the possibility of "trade-off between conservation and yield production" (ER-2) or even the possible danger of "turning forests into a slave for human needs" (ER-3). Meanwhile, a different view was expressed: "Food forestry perhaps has more utilitarian slant to it than ecological restoration, but … ecological restoration has a utilitarian slant to it as well. It might be a different kind of utility. It is looking at the utilitarian value of ecosystems, I suppose, and original ecosystems and combinations. A food forest is not all about food production. It embodies values of biodiversity, cultural diversity, local productivity and bioregionalism—all of these things are part of it" (ER-8).

Supporting Wildlife. Both successful systems can support wildlife, but possibly different types of species. An invertebrate survey (West 2006) found that a food forest (of FF-2) had higher invertebrate taxa richness and more even distribution of the individuals across the taxa than a restored woodland at Dartington, in south Devon, United Kingdom. Yet, the maximum similarity of compositions was less than 50%, which indicates two systems supported different invertebrate communities (West 2006). Similar results were found in a limited study on wildlife biodiversity of tropical homegardens in India by a student of a restoration interviewee (ER-6). These observations might support one of the FF interviewees' argument: "All of these [human/nature exchange at the ecological edges] create an optimal habitat for species that are more dependent on a mosaic of successional vegetative stages and conditions that are harder to find in a climax, closed canopy woodland" (FF-4).

A restoration interviewee (ER-6) suggested FF is an "interesting restoration model" to explore for places where restoring to a historical baseline is no longer possible. She asked: "What is the niche in the middle between recreating something having solid human benefits and restoring function and bringing back some biodiversity and … between that middle of that gradient of wild on one hand and very managed on the other hand?"

Discussion

Good ER should address "ecological, cultural and socioeconomic values of natural-human systems" (Suding et al. 2015). Projects focused on a single principle (e.g. carbon farming with a monoculture of fast-growing species), even though they are valuable themselves, may compromise biodiversity and/or lead to commodification of ecosystems and will not be considered as good restoration (Suding et al. 2015). On the other hand, restoration failing to address a broad range of human needs may experience lack of long-term, public support, which is key for ultimate success of many restoration projects (Hallett et al. 2013).

Suding et al. (2015) propose four core principles for guiding and planning ER as a response to the New York Declaration on Forests at the 2014 United Nations Climate Summit, manifesting global, concerted ambition to restore 350 million hectares of degraded lands by 2030:

1. Restoration increases ecological integrity;
2. Restoration is informed by the past and future;
3. Restoration benefits and engages society; and
4. Restoration is sustainable in the long term.

With careful consideration of emerging challenges that restoration is facing, the core principles are intended to amplify diverse benefits and opportunities of up-scaling of restoration without ecological net loss. These extend earlier work on guidelines, including those issued by the World Commission on Protected Areas (Keenleyside et al. 2012) and the Society for Ecological Restoration Primer (2004). We used these four principles to guide a further examination of the relationships between FF and ER, and to discuss key elements that must be in place for a food forest to contribute to restoration efforts.

Ecological Integrity

What constitutes ecological integrity differs across social, environmental, and ecological settings. Consequently, many definitions exist, encompassing ecosystem health, biodiversity, ecological processes, native species, stressors, resilience, and self-maintenance (Ordóñez & Duinker 2012). These elements are weighted differently in each restoration project (Andreasen et al. 2001; Suding et al. 2015). Restoration in protected areas would prioritize native, "wild" or "pristine" components of ecosystems (e.g. Parks Canada Agency 2005), which sometimes requires exclusion of human activities including use of natural resources and allows only "minor consideration of human dynamics and needs" or activities that assist natural processes (Sarr & Puettmann 2008; Suding et al. 2015). On the other hand, urban forest restoration may focus more on improving ecological processes to support ecosystem services often for human benefits (e.g. flood control), while trying to retain some native species diversity (Ordóñez & Duinker 2012).

Defining Ecological Integrity for Restorative Food Forestry. Defining ecological integrity for restorative FF may not be an easy task; yet, this process will be essential in order to assess the contribution of a food forest project to improving ecological integrity in support of restoration efforts. Suding et al. (2015) suggest that restoration efforts should recover "the complexity of biological assemblages, including species composition and representation of all functional groups, as well as the features and processes needed to sustain these biota and to support ecosystem function" (Suding et al. 2015). Accordingly, the food forest project may consider biotic and abiotic elements of ecological integrity that are essential to sustain ecosystem functions. Similar to restoration projects, specific components of ecological integrity (e.g. native biodiversity, function, productivity) and their relative importance may differ across restorative food forest projects. Meanwhile, a food forest is considered a "human ecosystem" (Jose & Shanmugaratnam 1993) or "designed ecosystem" for production (Higgs 2017). In reality, a food forest project may not necessarily restore the same habitat quality, the same species composition, and/or all values of native forests (Sarr & Puettmann 2008; Crawford 2010).

Discussion on ecological integrity may continue by asking what existing definitions are applicable for restorative FF. Which definitions could manifest the nature of such interdependent, complex social-ecological systems while addressing restoration challenges? As a starting point, we propose the WWF/IUCN (2000) definition used in the context of forest conservation: "Maintaining the diversity and quality of ecosystems, and enhancing their capacity to adapt to change and provide for the needs of future generations." This definition encourages consideration of multiple facets of ecological integrity, from functions, to composition and structure, to resilience, to human needs. It is future-oriented and comprehensive, addressing interdependent relationships between humans and nature embedded in FF. Yet, the food forest project will have to decide specific components of ecological integrity that are most relevant to its landscape settings and objectives.

Informed by Past and Future

Historical knowledge can shed light on how ecosystems functioned in the past and how they might operate in response to changing conditions. In addition, historical knowledge can help to attend to indigenous species, restore cultural significance, and conserve native systems (Higgs et al. 2014).

Use of Native Species and Traditional Knowledge for Food Forestry. Food forests may be used for recovering native structural and compositional diversity to varying degrees. The use of native species that are already adapted to local conditions can help to enhance the habitat quality of food forest for native species and to facilitate continuity of local traditions (Jacke & Toensmeier 2005; Harris et al. 2006; Shackelford et al. 2013). In order to select appropriate native species of varying functions for different conditions, traditional ecological knowledge will be invaluable. For example, the Galiano Conservancy Association in British Columbia, Canada plans to consult with Indigenous Peoples and employ traditional land management techniques and feature native species in one of their food forests.

Building Cultural Fidelity and Diversity Through Food Forestry. Food forestry may contribute to building cultural fidelity. Cultural fidelity includes restoration of a particular traditional activity as well as development of "ways of matching functional characteristics of former practices" from community participation, cultural livelihoods, sense of place, health, traditional knowledge, and local economies, to social justice (Higgs 2003). Throughout the Pacific Northwest, lands and plants have been traditionally managed for food production in ways that promote ecological and cultural diversity through social interaction and exchange of products (e.g. roots, berries, Pacific salmon), knowledge, skills, and beliefs (Turner et al. 2003; Apostol et al. 2006; Turner et al. 2013). The Cottonwood Community Garden produces a variety of edible plants from different cultural traditions and regions as well as native plants. Community members of this garden share recipes and try each other's cuisines, which creates "this wonderful enhancement of the cross-cultural understanding" (FF-6). The Cottonwood Community Garden may help to test if, and how much, FF contributes to restoring a myriad of functional characteristics of traditional food systems in a fast-changing, multicultural urban environment.

Experimenting Cautiously With a Wide Range of Species. In rapidly changing environments, flexibility will be needed regarding the degree of historical fidelity (Suding et al. 2015). Food forests can be used for exploring a wide range of species, especially in urban environments, that are adaptive to different climate trajectories (Gobster 2012). Yet, a thorough assessment of potential impacts of new species, ecologically (including biodiversity, function and resilience), culturally, and economically, should be made before and after introduction (Shackelford et al. 2013). Moreover, any information on anticipated future conditions will be valuable in FF design, for FF to be proactive and adaptive to climate change (Crawford 2010; Walker 2015).

Social Benefits and Community Engagement

Both ER and FF may unintentionally promote adverse commodification of nature and, in doing so, compromise biodiversity and ecological integrity (Suding et al. 2015). Globally, many ER projects attempt to incorporate food crops and economic benefits into restoration (Hallett et al. 2013). Similarly, food forest projects are aimed to deliver ecosystem services (e.g. carbon sequestration, flood control, food production, income generation). As a result, ethical concerns may arise regarding projects that focus solely on economic benefits or ecosystem services.

As an antidote, Suding et al. (2015) underscore the importance of fostering greater understanding of ecosystems and their values through community engagement and education, and of reinforcing a stronger relationship between people and nature. In urban landscapes, many community food forest projects have already placed emphasis on cultivating social learning, stewardship, and connections between people and their landscapes (Jacke & Toensmeier 2005; Clark & Nicholas 2013). Yet, if a food forest project is to contribute meaningfully to restoration efforts, the project should promote the value of other species including ones that seem to play no beneficial role in food production and try to meet needs of these species to cohabit and flourish in the same landscape. Therefore, education and engagement should encourage ongoing dialogue and self-assessment on the ethical balance between conservation and production in FF practices (ER-3; ER-6; ER-8; FF-1).

Long-Term Sustainability

Self-Sustainability. In principle, both ER and FF aim to create self-sustainable systems with intent to minimize intervention over time (SER 2004; Walker 2015). Yet, many studies show that ecosystems have been and will continue to be altered by people living in or nearby (Hills 1988; Kumar & Nair 2006; Hallett et al. 2013; Boivin et al. 2016). In fact, self-sustainability has rarely been stated as a goal for restoration projects, and it can be an unrealistic goal. Instead, public support and long-term stewardship are often considered to be critical attributes of successful restoration projects (Hallett et al. 2013). For FF, ongoing human interaction in many different forms—e.g. (re)designing, pruning, harvesting, and directed succession—is viewed as essential for developing productive, sustainable systems (Kumar & Nair 2006).

Resilience. The earth's systems are undergoing transformation "outside its Holocene stability domain" (Folke et al. 2010) and arguably entering into the Anthropocene (Higgs et al. 2014; Boivin et al. 2016). As a result, "resilience thinking" that emphasizes the capacity of the interdependent social and ecological systems to adapt or transform to, and persist in a desired state has become a crucial aspect of environmental management (Fischer et al. 2009; Folke et al. 2010; Rist & Moen 2013). Concurrently, a growing body of restoration literature is acknowledging the role of humans as an integral part of the development of dynamic and resilient ecosystems, particularly in urban landscapes (Gobster 2012; Davidson et al. 2016). As FF creates and manages a complex social-ecological system that is intended to be sustainable and resilient, resilience thinking could be a powerful guide for FF. However, further discussion is required on how to effectively operationalize the concept of resilience thinking in food forest projects.

Suding et al. (2015) stress that all four restoration principles discussed previously lay "a necessary foundation to achieve sustainability and resilience." Based on their principles, we suggest three considerations to help to achieve long-term sustainability of a food forest project. First, a food forest project should consider environmental and ecological attributes (e.g. genetic diversity, high species interaction, tolerance of ecological communities to extreme events). Second, social elements of resilience are essential and should be carefully integrated in project planning and management: e.g. social learning, economic resources, collective capacity, and governance (Keenleyside et al. 2012; Davidson et al. 2016). Among them, our interview data show that economic self-sufficiency and systematic governance are key social elements for long-term sustainability of food forest projects, in particular community projects. Last, a food forest should not compromise sustainability and resilience of natural and other valued systems in the landscape (Mesquita et al. 1999). Therefore, social and ecological settings will affect the degree and types of ongoing interventions considered appropriate and/or required (Kumar & Nair 2006).

Urban Restorative Food Forestry

Our study suggests that FF may have the biggest ER impact in urban landscapes that often comprise hybrid and novel ecosystems and thus are difficult or impractical settings in which to implement conventional restoration. Urban FF can be used to improve biodiversity, social and environmental justice, and local food security; provide important ecosystem services (e.g. flood control) and economic opportunities; and promote appreciation of multiple values of ecosystems and human-nature connection. Clark and Nicholas (2013) introduce urban FF as "an emerging multifunctional and interdisciplinary approach to increase urban sustainability and resilience" as far as food security is concerned. Urban FF may provide a distinctive opportunity to explore how we might restore unproductive or undesired ecosystems in cities while achieving multiple goals. Yet, this opportunity comes with many challenges such as public safety, governance, land-use competition, regulations of urban planning and landscaping, and the potential dispersal of invasive species. Also, a critical assessment of urban food forests through long-term, systematic monitoring will be essential to test and strengthen urban FF and its applicability to contribute to ER.

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Supporting Information

The following information may be found in the online version of this article:

Table S1. Sixteen interviewees from the fields of food forestry and ecological restoration.
Table S2. Description of the food forests observed.
Table S3. Goals and attributes of participants' food forest(s).
Table S4. Similarities and differences between food forestry and ecological restoration.

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