PERMACULTURE AS FARMING PRACTICE AND INTERNATIONAL GRASSROOTS NETWORK: A MULTIDISCIPLINARY STUDY

BY

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DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Crop Sciences
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2015

Urbana, Illinois

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ABSTRACT

Agroecology is a promising alternative to industrial agriculture, with the potential to avoid the negative social and ecological consequences of input-intensive production. Transitioning to agroecological production is, however, a complex project that requires action from all sectors of society – from producers and consumers, and from scientists and grassroots networks. Grassroots networks and movements are increasingly regarded as agents of change, with a critical role to play in agroecological transition as well as broader socio-environmental transformation. Permaculture is one such movement, with a provocative perspective on agriculture and human-environment relationships more broadly. Despite its relatively broad international distribution and high public profile, permaculture has remained relatively isolated from scientific research. This investigation helps to remedy that gap by assessing permaculture through three distinct projects. A systematic review offers a quantitative and qualitative assessment of the permaculture literature, through the lens of agroecology. This review is organized around a layered conception of permaculture as design, practice, movement, and worldview. The major points of our analysis are as follows: (1) principles and topics largely complement and even extend the agroecological literature; (2) distinctive approaches to perennial polyculture, water management, and agroecosystem configuration suggest promising avenues of inquiry; (3) discussions of practice consistently underplay the complexity, challenges, and risks that producers face in developing diversified and integrated production systems. The second project, an international web survey, with over 700 responses from over 40 countries, provides a first look at permaculture as an international grassroots network. The survey examined self-identified roles of permaculture participants and explored the relationships between those roles and socio-demographic factors race, gender, and socioeconomic status. The influence of structural factors on participant roles was examined by including multidimensional national indices of development, inequality, and ecosystem vitality, for the 45 countries in the sample. Results showed the participation of women at or above parity (53%), while participation by race showed a white supermajority (96%). Multivariate regression demonstrated that race, gender, and socioeconomic status are shaping participation in distinct ways and that each of these variables interacts with structural factors. The third project provides the first systematic investigation of the agricultural sector in permaculture, using innovative methods to gather enterprise-level data at 48 self-identified permaculture farms in the US. This project develops a

preliminary typology of permaculture farms based on livelihoods, and assesses the relationship between farm diversification and labor efficiency. Multilevel modeling shows that both diversification and involvement with permaculture increase returns to labor, but may interfere with each other, and that tree crops have significantly higher returns to labor when integrated with animal production systems.

This project was made possible through the support of the Jonathan Baldwin Turner Graduate Fellowship, and the Agroecology Scholars Fund of the Agroecology and Sustainable Agriculture Program.

Thank you to the 196 donors to the crowdfunding campaign that made my field research possible. Special thanks to Andy and Peter for especially generous donations. My heartfelt gratitude to the 48 farmers who took time from their demanding schedules to spend a day with me, and the hundreds of permaculturists around the world who took time to respond to the web survey. In the most literal sense this project could not exist without you.

To my committee, thank you:
Tom Bassett, for introducing me to political ecology and thereby inspiring this project.
My advisor Sarah Taylor Lovell, for giving me enough rope – and not letting go of the rope.
Michelle Wander, for being authentically excited about my work.
Ashwini Chhatre, for real talk and an activist's critical commitments.

To all of my family, thank you for all of your multifaceted support through the years and through this academic venture. To my sister Melissa, thank you for all the coaching from your insider's perspective on academia. I probably wouldn't have even stuck my foot in the door without your encouragement.

To my chosen family, thank you:
Brook, Eric, and Meadow, for believing in me.
To the whole Salon for Major Works in Progress crew,
for all of us believing in each other.

TABLE OF CONTENTS

1
Introduction

WHY PERMACULTURE?

The challenges of transitioning our global society to a mode of operation that does not erode its own prospects for survival are complex and multi-layered. There is no longer any doubt that we face a host of converging and intersecting crises. Attempting to inventory these crises produces a list that is inevitably messy, overwhelming, and incomplete: climate change, peak oil, habitat loss and mass extinction, ocean acidification, the ongoing release of toxic and long-lived pollutants, and so on. While such an inventory is inevitably incomplete, as written this list is not only unfinished but critically deficient. Environmental crises are always already political-economic crises (Moore 2015; Park et al. 2008). Any attempt to diagnose the former is hopeless without accounting for their complex linkages with the latter, e.g. spiraling inequality within and between nations (Piketty 2014; Pickett and Wilkinson 2011), the increasingly unstable global economic order (Crotty 2009; Klein 2015), the active erosion of democratic processes and the commensurate accumulation of power in the capitalist owning class (Cerny 1999; Klein 2008; Gilens and Page 2014), and global military conflict (Le Billon 2001; Brauer 2011; Hsiang et al. 2011.)

Evidence and theory both suggest that institutions that have been entrusted with the administration of a ruinous industrial society are not up to the task of navigating the transition to a radically different socio-environmental order (Smith and Watch 2007; Bekessy, SA et al. 2007; Krey and Riahi 2009; Houston 2013). The tools used to build and maintain the world-system are especially ill-suited to transform that system - or as Audre Lord put it so powerfully: “The master’s tools will never dismantle the master’s house” (Lorde and Clarke, 2007). With increasing recognition of the failure of top-down regulatory and market-based initiatives to address socio-environmental issues, more attention is being paid to the importance of actors from outside of large institutions (Seyfang and Haxeltine 2012, Ernstson et al. 2008, Leach et al. 2012, Bergman et al. 2010). Grassroots actors and their aggregates - networks, communities, and movements - are increasingly looked to as critical agents in transition and transformation.

The food system is no exception to the diagnosis of institutional failure and grassroots agency. To the contrary, the food system by nature occupies a central position within broader issues of sustainability. The emerging food sovereignty perspective illustrates the international rise of a shared understanding of the importance of grassroots agrarian perspectives and the centrality of the food system within broader projects of collective liberation (Patel 2009; Wittman et al. 2011). In short, a societal transition to sustainability requires an agroecological transformation, and such an agroecological transformation requires, in turn, a transformation of society at large.

We are interested, therefore, in perspectives and modes of action based in the grassroots, and that encompass both agrarian sectors (those working directly at the production end of the food system) and metropolitan sectors (non-agrarian society at large). This investigation addresses permaculture, an international grassroots movement that fits these criteria and thus represents a potential force for transformation. Loosely coordinated and sparsely institutionalized, permaculture includes agrarian and metropolitan sectors in a vision of bottom-up socio-environmental transformation. It mobilizes participants in agrarian and metropolitan settings in ways that help transcend the agrarian/metropolitan binary: land-based livelihoods, grassroots action networks, and cultural service professions (such as teaching and design) are spread widely across rural-urban gradients – and sometimes, across national boundaries.

This anecdotal description does not get us very far in understanding what is at stake in invoking permaculture as a contributing force for transformation. To date, there has been very little critical, systematic assessment of any sector of permaculture, and this has placed severe limitations on our ability to assess the potentials and pitfalls of looking to permaculture in this capacity.

GUIDING QUESTIONS

The overriding question motivating this investigation is:
To what extent, and how, does permaculture represents a force for positive change toward socio-environmental transformation?

This overriding question is embodied in three other questions, each of which serves as a starting point for a project. How credible and plausible are the proposals emerging from the permaculture perspective on agriculture? Who, in socio-demographic terms, is participating in the permaculture network, and how do socio-demographic factors shape participation? What happens when the principles and ideals of permaculture touch down in production landscapes –in other words, what is happening on permaculture farms?

How credible and plausible are permaculture's proposals?

While permaculture originally emerged from an academic collaboration between Bill Mollison and David Holmgren, since that point it has been largely isolated from the scientific community. Despite a high public profile, broad international distribution, and a voluminous popular literature, the claims and proposals of permaculture's advocates have never been systematically reviewed or assessed. This has created a bottleneck for the emergence of permaculture research. It is difficult to investigate any topic in a rigorous fashion when basic questions about *what has been said* remain unanswered.

Who, in socio-demographic terms, is participating in the permaculture network, and how do socio-demographic factors shape participation?

There is ample anecdotal evidence, in the form of popular literature and web presence, to situate permaculture as an international grassroots network with a distinctive focus on socio-environmental transformation. This same anecdotal evidence suggests that participation in permaculture is strongly shaped by socio-demographic factors. There has never, to our knowledge, been any systematic assessment of participation in the permaculture movement, in socio-demographic or any other terms. Our ignorance of who is participating in permaculture, and how socio-demography shapes participation, is a serious constraint on our ability to assess permaculture's actual and potential impact or to identify barriers to efficacy and growth.

What happens when the principles and ideals of permaculture touch down in production landscapes –in other words, what is happening on permaculture farms?

Diversified farming systems in the US have been in stark decline for the past 80 years, and face formidable challenges in the contemporary market and policy environment. Facing a lack of

programmatic support, many farmers turn to alternative and grassroots farmer networks for support. While historically associated with garden- rather than farm-scale production, it appears the permaculture network is increasingly involved in this role: as farms, as a venue for farmer-to-farmer knowledge exchange, and as a set of resources (workshops, literature) intended for farmers managing diversified systems. We have no knowledge, however, of what is happening on farms that identify with permaculture, or that are involved with the permaculture network. In order to understand the growing agrarian sector in US permaculture, and the challenges and opportunities it represents, we need to develop a first look at permaculture-identified farms.

PROJECTS

The commonalities and parallels between permaculture and agroecology make the latter an especially useful lens for building a more systematic understanding of the former. Both agroecology and permaculture are multilayered phenomena, that include professionals charged with promulgating a formal, universalized, abstract system of knowledge, as well as a community of land users applying and adapting principles in particular, concrete, dynamic places. Both share a central concern with the intersection of ecology and production landscapes, and a fundamentally critical, normative orientation toward agroecological transition.

Chapter 2 contributes an understanding of permaculture through a systematic review of the permaculture literature, relating it to the literature of agroecology and closely allied disciplines. The transdisciplinary nature of agroecology permits the organization of the review around four aspects of permaculture: design system, best practices framework, movement, and worldview. This review addresses foundational questions: What are the major themes and proposals emerging from the permaculture literature? Where does the permaculture literature line up with the agroecology literature? Where the two literatures are not in accordance, when is it the case that the permaculture literature is shining a light on a topic that agroecologists should be paying better attention to? When is it a case of potential distortion and oversimplification in the permaculture literature?

Permaculture is not only an agrarian phenomenon, and the project described in Chapter 3 was directed toward an understanding of permaculture across the rural-urban gradient. This chapter

describes the results of a web survey conducted in 2012 which was open to anyone who identified with permaculture in any way. The survey received a high level of response despite being rather long, with no financial incentive, administered only through the web, and only being available in English. After culling responses with low levels of completion and/or no geographic information, 731 responses from 44 countries remained. In the analysis presented here, the socio-demographic distribution of the sample is described and related to national-level distributions. Multivariate statistical analysis is used to identify modes of participation with permaculture, and to identify the ways in which those patterns are shaped by socio-demographic factors.

Chapter 4 presents the results of field research to address the gap in our understanding of permaculture's growing agrarian sector. In between June 2013 and January 2014 and over 18,000 miles of driving, the author visited 48 self-identified permaculture farms. Sites were selected based on participants self-report of permaculture's influence on farming practice. No a priori assumptions about practice were made, in the interest of exploring the negotiation between the abstract principles of permaculture and specific sites, with their own complex social and environmental dynamics and livelihood needs. An innovative spreadsheet-based application was developed to facilitate gathering farm- and enterprise-level economic data from highly diversified operations with highly varying levels of documentation. The analysis presented here presents a preliminary typology of permaculture farms based on farm livelihoods, and a model of the relationship between diversification and returns to labor (or labor productivity).

DESIGN

One of the distinctive aspects of permaculture identified in this review is design (see Chapter 2 for more discussion of these issues). Permaculturists themselves most often define permaculture as a design system. The spatial conceptual tools discussed in permaculture literature and taught in permaculture design courses appear to be original to permaculture (unlike permaculture practices, which are adopted from various sources). Embedded in the discussion of these design tools are salient and provocative hypotheses about spatial configuration in agroecosystems.

Despite the importance of design to understanding permaculture, design is not addressed directly in the analyses presented here. However, data on land use and agroecosystem configuration gathered in the course of this investigation, but not integrated into this document, will provide the basis for future publications that directly address questions of design.

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2

Permaculture for agroecology: design, movement, practice, and worldview[1]

INTRODUCTION

Increasing concerns about the negative impacts of industrial agriculture have generated a vigorous debate over the feasibility of transition to alternative forms of agriculture, capable of providing a broad suite of ecosystem services while producing yields for human use. The transition to diversified, ecologically benign, smaller-scale production systems is addressed in the literature of agroecology (De Schutter 2010), diversified farming systems (Kremen et al. 2012), and multifunctional agriculture (Wilson 2008). Agroecological transition must be regarded as a complex, multi-sector project, operating at multiple temporal and spatial scales and involving diverse constituencies (Geels and Kemp 2007; Marques 2010; Piraux et al. 2010). For this reason, researchers have often directed their attention outside of institutional science, to document the contributions that traditional and innovative practices offer to the process of transition (Altieri 2004; Ingram 2007; Rocha 2005; Koohafkan et al. 2012; Rosset et al. 2011). Alternative agroecology movements, for example, have been critical in the process of regional agroecological transition (Nelson et al. 2009; Altieri and Toledo 2011), and likely will be in the future (Fernandez et al. 2012; Petersen et al. 2012).

This paper addresses the alternative agroecology movement called permaculture and its potential contributions to agroecological transition. Permaculture is an international movement and ecological design system (Figure 2.1). Despite permaculture's international extent and relatively high public profile, it has received very little discussion in the scientific literature. The term originated as a portmanteau of permanent agriculture, and is defined by co-originator David Holmgren as "Consciously designed landscapes which mimic the patterns and relationships found in nature, while yielding an abundance of food, fibre and energy for provision of local

[1] Reprinted with permission from: Ferguson RS, Lovell ST (2014) Permaculture for agroecology: design, movement, practice, and worldview. A review. Agronomy for Sustainable Development 34:251–274. doi: 10.1007/s13593-013-0181-6

needs" (2004, p. xix). As a broadly distributed movement with a distinctive conceptual framework for agroecosystem design, permaculture's relevance to the project of agroecological transition has several aspects. Permaculture can function as a framework for integrating knowledge and practice across disciplines to support collaboration with mixed groups of researchers, stakeholders, and land users. Permaculture contributes to an applied form of ecological literacy (Orr 1992), supplying a popular and accessible synthesis of complex socio-ecological concepts. The design orientation of permaculture offers a distinctive perspective that suggests avenues of inquiry in agroecosystem research. Lastly, these factors are embodied in an international movement that operates largely outside of the influence and support of large institutions, which suggests opportunities for participatory-action research and the mobilization of popular inquiry and support (Méndez et al. 2013).

The potential of permaculture to contribute broadly to agroecological transition is limited by several factors. Of primary importance is the general isolation of permaculture from science, both in terms of a lack of scholarly research about permaculture, and neglect within the permaculture literature of contemporary scientific perspectives. This deficit is compounded by overreaching and oversimplifying claims made by movement adherents, and the absence of any systematic multi-site assessment of permaculture's impacts. Additionally, the difficulty of providing a clear and distinguishing description of permaculture can cause confusion and hinder rigorous and systematic discussion.

The objective of this paper is to contribute to a better understanding of the substance, strengths, and limitations of permaculture as a potential contributor to agroecological transition. Introductory material includes a brief overview of the origins and development of permaculture, the growth of the movement over time, and a preliminary heuristic for comparing the prominence and overlap of permaculture and agroecology across several sectors. The introduction is followed by a systematic review of scientific and popular permaculture literature, analyzing publication type, date, and location, topic location, scholarly discipline, and citations. Systematic analysis also includes quantitative content analysis using a concept network approach. Qualitative review of the permaculture framework then identifies and evaluates prominent themes in the permaculture literature, focusing on agroecological topics. Finally,

qualitative and quantitative analyses are synthesized to produce an overall evaluation of permaculture, including recommendations for future directions for research and dialog.

BACKGROUND

Shifting Definitions

The definition of permaculture varies among sources, and displays an expansion in subject area over time. In 1978, permaculture was defined in the founding text as "an integrated, evolving system of perennial or self-perpetuating plant and animal species useful to man ... in essence, a complete agricultural ecosystem, modeled on existing but simpler examples." (Mollison & Holmgren, p. 1). By the 1988 the definition had grown in scope to encompass broader issues of human settlement, while maintaining a core agricultural focus: "Permaculture … is the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems. It is the harmonious integration of landscape and people providing their food, energy, shelter, and other material and non-material needs in a sustainable way" (Mollison). While permaculture addresses multiple aspects of human settlement, this paper will focus primarily on those aspects of permaculture relevant to agriculture and agroecological transition.

Historical Context

Permaculture emerged in parallel with other movements and disciplines with a focus on sustainability. In the past 50 years, concerns over the negative social and environmental impacts of urbanization, industrial agriculture, and resource extraction and depletion, have expanded dramatically (De Steiguer 2006; Hawken 2007; McCormick 1991). Over this period, public and scientific concern for environmental degradation has spread from isolated voices, through environmental movements and emerging scientific disciplines, and into mainstream science and popular culture (FitzSimmons et al. 1991). Environmental movement participants have produced diverse proposals for alternative food production (Lockeretz 2008), international development (Dahlberg 1979; Cole 1981), generating energy (Clark 1975), and planning settlements (Alexander 1977). In parallel, and often intersecting with, the proposals of environmental and social movements, scientists and development professionals have proposed alternative

frameworks for managing natural resources and fostering economic development. Through the 1970s and 1980s, agroecology (Wezel and Soldat 2009), agroforestry (Nair 1993), ecological design (Todd 2006), and appropriate technology (Pursell 1993) emerged as movements and disciplines of their own. Other and older approaches, such as organic farming, experienced rapid growth and widespread acceptance (Lockeretz 2008). Many of these alternative frameworks now approach the mainstream, through the incremental accumulation of scientific evidence, institutionalization, or as in the case of organic farming, through certification and large-scale commercialization.

Permaculture was founded in the 1970s by Bill Mollison and David Holmgren, and now has a presence on every inhabited continent. Permaculture's founders shared broad environmental concerns with the movements described above, while focusing specifically on the threat of energy scarcity for energy-intensive agricultural systems (Mollison and Holmgren 1978). Mollison and Holmgren drew on many sources in their development of the permaculture framework, but were especially influenced by the British and US literature of permanent agriculture, and the systems ecology/ecological engineering perspective of H.T. Odum (Mollison and Holmgren 1978; Holmgren 2004).

Conceptual Influences

Permanent as Sustainable and Perennial

The term permanent agriculture, from which the word permaculture is derived, has multiple uses. Permanent agriculture is used to contrast sedentary, continuous agriculture with shifting cultivation in discussions of the latter (q.v. Rasul and Thapa 2003; Geist and Lambin 2002). Examination of the British and US literature on farming practices in the early 1900s suggests that the “permanent” was used in an analogous fashion to the current use of the term sustainable (King 1911; Howard 1940). With the publication of J. Russell Smith's foundational agroforestry text Tree Crops: A Permanent Agriculture, "permanent" came to connote agricultural systems incorporating a high proportion of perennial species (Smith 1929). It is this concept for which permaculture is named. Mollison and Holmgren adopted Smith's emphasis on the importance of tree crops for soil stabilization in hillside agriculture, production of fodder, and production of complementary and staple foods for human consumption (Mollison and Holmgren 1978). The

portmanteau of "permanent agriculture" was later redefined as "permanent culture" as the scope of permaculture expanded from the design of smallholder agriculture to encompass human settlement more broadly (Mollison 1988).

Systems Ecology

Permaculture's emphasis on whole-systems design is heavily influenced by the work of ecologist H.T. Odum (Holmgren 1992). Odum developed the influential framework of systems ecology, a thermodynamic perspective that regards ecosystems as networks through which energy flows and is stored and transformed, which can be diagramed and modeled in a manner analogous to electronic circuits (Odum 1994). Odum referred to the applied form of systems ecology as ecological engineering, and this design perspective would shape fundamental components of the permaculture perspective (Holmgren 2004). In the highly cited book Environment, Power, and Society (1971), Odum proposes an approach to the design of novel and productive ecosystems in which species are regarded as distinctive but interchangeable system components which should be selected from a global pool without regard to place of origin. In this view, the distinctive inputs and outputs of each species will connect in novel assemblages, and the exchanges of energy and resources between system components will substitute for human labor and material inputs. Ecosystems designers should therefore foster self-organization through the iterative "seeding" of diverse species from the global species pool, in order to generate and select ecosystems which produce yields for human use with minimal labor input (Odum 1971, p. 280). The influence of this focus on functional relationships between components, the self-organization of systems, and species selection practices, is reflected throughout the permaculture literature (Mollison 1978; Mollison 1988; Holmgren 2004; Hemenway 2009).

Keyline Planning

Holmgren and Mollison were also informed by the whole-landscape approach of the Australian Keyline design system (Holmgren 2004). From the 1950s to the 1970s, farmer and writer P.A. Yeomans developed a system that integrated novel methods for landscape analysis with whole-farm water management, agroforestry, soil building strategies (using slightly-off-contour chisel plowing and rotational grazing), and the development of new chisel plow designs for use in the

system (Yeomans 1954; Yeomans 1954; Yeomans 1971; Yeomans 1981). Yeoman's Keyline system has received very little attention in the scientific literature. Keyline Planning is nevertheless an innovative application of design to agricultural landscapes, and shaped the approach taken by Holmgren and Mollison (Mulligan and Hill 2001, p. 202), who adopted many of the concepts of the Keyline plan directly into the developing permaculture framework (Mollison and Holmgren 1978; Mollison 1979).

Permaculture and Agroecology

In the past three decades, permaculture has grown in parallel with agroecology, displaying overlapping concerns while developing different constituencies. Permaculture shares with the discipline of agroecology a focus on the intersection of ecology and agricultural production, a normative orientation toward agroecological transition, and an association with popular movements consisting largely of land users. Despite these parallels, permaculture has received very little discussion in the agroecological literature. When permaculture is mentioned, it is frequently found as an item on a list of alternative agricultural frameworks, the value of which is either explicitly in question (Gomiero et al. 2011; Pretty 2006; Bavec et al. 2009; Pretty 2005), or positive but nonspecific (Leakey 2012; Deb et al. 2008; Lovell et al. 2010). Permaculture is elsewhere associated positively, albeit in passing, with agroforestry, perennial polycultures, agroecosystem design, ecosystem mimicry, and agrobiodiversity (Francis and Porter 2011; Torre Ugarte and Hellwinckel 2010). Substantive assessment of permaculture as an approach to agriculture, positive and negative, appears to be absent from the peer-reviewed literature.

This absence is surprising in light of permaculture's international public profile. Parallel queries of online databases for the terms ‘permaculture' and ‘agroecology' can be used to illustrate patterns in the relative prominence and overlap of each field across sectors. This fairly crude comparison is presented here (Figure 2.2) in a preliminary fashion, to demonstrate that the sparse representation of permaculture in the scientific literature is incommensurate with a high level of general interest. The proportions of results returned for each term varied widely across data sources. The scientific databases Web of Knowledge and Google Scholar returned 21 and 6 times as many results for agroecology as for permaculture, respectively, while general purpose internet search engines Google and Bing were skewed in the opposite direction, returning 11 and

7 times as many results for permaculture as for agroecology, respectively. Multipurpose literature databases for book sales were less asymmetrical, with approximately equal results for each term in Google Books and twice the results for permaculture in Amazon. Document archives of international development organizations (US AID, Peace Corps, and FAO) were highly and heterogeneously skewed, respectively returning 3 times the results for agroecology as for permaculture, 41 times the results for permaculture, and 21 times the results for agroecology.

In addition to the parallels described above, permaculture shares with agroecology a complex stratified definition. Recent scholarship has clarified that agroecology simultaneously refers to a scientific discipline, a social movement, and a set of agricultural practices (Wezel et al. 2009). Similarly, some of the confusion surrounding permaculture may be attributed to the use of the term to refer to a design system, to an international movement, to the worldview carried by and disseminated by the movement, and to the set of associated practices. Figure 3 is a conceptual map intended to clarify the relationship among the different strata that make up permaculture, each of which intersects with the project of agroecological transition. This conceptual structure will be used to organize the examination and assessment of the permaculture literature.

REVIEW METHODS

This study integrates multiple review methods to address the challenges of assessing and synthesizing a large and diverse literature, much of which is intended for a popular audience. In the absence of any previous reviews, it is useful to address quantitative questions of what has been published, in what form, where, and about what geographic regions. Qualitative review will then address questions of topic, theme, and assessment in terms of current scientific understanding, in order to evaluate the actual and potential contributions of permaculture to agroecological transition.

Systematic Review

A systematic review methodology used in numerous previous studies was adapted for application to the body of permaculture literature (Guitart et al. 2012; Wezel and Soldat 2009). The permaculture literature differs from most subjects of systematic review in the large number of publications intended for a popular audience, the large number of book-length publications, the

small number of peer-reviewed works, and the absence of experimental design and statistical analysis from almost all works.

Search Protocol

Parallel searches were conducted on Web of Knowledge (WOK), Google Scholar, AGRIS, and ERIC, using the search term "permaculture." In the case of Google Scholar, the search was constrained to articles with the search term appearing in the title field. While this criterion excluded many works that substantively pertain to permaculture, it avoided including any works for which the relationship with permaculture was ambiguous or trivial. Effort was made to eliminate self-published and exclusively electronic works, unless they were listed as having been cited within Google Scholar, in order to focus on publications for which there was some evidence of readership. Academic theses and dissertations were exempted from this consideration. For WOK, AGRIS, and ERIC, publications with 'permaculture' appearing in any field were included. References for book reviews of works appearing elsewhere in the bibliography were not included. The search protocol was concluded 18 December 2012. Results included prepublication data on one book chapter slated for publication in April 2013, and the terminal year of the bibliography is therefore 2013.

While this study addresses English-language literature only, a supplementary search protocol was used for the preliminary identification of concentrations of permaculture literature in other languages. Language localizations of Google Scholar were queried in Spanish, Portuguese, German, French, Arabic, Japanese, and Russian, and the number of search results was recorded and compared to results for the English-language search. No other data were collected for non-English literature.

Bibliometric Analysis

The search protocol described above was used to assemble the bibliography for analysis. After the elimination of duplicate and spurious results, the bibliography contained 230 references. Each reference in the bibliography was identified as book, journal article, graduate thesis, book chapter, conference proceeding, periodical article, or miscellaneous (Table 1). Journal articles included peer-reviewed and non-peer reviewed works. Periodical articles included magazine, newspaper, and newsletter articles. Scholarly and technical publications were identified as a

subset of total publications. Peer-reviewed publications were identified as a subset of scholarly publications.

For scholarly works (including refereed and non-refereed publications), the discipline of the journal (for articles), the academic program (for theses and dissertations), or the conference (for proceedings) was determined. When the institutional discipline could not be determined, the discipline of the author(s) or the apparent discipline of the publication topic was used. Disciplines were sorted into categories according to a three-tiered disciplinary taxonomy that synthesizes seven other major disciplinary taxonomies (bepress 2010). Citation statistics were recorded for each reference. As the majority of the references in the bibliography appeared solely in the Google Scholar searches, citation statistics were derived exclusively from Google Scholar queries. The bibliography was analyzed for two geographic values: place of publication, and place of topic. Place of publication data was obtained for all references, and a place of topic was identified in 135 references.

Concept Network

Keywords for each reference were drawn from multiple fields to accommodate the diversity of publication types represented. Title keywords were included for all publications, and author keywords were included whenever present. Abstracts were included for scholarly articles whenever available. Jacket blurbs were included for books whenever available. Textual analysis was carried out with word co-occurrence analysis (He 1999) using a concept network approach (Popping 2003) that incorporates analysis of probabilistic word co-occurrence with relative word position, and represents relationships between keywords as a network graph. This quantitative approach to text analysis allows for the exploratory analysis of meaning, context, and change over time, in large bodies of text, while providing an alternative or complement to qualitative coding (He 1999). Keyword text was analyzed in four time frames: the three sequences of 1978-1992, 1993-2002, 2003-2013, and also as a complete sequence 1978-2013. The text of each sequence was submitted individually to the web-based analytical engine Textexture (http://textexture.com/). Textexture performs several pre-analysis processes, including the removal of common and semantically trivial words (including articles, conjunctions, modifiers, etc.), and stemming words using the Krovetz Stemmer algorithm to reduce complexity and redundancy between closely associated words (Paranyushkin 2011). Once the text is prepared,

Textexture performs a two-pass analysis to convert text into network data. Scanning first in 2-word and then in 5-word units, Textexture creates a node for each novel word it encounters, and creates or strengthens links between nodes each time words co-occur within a scanning unit (Paranyushkin 2011). Textexture provides its own visualization engine, but for the purposes of this study, the graph data was downloaded as a Graph Exchange XML Format (GEXF) file, and visualized using the open-source graphing software Gephi (Bastian et al. 2011). Once loaded into Gephi, each of the four graph files was processed identically. Nodes were sized according to the betweenness centrality (BC) metric, which measures the number of node-pairs whose shortest connecting path passes through the target node (Brandes 2001). Nodes were then clustered using a community detection algorithm based on modularity, which identifies groups of nodes whose mutual connections are denser than their connections to the rest of the network (Newman 2006; Paranyushkin 2011). Each cluster was assigned random colors. Size of nodes therefore shows the number of contexts in which each term appears, while color and grouping show the most significant contexts in which each term appears. Edge thickness was determined by weight — the frequency of the word-pairs represented by each node. Only 100 most significant nodes from each time frame, by BC, are represented in each graph. All edges with a weight of 1, signifying that the word pair they connected only co-occurred in a single instance, were filtered from the visualization to enhance readability.

Qualitative Review

The texts examined for qualitative analysis included additional publications, not included in the bibliography, selected on the basis of authorship by key movement figures, reference in influential works in the bibliography, or special relevance to themes identified in ongoing analysis. Qualitative analysis also draws on additional non-print sources, including websites, online discussion platforms, and video. Sources were examined for prominent themes with a bearing on agroecological transition, and assessed in relationship to contemporary science. Results from the systematic review were used to triangulate with and inform qualitative analysis.

The high level of redundancy in the permaculture literature has been noted elsewhere (Scott 2010), such that a significant portion of publications devote some space to reiterating foundational material developed in a small number of key publications (Mollison and Holmgren 1978; Mollison 1988; Mollison and Holmgren 1978; Holmgren 2004). Key publications will be

cited when the intent is to clarify origins, while multiple derivative publications will be cited when the intent is to illustrate prevalence.

RESULTS

Systematic and Bibliometric Review

In this section, the results of the systematic and bibliometric analyses are presented, including publication type, citations, publication and topic geography, scholarly discipline, and concept network.

Publication Type

The three most prolific publication types in the bibliography were journal article (50), graduate thesis (46), and book (41). While journal articles and theses are most numerous, when publication length is considered it is clear that books represent the bulk of published content on permaculture. Along with overall growth in publications, the distribution of publication types changes over time (Figure 2.4a), and the three publication types showing the most growth in per year publications were journal articles (from 0 to 21), graduate theses (0 to 20), and book chapter (0 to 11). The majority of the permaculture literature is written by non-scientists for a popular audience. Scholarly works, and the subset of peer-reviewed publications within that category, are present as a minority of publications throughout the bibliography, representing 54.3% and 13.9%, respectively. The total share of scholarly and peer-reviewed publications has fluctuated while growing over time (Figure 2.4b), from 33% from 1978-1982, to 71% from 2008-2013.

The 122 scholarly publications in the bibliography are distributed across a broad set of natural and social scientific and professional disciplines (Figure 2.5). The most prevalent disciplinary categories, in descending order, are Social and Behavioral Sciences (41), Life Sciences (28), Architecture (23), and Education (14).

Geography of Publication and Topic

English-language permaculture literature originates predominantly from the United States, Australia, and the United Kingdom (Figure 2.6a). The geographic distribution of permaculture writing in the bibliography has become more widely spread over time, from 49% Oceania

(Australia and New Zealand) and 41% North America in 1978-1987, to 43% from North America, 34% Europe, 9% Oceania, 6% Africa, and 9% Asia, in 2008-2013.

Sixty percent of the references in the bibliography could be determined to have a geographically specific topic. As in the geographic distribution of the publishing, the topics of permaculture publications were initially confined to the US and Australia, and became more widely distributed over time (Figure 2.6b). In 2008-2013 period, 35% of publications in the bibliography referred to North America, 8% to Oceania, 22% to Europe, 18% to Africa, 6% to Latin America, 6% to South Asia, 4% to East Asia, and 2% to West Asia.

For references with geographically specific topics, both country of publication and country of topic were classified as "Developed" or "Developing," using the Human Development Index (Malik 2013). Countries in the "Very High Human Development" category were classified as "Developed," and countries in the other three categories were classified as "Developing." Of the 135 references with geographically specific topics, 95 were classified as domestic, with publication and topic taking place in the same country, and 41 classified as international. Of domestic references, 76 were from the developed world and 19 from the developing world. Of the 37 international references published in the developed countries, 17 dealt with topics in developed countries, while 21 examined topics in developing countries. Of the 3 international references published in the developing world, 2 examined topics in developed countries, and 2 examined topics in developing countries — with one of the references dealing with topics in both a developed and a developing country. The country-by-country relationship between publication and topic is represented as a geographic network in Figure 2.7, while the proportional distribution of geographic publication-topic relationships is shown in Figure 2.8.

Queries to multiple language localizations of Google Scholar returned results concentrated in English-language literature. With 7190 search results, results in English represented 59% of the total results. In descending rank, returns for other languages were Spanish (2190), Portuguese (1980), German (294), French (267), Arabic (95), Japanese (44), and Russian (30). Past research has identified an English-language bias in Google Scholar (Kousha and Thelwall 2008; Neuhaus et al. 2006). Interpretation of these results is therefore limited to the observation that a significant

minority of permaculture literature is in languages other than English, and is not addressed in this study.

Concept Network

The network graph produced from the complete series of references, from 1978-2013, contained 1330 edges, with each edge representing the co-occurrence of one word pair. Figure 2.9 shows the full 100-node network for each time interval and the complete set, illustrating the changing centrality and contextual significance of key terms over time and in aggregate. The modularity algorithm produced six conceptual clusters in the complete sequence, each densely linked to a central term and to each other (Figure 2.9d). The central terms, in descending order of importance (by BC), were design, community, sustainable, farm, study, and resource. The network produced from the text of the first sequence of references, from 1978-1992, contained 526 edges (Figure 2.9a). The modularity algorithm identified eight conceptual clusters, organized around the following terms: design, agriculture, present, urban, resource, create, base, and housing. The five most central clusters in each interval, with the five most central terms in each cluster and their BC score, are shown in Table 2. The text extracted from the 1993-2002 references produced a network with 911 edges (Figure 2.9b). Seven conceptual clusters were organized around the terms design, community, book, garden, land, study, and system. The 2003-2013 text produced a network with 1467 edges (Figure 2.9c). Seven conceptual clusters were identified by the modularity algorithm, organized around the terms design, development, farm, food, land, sustainability, and study

Qualitative Review

In the following section, prominent themes in the permaculture literature are synthesized and assessed in relationship to contemporary scientific perspectives on agroecological transition. Results from the quantitative analysis are used to triangulate with and inform qualitative interpretation of permaculture literature. Qualitative results are organized by the levels of the stratified definition of permaculture proposed above.

Design

Published definitions of permaculture emphasize its status as a system for the design for human settlements, with an emphasis on productive landscapes (see Sec. 2.1 above). The concept network analysis reinforces the importance of design as a core component of permaculture, as 'design' is the most central concept in each of the three sequential analyses (1978-1992, 1993-2002, 2003-2013) and in the complete sequence (1978-2013).

The permaculture design system utilizes ecological and systems-thinking principles, and spatial reasoning strategies, which are used to analyze site conditions, select practices, and integrate them with site conditions and land use goals (Mollison and Holmgren 1978; Mollison 1988; Holmgren 2004). Figure 10 shows a selection of permaculture principles, grouped into themes and related to principles and design issues in agroecology and related literature. The most distinctive aspects of the permaculture orientation toward agroecosystem design are its emphases on (1) site specificity, including attention to microclimate; (2) interaction between components at multiple scales, from field-scale polycultures to agroecosystem-scale land use diversity; and (3) spatial configuration as a key driver of multiple functions.

From the perspective of permaculture design, crops and land uses should be selected and placed to reflect a fine-grained analysis of in-site heterogeneity, including topography, microclimate, and existing vegetation (Mollison 1988; Jacke and Toensmeier 2005). Microclimate effects, driven by local and regional topography and vegetation, can be leveraged to maximize energy efficiency and identify sites for otherwise marginal crops (Mollison 1988). Ponds and equatorially-oriented slopes, structures, and woody vegetation, are identified as key sites at which extreme cold temperatures are moderated by thermal-mass and heat-trapping effects (Mollison 1988; Holzer 2011), which may accommodate less hardy species. The permaculture

approach to microclimate is derived from a single influential source first published in 1927 (Geiger and Steward 1950). Discussion of agricultural microclimate in the scientific literature is ongoing (Orlandini et al. 2006).

Land use diversity appears in the permaculture literature in forms that include tightly integrated terrestrial and aquatic systems, animal and plant production, and annual and perennial plants (Mollison and Holmgren 1978; Mollison 1988; Bane 2012). This emphasis is consonant with the scientific literature, in which the benefits to productivity generated by synergies between multiple enterprises have been demonstrated repeatedly (Frei and Becker 2005; Jamu and Piedrahita 2002; Berg 2002; Gomiero et al. 1999; Kadir Alsagoff et al. 1990; Talpaz and Tsur 1982; Devendra and Thomas 2002; Rukera et al. 2012; Dey et al. 2010; Pant et al. 2005; Dalsgaard and Oficial 1997). Integration of multiple enterprises has been shown to increase labor efficiency (Dey et al. 2010), and to enhance all dimensions of multifunctionality, including food security and environmental, economic, and social functions (Tipraqsa et al. 2007).

Permaculture's emphasis on configuration is expressed in the Principle of Relative Location, and the design tools Zones of Use and Sectors. Hemenway defines Relative Location in this way "…place the elements of your design in ways that create useful relationships and time-saving connections among all parts" (2009, p. 6). 'Sectors' refers to directional forces that impinge on the site from the outside, including sun, wind, water, and wildfire (Mollison and Holmgren 1978; Mollison 1988; Holmgren 2004; Mars 2005; Bell 2005; Hemenway 2009; Bane 2012). Landscape components can be arranged in order to manage these forces, through exclusion (firebreaks), channeling (windbreaks and water-control features), and inclusion (maximizing insolation/minimizing shading for crops and structures). Zones of Use is a concentric model of land use planning intended to maximize farm labor productivity, by siting land uses that require frequent management or use closer to the home or other centers of activity (Mollison and Holmgren 1978; Mollison 1988; Mars 2005; Holmgren 2004; Mars 2005; Bell 2005; Hemenway 2009; Bane 2012).

These principles of agroecosystem configuration, while lacking an explicit parallel discussion in the scientific literature, appear reasonably well supported by existing science. This lack of

consideration of spatial relationships in agronomy has been noted by many authors (Cavazza 1996; Veldkamp et al. 2001; Hatfield 2007; Osty 2008; cited in Benoit and Rizzo et al. 2012). Configuration is a nevertheless an implicit issue for land use functions that depend on spatial and topographic relationships, including windbreaks, runoff filtration, habitat provision, nitrogen fixation in polycropping (Ajayi 2004; Fujita et al. 1992), contour cultivation (Tacio 1993; Bunch 2002), and soil and water conservation. At larger scales, configuration is regarded as a driver of ecosystem functions (Uuemaa et al. 2012; McNeely and Scherr 2001; Scherr and McNeely 2008), and to a lesser extent cultural functions (Dramstad et al. 2006). While no agroecological literature addresses configuration vis-à-vis labor efficiency, the topic of workplace configuration and its effects on efficiency has a long history and an actively developing literature in other disciplines (Taghavi and Murat 2011; Venkatadri et al. 1997; Becker and Steele 1995; Burbidge 1971).

Practice

While permaculture has a distinctive description of the techniques for which it advocates, few if any of those techniques originated from within the permaculture milieu. Permaculture practices are often adopted from or inspired by traditional agroecological systems, as in the case of tropical homegardens and the permaculture "food forest" (Mollison and Holmgren 1978). Natural systems are another source of inspiration, as demonstrated by the guild concept, in which polycultures are designed as analogs to natural functional assemblages (Mollison et al. 1997). Alternative agricultural techniques, such as the original adoption of the Keyline system of landscape planning, may also be adopted by permaculturists (Mollison and Holmgren 1978; Yeomans 1954). Contemporary examples include the widespread enthusiasm in the permaculture community for aerobic compost tea (Avis 2012) and biochar (Soleil 2012). The "herb spiral," a mound garden design proposed by Mollison for the production of culinary herbs, may be the only practice to have emerged from the permaculture movement itself (Mollison 1988).

In this light, the practical stratum of permaculture might be more productively regarded as a conceptual framework for the evaluation and adoption of practices, rather than a bundle of techniques. Criteria for the evaluation of practice are not articulated explicitly in permaculture principles, but consideration of principles and favored practices suggests two broad conceptual

criteria: ecosystem mimicry and system optimization. The criterion of ecosystem mimicry regards the structure and function of unmanaged ecosystems as models, and attempts to create highly productive systems with analogous structure and function using species that produce yields for human use (Lefroy 2009; Hatton and Nulsen 1999). The criterion of system optimization does not refer to a model ecosystem, but seeks to identify strategic points of leverage where minimal intervention may enhance performance of desired functions beyond that of naturally occurring systems. Together, these criteria outline an implicit conceptual framework for the evaluation of practices in the permaculture movement, and may inform future investigation of these issues.

The design and use of perennial polycultures is a core theme of the permaculture literature (Mollison and Holmgren 1978; Mollison 1988; Mollison et al. 1997; Jacke and Toensmeier 2005; Hemenway 2009; Frey 2011; Bane 2012), and strongly reflects the criterion of ecosystem mimicry. The design of plant/animal or other multi-kingdom polycultures receives somewhat less attention (Mollison and Holmgren 1978; Holzer 2011; Shepard 2013). Diverse polycultures are valued for resistance to pests and pathogens, resilience to climate variability, diversification of production, and as a prerequisite for facilitative interactions between plants that can reduce the need for material and labor inputs (Mollison and Holmgren 1978; Shepard 2013). Perenniality in cropping species is valued for soil stabilization and conservation functions, and for labor efficiency (Mollison and Holmgren 1978; Hemenway 2009).

This view is largely consonant with the emerging scientific perspective on perennial polycultures (Ewel 1999; Lefroy 1999; Jordan and Warner 2010; Malézieux 2011; Picasso et al. 2011; Schoeneberger et al. 2012), as well as the more extensive discussions of field-scale diversity (Francis and Porter 2011; Mt. Pleasant and Burt 2010; Kalame et al. 2011) and perenniality (Jose 2009; Ewel 1986; Cox et al. 2006; Jordan and Warner 2010; Jordan et al. 2007). Permaculture is exceptional in emphasizing the potential of perennial polycultures to replace some portion of annual vegetable crops (Mollison and Holmgren 1978; Jacke and Toensmeier 2005; Holmgren 2004) and staple crops (Toensmeier 2011). Claims made by some permaculturists concerning the land and labor productivity of complex perennial systems exceed what has been documented in the scientific literature, especially but not exclusively in cold-temperate climates (Williams et al.

2001; Williams 2012; cf. Mollison, 1997; Hemenway 2009; Shepard 2013). Dense and complex plantings can have a variety of effects, including the reduction of productivity through above and below-ground competition for resources, increased pathogen pressure due to lack of air circulation, and increased harvest labor.

The permaculture literature advocates for the intensive management of water throughout the agroecosystem, through an integrated network of surface impoundments, contour ditches, small scale berms, and basins (Lancaster and Marshall 2008; Holmgren 2004). Redundancy in water storage systems is emphasized, with the priority placed first on soil storage, then surface water impoundments, followed by tank storage (Mollison 1988).

The use of earthworks for water harvesting and control is a global phenomenon in traditional agriculture systems. The productivity and multifunctionality of such systems has been demonstrated across multiple contexts, including arid-land agriculture (Evenari et al. 1982; Bruins et al. 1986; Boyd and Gross 2000; Mussery et al. 2013), hillside agriculture in humid zones (Holt-Gimenez 2006), and in aquaculture/irrigation systems in a wide range of contexts (Prein 2002; Boyd and Gross 2000; Smukler et al. 2010). Despite the frequency with which water harvesting earthworks are addressed in the permaculture literature, discussion of quantitative planning tools is rare (Lancaster and Marshall 2008; Frey 2011). Discussion of the risks posed by dispersive soils, which are highly vulnerable to tunnel erosion and thereby to catastrophic failure (Sherard et al. 1976), is entirely absent.

Permaculture literature advocates for attention to new and underutilized crops, consideration of wild relatives of domesticated species, and on-farm breeding of new cultivars (Mollison and Holmgren 1978; Jacke and Toensmeier 2005; Shepard 2013). Informed by the writings of H.T. Odum, the multifunctionality of cropping species is valued over place of origin, and the introduction of non-local species is regarded as desirable. In response to internal and external criticism from native plant advocates over the extreme versions of this position (Grayson 2003; Holmgren 2004; Hemenway 2009), many permaculturists have moderated their views on species selection and regard nativity as an important consideration alongside functional criteria (Jacke

and Toensmeier 2005; Hemenway 2009). Conflicts on this topic continue, however (Gehron and Webster 2012).

Permaculturists claim that anti-exotic positions are not based in ecological science, and that estimates of ecological and economic impacts of introduced species are exaggerated (Jacke and Toensmeier 2005; cf. Clark 2006). At the same time, more complex positions on the native/invasive question are being articulated within the scientific community (Davis 2009). In emerging discussions of novel ecosystems (Seastedt et al. 2008; Buizer et al. 2012) and intervention ecology (Higgs 2012; Hobbs et al. 2011), the value of native-oriented restoration efforts is questioned in favor of management for ecosystem services. These emerging perspectives on non-native species and assemblages are consonant with the moderate turn in permaculture, and more broadly, with that aspect of the permaculture worldview that positions humans as ecosystem managers within, rather than separate from, nature (see Sec. 4.2.4 below).

Movement

The permaculture movement communicates a distinctive worldview to new and potential participants, and disseminates elements of practice and design through networks of practitioners and small institutes. The role of such popular movements and networks in advancing agroecological transition through the mobilization of social and political support is increasingly acknowledged in the peer-reviewed literature (Nelson et al. 2009; Ferguson and Morales 2010; Rosset et al. 2011; Altieri and Toledo 2011).

The growth and dissemination of permaculture is built on two basic patterns: a widely-dispersed network of ‘itinerant teachers' (Mollison 2003), and local/regional organizing based around ‘bioregional' cultures and the development of alternative economic and social institutions (Mollison 1988; Holmgren 2004). The bioregional organizing aspect of permaculture promotes ideas associated with alternative institutions, and realized projects include gardening organizations, farms, demonstration sites, credit unions, multi-issue community organizations, numerous periodicals, campus greening and local food initiatives, and a variety of accredited and unaccredited institutions of higher learning (Ochalla 2004; Grayson 2010a; Battisti 2008; Harb 2011). The concept network analysis reflects the importance of concepts of community and

sociality in the permaculture literature. The concepts ‘community' and ‘development' are present and closely related in all three sequential analyses, becoming more central over time. In the complete sequence (1978-2013), the centrality of ‘community' is nearly equal to ‘design.'

The focus on itinerant teachers has distinctively marked permaculture's development with high-profile professionals - ‘permaculture celebrities' whose international travel is organized around invitations to teach courses (organized by local conveners), and by employment opportunities as designers and consultants (Mollison 2003). The focus on traveling teachers likely played a significant role in the rapid expansion of the movement (Grayson 2010a). The permaculture movement, however, displays significantly less organization and institutionalization than other international agroecological movements, e.g. La Via Campesina, Campesino à Campesino, or International Federation of Agricultural Producers (Borras Jr et al. 2008; Rosset et al. 2011; Martínez-Torres and Rosset 2010; q.v. Grayson 2010b). This lack makes the coordination of action beyond the immediate community scale difficult or impossible, and thus limits the potential for mobilization of political support for diversified farmers (de Molina 2012).

The distribution of permaculture publications has transitioned from sharply delimited to relatively diverse. The initial geographic limitation can be traced to the English-language origin of the permaculture framework in Australia. Due to the English-language constraint of this study, results can be assumed to skew in the direction of publications from Oceania, the UK, and the USA, and that actual publishing is more geographically diverse than reported here. The geographic relationships between place of publication, and place of topic, however, show a consistently low level of diversity that parallels the ‘coloniality of knowledge' described in the agroecological literature (Gómez et al. 2013), wherein writing on both the developed and the developing world are published in highly developed countries, and very few studies of developed countries are published in the developing world.

Worldview

The relevance of permaculture to agroecological transition is driven in part by the worldview disseminated by the movement. The emerging focus in the agroecological literature on the ‘worldview challenge' acknowledges the importance of knowledge and beliefs for transition

(Jordan et al. 2008; Berkes et al. 2000). Any agricultural system is not only set of practices, but also a framework of knowledge about how and when to apply any given technique, a belief system that proposes a mechanism of action, and a normative proposal about what practices and land use goals are desirable and why (Norgaard 1984; Berkes et al. 2000). Agroecological transition requires not only new techniques, but new stories to provide context and meaning for those techniques (Sanford 2011).

Key elements of the permaculture worldview include ideas about human-environment relations, a populist orientation to practice, and a model of social change. The permaculture literature expresses a theory of human-environment relations that highlights the positive role of humans in the landscape, as ecosystem managers. This perspective is expressed through a literature-wide insistence on the need for holistic planning and design, and an optimistic assessment of what these styles of management can achieve. This perspective on human-environment relations cuts against the grain of the dualistic worldviews of both growth-oriented development and preservation-oriented conservation, each of which describe a fundamental conflict between the needs of society and those of nature (Pálsson 1996; Strongman 2012). At the core of the permaculture worldview is the idea that — with the application of ecologically-informed holistic planning and design — humans can meet their needs while increasing ecosystem health (this author, quoted in Toensmeier and Bates 2013).

The populist orientation in the permaculture literature repeatedly (though not uniformly) portrays the solutions to environmental and social crises as both simple and known. Academic institutions and researchers are common topics of criticism for conservatism, the plodding pace of change, failure of vision, and for being beholden to corporate interests (Mollison and Holmgren 1978; Mollison 1979; Holmgren 2004; Holzer 2011; Shepard 2013). Mollison and Holmgren claim that permaculture requires only the recombination of existing knowledge, rather than the generation of new knowledge (Mollison and Holmgren 1978), and one of Mollison's most widely quoted aphorisms is "Though the problems of the world are increasingly complex, the solutions remain embarrassingly simple" (Permaculture Institute 2013). Some recent permaculture authors, in contrast, do present their proposals as hypotheses in need of testing (Jacke and Toensmeier 2005).

The emphasis on practice over theory, and on networks of practitioners, is reflected in a model of social change that emphasizes individual personal responsibility and voluntary action, and a relative lack of interest in influencing policy or large institutions (Mollison and Holmgren 1978; Holmgren 2004; Shepard 2013). Mollison proposes a "prime directive" that states "The only ethical decision is to take responsibility for our own existence and that of our children's" (1988, p. 1). This focus on individuals as the locus of change is moderated by principles of cooperation at the level of the community or bioregion (Mollison 1988; Holmgren 2004). In a quotation that captures both the simplicity and the scale of permaculture's model of change, prominent permaculturist Geoff Lawton uses the tagline "All the world's problems can be solved in a garden" (Lawton 2008).

SYNTHESIS

Integrating quantitative and qualitative review methods to evaluate the English-language permaculture literature, this study establishes a foundation for future dialog between permaculture and agroecology. The integrated analysis of popular and scientific literature is necessitated by the nature of the permaculture literature, and entails the adaptation of established review methods. This mixed-methods approach is useful for addressing the challenges of a large and heterogeneous field divided between scientific and popular literature. Triangulation between qualitative and quantitative analysis supports the synthesis of broad generalizations about the permaculture literature, while the limits to these generalizations are also identified. Highlighting the limitations in our knowledge of permaculture will help outline directions for future research.

By developing the first critical scientific review of the permaculture literature, organized around a novel stratified definition, this project contributes to the understanding of an agroecological movement which has received very little rigorous scrutiny. By using the concept of 'agroecological transition' as an analytical frame, this study moves beyond the fragmentary and often one-sided analyses that characterize previous discussion of permaculture, and supports a balanced and holistic evaluation of biophysical and social factors. Figure 11 expands the stratified definition offered above (Figure 2.3) to incorporate themes and patterns revealed in this project.

This review supports the idea that permaculture has contributions to offer the project of agroecological transition. Principles and themes in the permaculture literature largely complement, and sometimes provide useful extension of, those found in the agroecology literature. The permaculture approach to agroecosystem design and practice offers a distinctive perspective and emphasis on the value and potential of perennial crop species, polyculture, integrated water mangement, and the importance of agroecosystem configuration. Systematic and bibliometric analysis reveal an increasing diversity in geography over time. The movement is mobilizing diverse forms of social support for sustainabililty, in geographically diverse locations, although there is less evidence for direct impact on agroecological transition. The value of permaculture's contributions remains constrained by several significant factors in the culture of the movement.

Substantiation and Scholarship

Overreaching Claims

Permaculture has frequently been the target of criticism for overreaching and oversimplifying claims about the achievements and state of knowledge represented by the permaculture system. The tendency towards overreach and oversimplification are encapsulated in the notion that humanity already possesses all the knowledge necessary to replace current land use with permaculture systems in all contexts (Mollison et al. 1997, p. 1), and that the process of redesign is itself straightforward. In the absence of reliable data to support these proposals, permaculturists often rely on anecdotal report and sweeping extrapolation from ecological principles.

Permaculturists have been accused repeatedly of inflating both the land- and labor-productivity of complex polycultures and perennial systems. The derivation of production figures in Mollison's canonical Permaculture Designer's Manual (1988), as in most permaculture publications, are unreferenced and unknown. Claims of productivity are sometimes justified through misreading or misapplication of ecological principles (Romanowski 2007). One common example is the conflation of net primary production with the production of edible tissue (Williams et al. 2001; Williams 2012; cf. Mollison 1988, Hemenway 2009; Jacke and

Toensmeier 2005; Shepard 2013). While forest ecosystems are among the highest in NPP, perennial plants allocate a higher percentage of photosynthetic activity to structure than annuals, and therefore have a slimmer margin for export as edible tissue (Jordan 1971; Malézieux 2011), rendering the comparison of potential yields a complex empirical question rather than a simple maxim. Anecdotal reports on the productivity of multi-strata silvopasture integrated with multi-species rotational grazing are promising but unsubstantiated (Shepard 2013) and point the way toward future research. An additional example of the misapplication of ecological principles is the claim that complex shapes in fields, garden beds, and ponds, will increase productivity (Mars 2005; Hemenway 2009; Bell 2005). This claim is based on the permaculture principle of Edge Effects, that was itself extrapolated from the ecological characteristics of ecotones and anecdotal reports of edge effects in grain cropping systems (Mollison and Holmgren 1978; Mollison 1988). Some recent permaculture publications, however, have provided more complex and empirical descriptions of edge effects (Holmgren 2004; Jacke and Toensmeier 2006).

The permaculture literature often downplays or ignores the risks and challenges of planning and maintaining highly complex agroecosystems. Permaculture has been criticized for the increased harvest labor associated with structural complexity (Reich 2010). Planning for diversified enterprises is complex and challenging, and while there are signs of change, currently the majority of planning and support resources are oriented toward simple non-diversified farming operations (McIntyre et al. 2009). Farmers utilizing complex polycultures and diverse enterprises will likely face significant hurdles to attain economic viability. In this, however, permaculture does not differ from other approaches to farm diversification and integration (Morris and Winter 1999; Tipraqsa et al. 2007; Amekawa et al. 2010; Kremen et al. 2012).

The inattention to complexity and risk in the permaculture literature may have serious consequences on and beyond the farm. In the case of water management, modification of existing natural grade and site hydrology may result in flooding, increased erosion, and loss of topsoil. For extensive and interlinked modifications that include impoundments, the risk is proportionally greater — both to the landowner's investment in earthmoving, and in potential damage to structures and fields downslope. The potential impacts of extensive earthworks on

catchment-scale hydrological processes are complex, and will likely include consequences for both upstream and downstream landscapes and communities (Rockström et al. 2010).

Isolation from Science

This study underscores the observation that, although permaculture emerged from an academic collaboration between professor (Mollison) and student (Holmgren), the movement has been largely isolated from scientific research. Most permaculture texts do not refer to contemporary scientific research (Scott 2010; Chalker-Scott 2010). In a reading list for advanced study of permaculture, revised most recently in 2003, the average publication date of the 11 titles (excluding Mollison's own work) was 1964, and the most recent was 1985 (Mollison 2003). Permaculture's lack of reference to contemporary science holds true even for fields that would seem to have the most bearing on the core premises and proposals of permaculture, such as agroecology and agroforestry. The permaculture literature assigns the blame for this isolation on the inability of scientists and institutions to comprehend or appreciate the radical proposals put forth by permaculture (Mollison and Holmgren 1978; Mollison 1979; Mollison 1988; Holmgren 2004; Shepard 2013). The counter-example of the Land Institute, however, and its project of replacing annual staple crops with perennial grains in diverse prairie-mimic polycultures, illustrates the way in which radical proposals may be grounded in rigorous empirical science, and be well-received by the scientific community (DeHaan et al. 2005; Cox et al. 2006; Glover et al. 2010).

While the increase in scholarly publications shown by the bibliometric analysis suggests that the situation may be changing, there are cumulative effects from decades of relative isolation that go beyond the lack of research on permaculture systems. These include the lack of awareness, in the permaculture literature, of contemporary developments in relevant science, the accompanying persistence of idiosyncratic or misleading terminology, and the potential for influence of pseudo-scientific theories. The idiosyncratic use of scientific and scientific-sounding terms, together with permaculture's heterodox stance on issues such as species selection, has persuaded some writers to label permaculture as pseudo-science (Chalker-Scott 2010).

An example of idiosyncratic use of scientific terms in permaculture is the use of the term ‘guild' to refer to complementary, mutually beneficial plant assemblages (Mollison et al. 1997; Holmgren 2004; Bell 2005; Burnett and Strawbridge 2008; Hemenway 2009; Bane 2012). This is nearly opposite of its scientific meaning, which describes a group of plants that occupy a similar niche and make use of the same resources — in other words, plants that are especially unsuited to being grown in a polyculture assemblage (Simberloff and Dayan 1991). Permaculture discussions of polyculture design also typically make use of the term “dynamic accumulators” to refer to plants that draw nutrients from the subsoil and concentrate them in the topsoil, thereby simultaneously benefiting nearby plants (Whitefield 2004; Jacke and Toensmeier 2005; Bell 2005; Jacke and Toensmeier 2006; Hemenway 2009). The term does not appear in scientific literature, and its use is regarded as evidence that permaculture is pseudo-scientific (Chalker-Scott 2010). As there is ample support in the ecological literature for importance of plant processes in determining the vertical distribution of nutrients in the soil column (Jobbágy and Jackson 2004; Callaway 1995; Porder and Chadwick 2009) — the less pejorative “folk science” may be a more appropriate label (q.v. Berkes 2008).

Permaculture Scholarship

Even within the growing scholarly sector, most authors are not from disciplines with close ties to agroecology. Scholarly work on permaculture from more closely related disciplines is often marked by sparse citations of relevant scientific literature. The work of Jacke and Toensmeier (2005) constitutes an exception to this pattern. The first volume of their two-volume work on edible forest gardening is devoted entirely to a review of relevant scientific theory, and both volumes draw heavily on the scientific literature.

Scholarship has historically comprised a marginal but diverse sector within permaculture. Concepts associated with scholarship, including ‘study,' ‘education,' ‘correlate,' and ‘paper,' have had a consistent presence in the literature but have never approached the first or second quartile of centrality. The high level of abstraction at which the permaculture design system is articulated appears to support engagement with topics beyond the strictly biophysical and agricultural, and to invite investigation from scholars from a diverse set of analytical and methodological traditions. While currently marginal, the historical isolation of permaculture from scientific

research may be diminishing — particularly if the significant growth in graduate theses documented in this review continues.

Limitations of this Study

This study is limited by its restriction to English-language literature. Both qualitative and quantitative analyses are likely skewed in unknown ways by this restriction. Follow-up reviews of permaculture literature in multiple languages should be carried out at the earliest opportunity. Additionally, this study addresses only those aspects of permaculture most pertinent to the question of agroecological transition. This is a necessary constraint, with the stipulation that this review should therefore not be read as a comprehensive assessment of the breadth of permaculture literature, as we are not concerned here with numerous topics discussed in that literature, including forest management, building techniques, settlement planning, and so on. Finally, by restricting this review to publications appearing in databases of scientific research, scholarly and technical literature are likely overrepresented in the bibliography, and therefore represent a smaller proportion of the total English-language permaculture literature than is represented here.

Future Directions

Permaculture's integrated approach to agroecosystem design offers tools and suggests directions for future research. Until recently, there was no parallel discussion in the scientific literature on farm design, which has largely consisted of computer modeling and simulation that are not well suited to complex diversified operations (Sterk et al. 2006) and do not deal substantively with spatial relationships (Martin et al. 2012). The importance of the abundance and distribution of land uses to farm sustainability, and interest in the development of tools to support spatially-explicit farm design processes, has only recently entered the scientific literature (Benoit et al. 2012; Lovell et al. 2010; Sterk et al. 2006), and remains largely exploratory.

Themes for investigation identified in this study include agroecosystem design and configuration, perenniality, and diversity. The role of agroecosystem configuration in driving multiple functions, including environmental functions, labor productivity, and land productivity, is a pressing question that has bearing for all diversified farming systems. The development of

design approaches to agroecosystem planning could make valuable contributions in the context of farmer-oriented participatory research. The role of principles and pattern (including natural pattern and pattern languages) in supporting site analysis and design solutions are also promising avenues of investigation. The farmer-friendly articulation of the permaculture principles, and the incorporation of principles meant to stimulate creative problem solving (e.g. “The Problem is the Solution”) represent a potential contribution to participatory research and development.

Permaculture's distinctive aggressive emphases on perenniality and diversity are useful provocations to supporters and researchers of diversified production systems. The potential of diverse perennial systems, such as rotational silvopasture systems (Shepard 2013), for the production of staple and complementary crops in temperate zones, has recently informed empirical field trials at a major agricultural research university in the US (WPP Research 2013), and should inspire more.

Permaculture continues to be hampered by overreaching and oversimplifying claims made by advocates. The portrayal of the scientific community as homogenous, too slow, or altogether reactionary, helped create a charismatic populist message in the early years of permaculture. While this approach may have been important in rapidly disseminating permaculture and creating an international movement, it now limits the value of permaculture by rendering it more difficult to interface with the larger community of researchers, institutions, and movements, addressing the project of agroecological transition. It is important to note that sciences that were in their infancy at the time of permaculture's origins, have now matured and begun to exert increasing influence, and that some of these sciences have a high degree of consonance with permaculture's aims and worldview (e.g. agroecology, agroforestry, ecological engineering). The value of permaculture for agroecological transition can only be enhanced by building dialog and exchange with related disciplines.

The relevance of permaculture to agroecological transition is not limited to issues of design and practice. The increasing interest within the agroecological literature on issues of worldview and popular movements supports further investigation of the social aspects of permaculture. Like other agroecological movements, the spread of permaculture in the absence of significant

scientific or institutional support, points to the importance of beliefs and norms for the adoption of new agroecological frameworks. Permaculture's optimistic focus on holistic and positive action, on personal responsibility, and on the simplicity of needed solutions, are empowering for participants (Smith 2002), and are likely significant drivers of the spread of the movement. However, the portrayal of agroecological transition as something that individuals can contribute to, using simple techniques at home, is a double-edged sword. While prioritizing the perspectives and capacities of land users is important, it may also run the risk of depoliticizing aspects of agroecological transition that are fundamentally political (de Molina 2012; Lovell et al. 2010; Rosset and Martínez-Torres 2012) and trivializing the complexity of socio-ecological processes and struggles. Investigating the conditions under which participation in the permaculture movement informs changes in agricultural practice, and mobilizes social and political support for diversified farming systems, will contribute to the scientific and practical understanding of agroecological transition.

While the overlap in topic and orientation between permaculture and agroecology is clear, assessing the value of permaculture to the task of agroecological transition continues to be confounded by gaps in our knowledge of the impacts of permaculture design and practice. This broad overview of the permaculture literature is not exhaustive, and points toward the need for further and more detailed systematic review of practices advocated for in permaculture literature. Opportunities for collaborative research and documentation of permaculture sites, and field trials of distinctive practices not reflected in the agroecological literature, should be vigorously pursued. The impacts of the design and practice aspects of permaculture should be assessed through comparative analysis of agroecosystems where the design framework has been implemented, focusing on (1) spatio-functional analysis to assess the role of configuration in determining production, ecological, and production functions (cf. Lovell et al. 2010), and (2) livelihoods-based research, including quality of life, to investigate the diversity of benefits and motivations for permaculture producers.

CONCLUSION

The project of agroecological transition is pressing and complex. Agroecologists must continue to look outside the boundaries of their discipline in order to evaluate the resources and opportunities presented by other disciplines and movements in supporting that transition.

Permaculture offers distinctive resources for that project, but further research, development, and collaboration is required to assess and realize its full value. This review provides a needed foundation and framework for that task.

If it were possible to distill the agroecological content of the permaculture literature into a single thesis, it might appear in this way: With systematic site design, emphasizing diversity at multiple scales, integrated water management, and access to global germplasm, we can increase the productivity demonstrated by heritage agroecosystems – especially labor productivity - while retaining their most desirable attributes of sustainability and multifunctionality. This thesis is highly relevant to the task of agroecological transition, and begs numerous questions that can only be answered through a dedicated research program. It also suggests the beginnings of a framework for the further integration of different sectors of agroecological research, through the lens of integrated design of agroecosystems. This view toward integration and application may be the most significant benefit offered to agroecology by the rigorous analysis of permaculture theory and practice.

FIGURES AND TABLES

Figure 2.1 Examples of production and education in the permaculture movement. (a) Small farm with intercropped annuals and perennials, worked partially with hand labor, (b) Workshop on the design and maintenance of perennial polycultures.

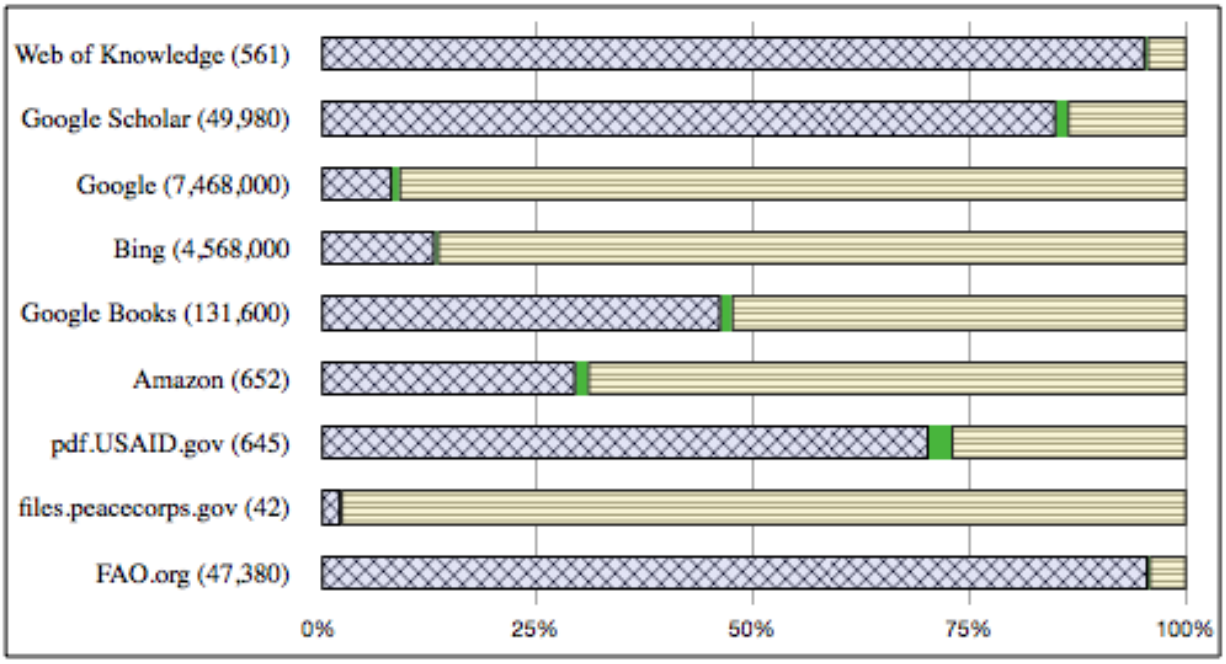

Figure 2.2. Proportional results from parallel search queries for ‘agroecology’ (crosshatch), combined ‘agroecology’ + ‘permaculture’ (solid), and ‘permaculture’ (horizontals), to multiple online data sources, illustrating the uneven relative prominence of agroecology and permaculture across different sectors. Numbers in parentheses indicate combined total responses from each data source.

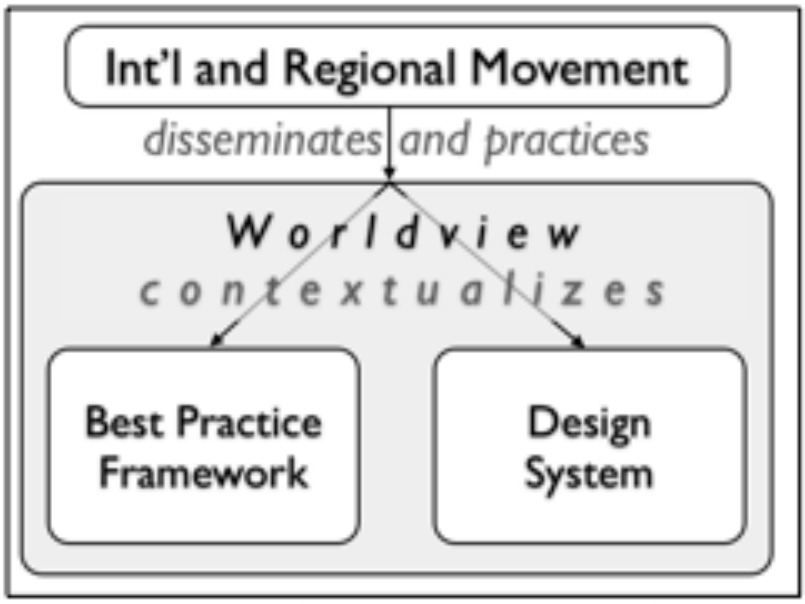

Figure 2.3. Stratified definition of permaculture, illustrating the relationships between four common referents of the term. Permaculture is (1) an international and regional movement that disseminates and practices (2) a design system and (3) a best practice framework. The design system and best practice framework are contextualized by (4) the worldview that is carried by the movement.

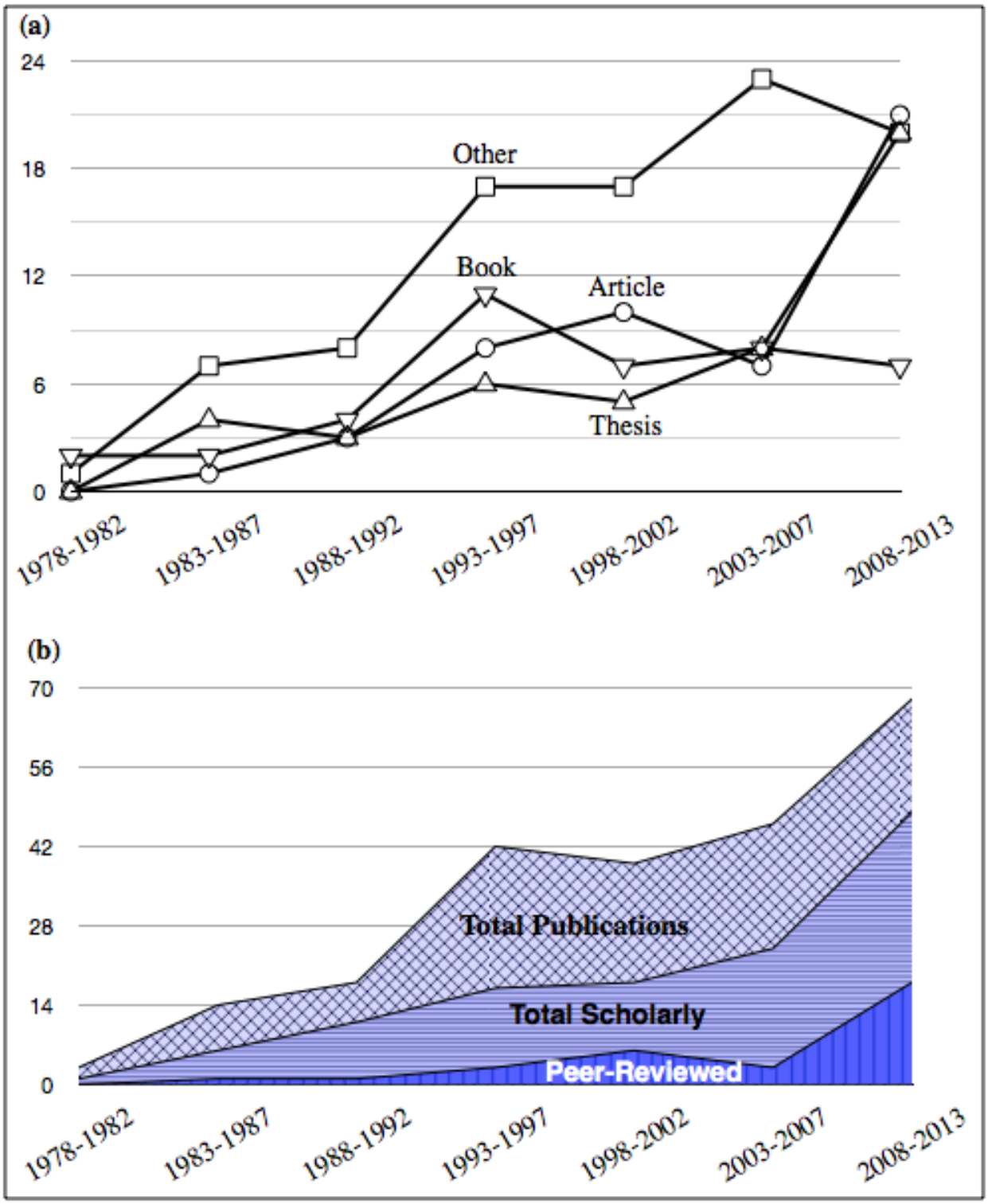

Figure 2.4. Distribution of publication types in a 230-reference bibliography of permaculture, in 5-year increments except for 2008-2013. (a) Distribution of publication types within the biography shows rapid growth in articles and theses since 2008. (b) Scholarly publications represent a growing share of the total bibliography over time, with peer-reviewed publications growing at a slower pace.

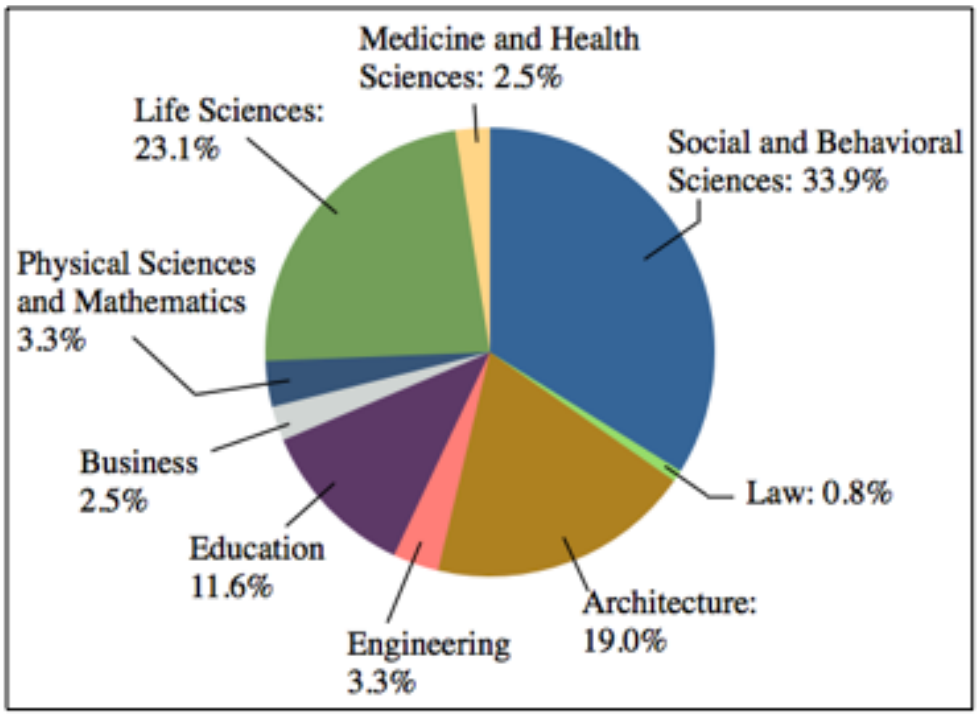

Figure 2.5. Distribution of academic disciplines among 122 scholarly publications addressing permaculture. Agroecology and closely related disciplines (grouped within life sciences) represent a minority of scholarly work in permaculture.

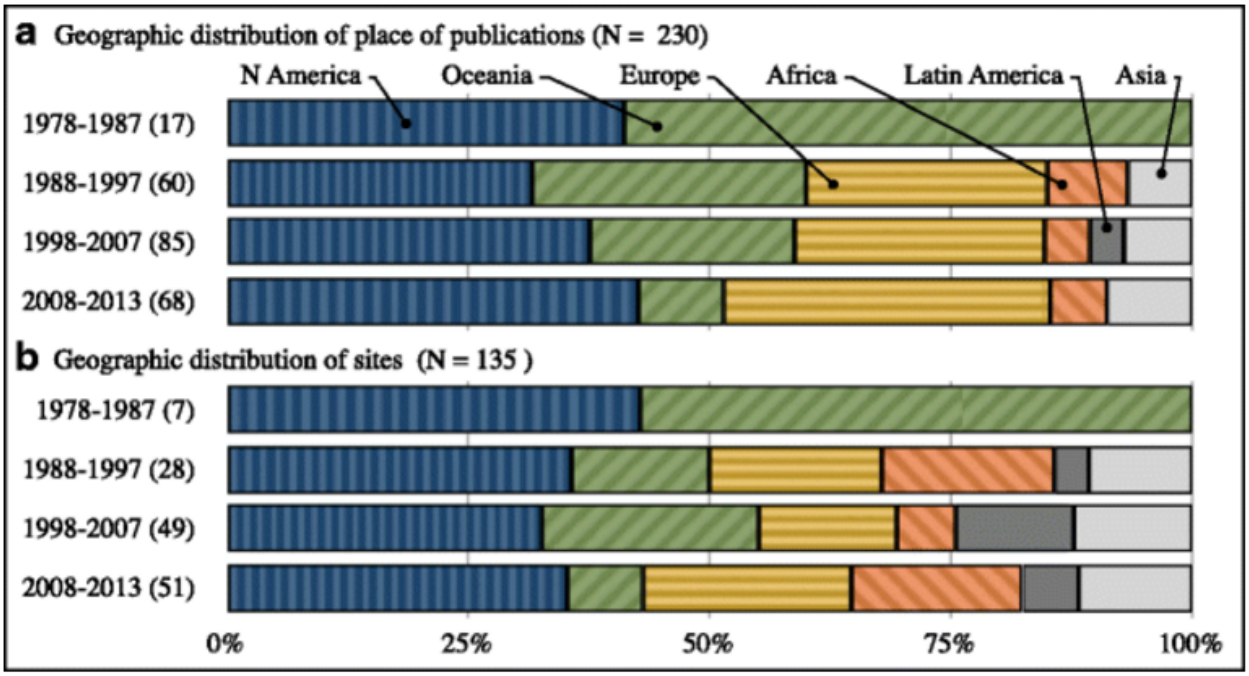

Figure 2.6. Geographic distribution of (a) place of publication and (b) sites discussed as topics in permaculture publications over time.

Figure 2.7. Network representation of country-by-country relationships between place of publication and place of topic in a 135 permaculture publications. The network illustrates a pattern in which developed countries commonly study developing countries, and the reverse is seldom true. Node size is scaled to indicate the number of publications originating from that country. Node color is a heat map representing number of publications with topics specific to that country, with green indicating few and red indicating many. Links between nodes represent publication/topic relationships, with number of publications indicated by line weight.

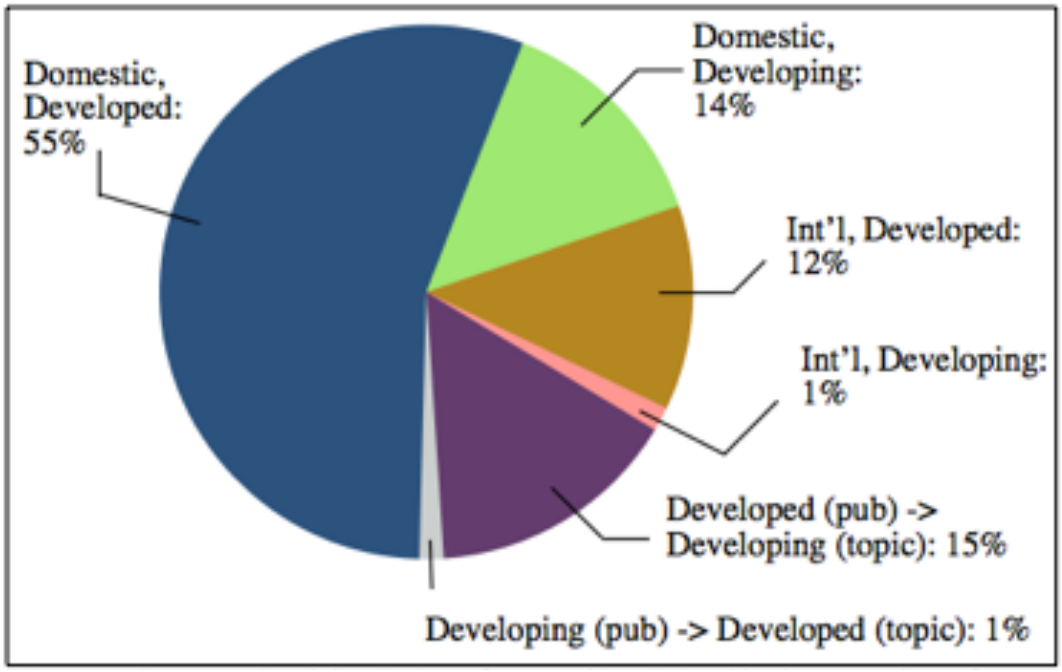

Figure 2.8. The proportional distribution of geographic relationships between place of publication and place of topic in 135 references in the permaculture bibliography. 'Domestic' describes research that is conducted and published with a single country. 'International' describes research that is conducted in one or more countries, and published elsewhere.

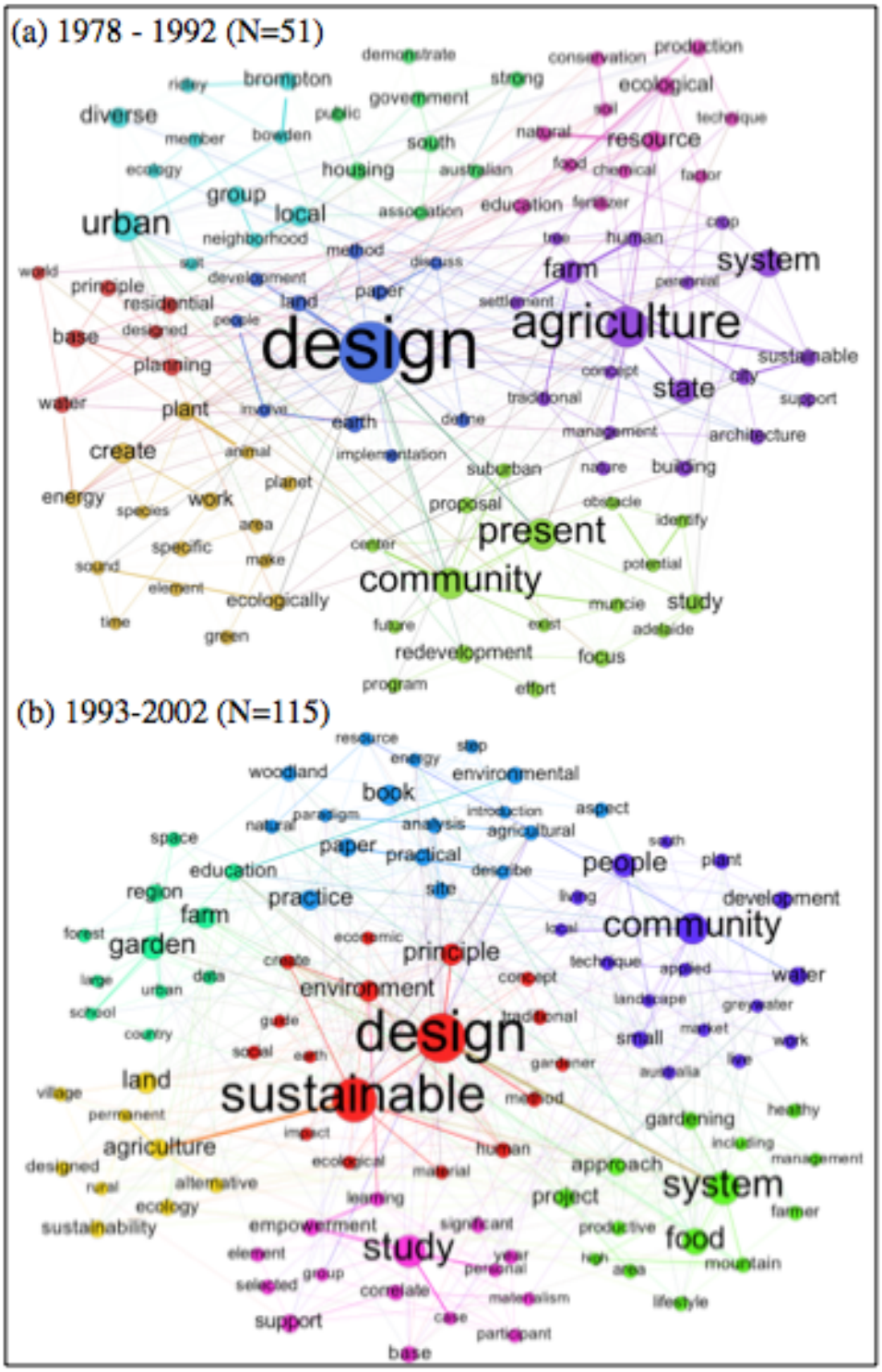

Figure 2.9. Concept network maps of keywords from permaculture publications. Node size denotes centrality of concepts, links represent concept co-occurrence, link width represents co-occurrence frequency, and color denotes conceptual cluster of tightly interlinked concepts. (a) Publications 1978-2002 (N=51); (b) Publications 1993-2002 (N = 115).

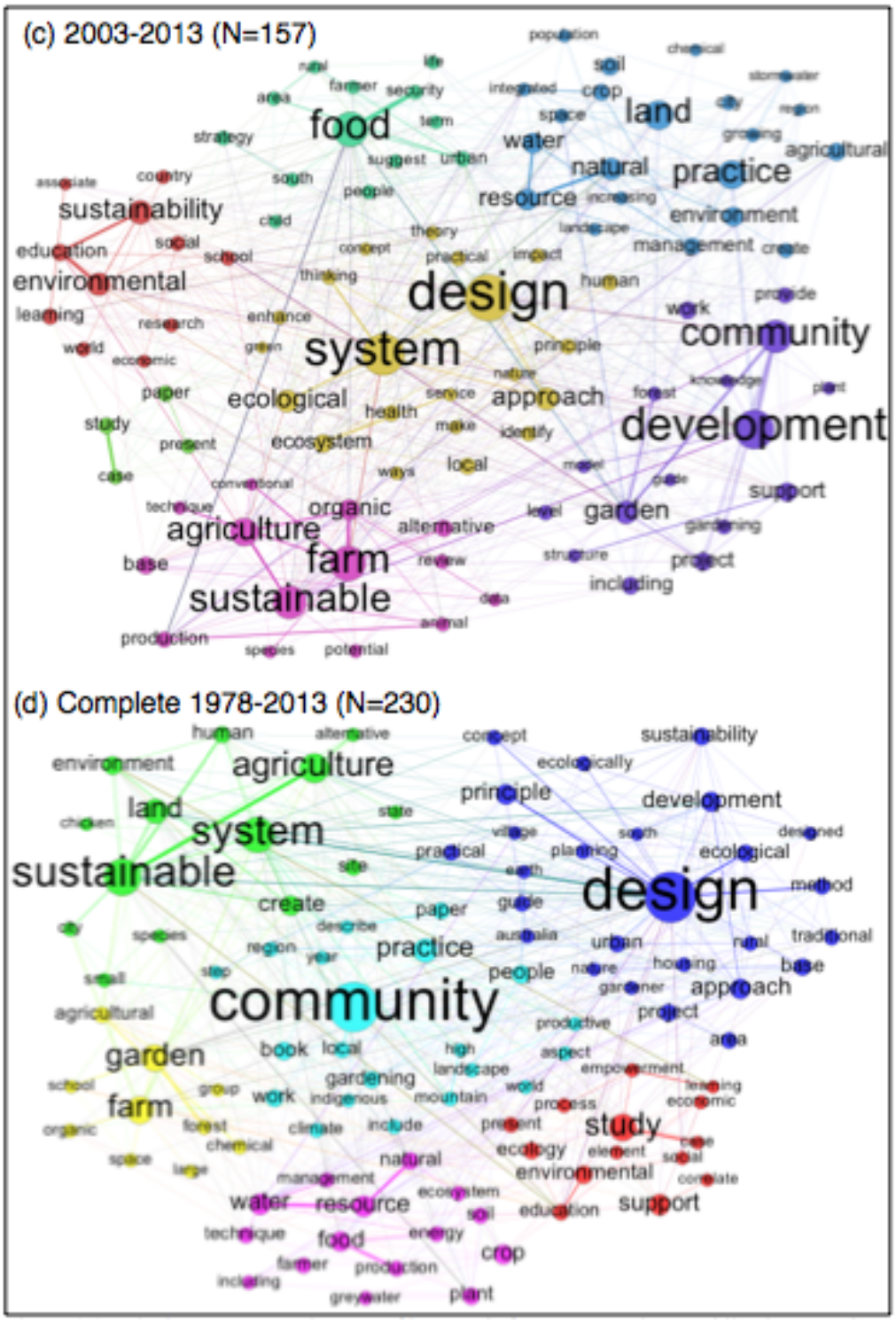

Figure 2.9 (cont). Concept network maps of keywords from permaculture publications. Node size denotes centrality of concepts, links represent concept co-occurrence, link width represents co-occurrence frequency, and color denotes conceptual cluster of tightly interlinked concepts. (c) Publications 2003-2013 (N=157); (b) Complete series 1978-2013 (N = 115).

Permaculture Principles	Agroecology and Related Principles
DIVERSITY	
Diversity, Plant Stacking & Time Stacking (PDM, IPM), Use and Value Diversity (PPBS)	Species and genetic diversification of the agroecosystem in time and space (Reijntjes et al. 1992) Contain pests through complex trophic levels (Malézieux 2011) Maintain landscape heterogeneity and capture environmental gradients (Fischer et al. 2008)
INTERACTION	
Edge Effects (PDM), Use edges and value the marginal (PPBS)	Optimize available resources through synergies between "plants, animals, soil, water, climate and people" (Pretty 1994, Vandermeer 1995)
Everything gardens (PDM)	Use complementary functional traits to ensure production and resilience. (Malézieux, 2011)
Relative location (IPM)	Enhance beneficial biological interactions and synergisms (Reijntjes et al. 1992)
Each important function is supported by many elements (PDM), Each element performs many functions (PDM)	Enhance recycling of biomass and optimizing nutrient availability and balancing nutrient flow. (Reijntjes et al. 1992)
CREATIVITY AND INNOVATION	
The problem is the solution (PDM) The yield of a system is theoretically unlimited (or only limited by the imagination and information of the designer) (PDM) Make the least change for the greatest possible effect (PDM)	*No corollary agroecological principles.*
ADAPTIVE MANAGEMENT	
Observe and interact (PPBS)	Management by experiment (Nudds 1999)
Apply self-regulation and accept feedback (PPBS)	Mobilize capacity for inquiry (Blann et al. 2003)
Creatively use and respond to change (PPBS)	Detect and foster novelty (Blann et al. 2003)
Accelerating succession and evolution (PPBS)	Create opportunities for self-organization (Folke et al. 2003)

Figure 2.10. A selection of permaculture principles and related principles in agroecology and allied disciplines, grouped by themes. With the exception of the principles grouped under the theme of Creativity and Innovation, permaculture principles have corollaries in the scientific literature, but are articulated at a higher level of abstraction. PDM refers to Mollison 1988, IPM to Mollison & Slay 1997, and PPBS to Holmgren 2004.

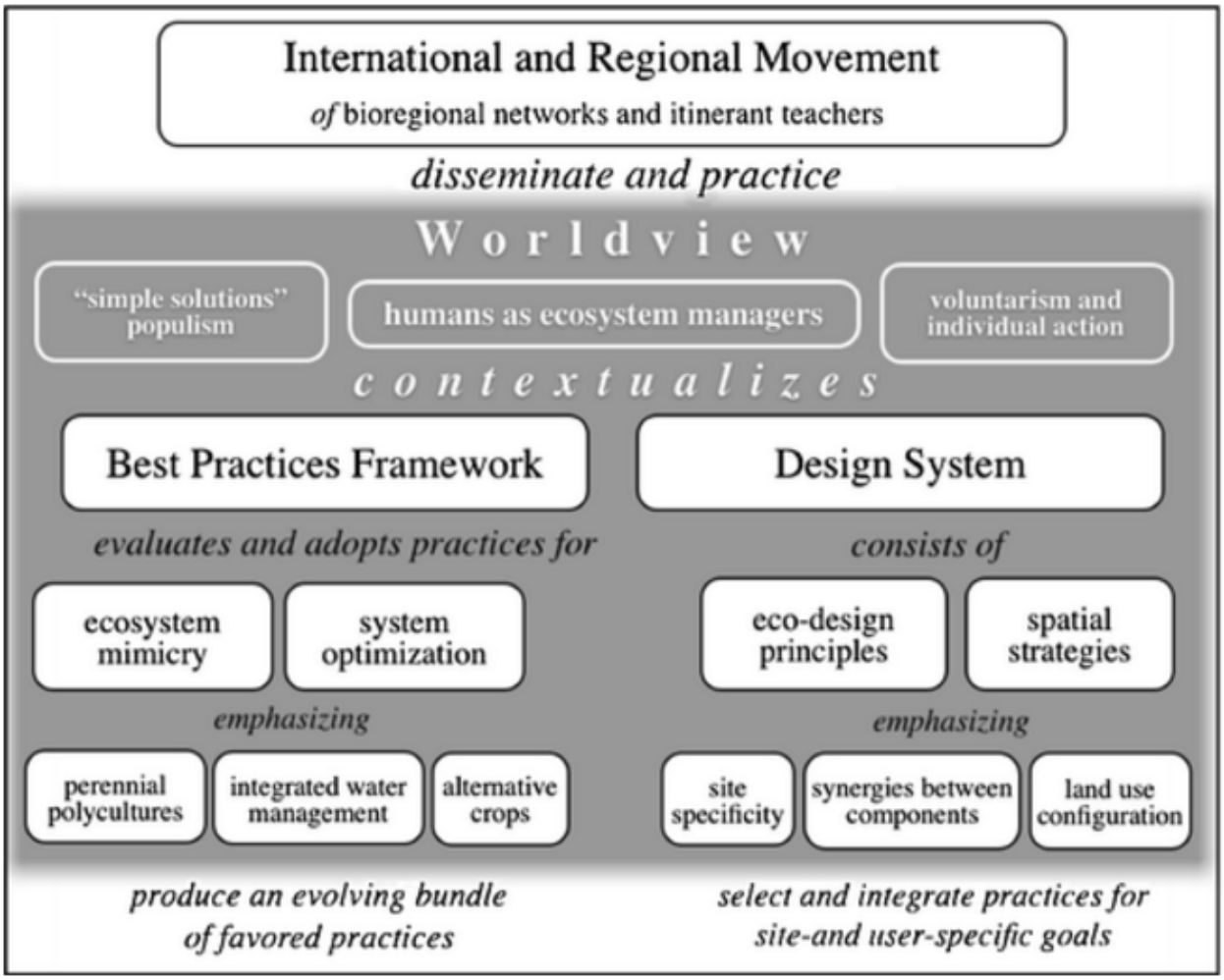

Figure 2.11. Stratified definition of permaculture, expanded to incorporate distinctive themes relevant to agroecological transition appearing in the permaculture literature, as addressed in this survey.

Table 2.1 Publication types in permaculture bibliography assembled for analysis.

Publication Type	N
Journal Article	**50**
Thesis	**46**
Book	**41**
Periodical Article	**28**
Proceedings	**27**
Chapter	**15**
Report	**11**
Miscellaneous	**12**
Booklet	5
Presentation	2
Meeting Abstract	1
Undergrad, Non-thesis	1
Occasional Paper	1
Interview	1
Seed Catalog	1
TOTAL	**230**

Table 2.2. Results of concept network analysis of 230 permaculture publications, showing five most important clusters (by modularity), and 5 most important terms in each. cluster (by betweenness centrality).

	Cluster 1	B.C.	Cluster 2	B.C.	Cluster 3	B.C.	Cluster 4	B.C.	Cluster 5	B.C.
	DESIGN	**2529**	**AGRICULTURE**	**1459**	**PRESENT**	**978**	**URBAN**	**851**	**RESOURCE**	**376**
1978-1992	earth	194	system	740	community	956	local	398	ecological	259
	land	186	state	573	study	337	diverse	364	production	156
	paper	149	farm	513	redevelopment	239	group	323	education	155
	method	78	sustainable	189	focus	185	brompton	224	natural	112
	DESIGN	**1199**	**COMMUNITY**	**617**	**BOOK**	**273**	**GARDEN**	**374**	**LAND**	**297**
1993-2002	sustainable	1044	people	367	practice	257	farm	290	agriculture	257
	principle	314	water	190	paper	199	region	173	sustainability	137
	environment	284	development	180	practical	155	education	153	ecology	110
	human	96	small	150	environmental	151	space	87	alternative	92
	DESIGN	**240**	**DEVELOPMENT**	**192**	**FARM**	**162**	**FOOD**	**161**	**LAND**	**122**
2003-2013	system	209	community	147	sustainable	149	urban	24	practice	118
	approach	74	garden	77	agriculture	112	security	19	natural	72
	ecological	73	support	52	organic	60	strategy	19	resource	66
	ecosystem	47	project	46	base	38	people	16	water	61
	DESIGN	**345**	**COMMUNITY**	**338**	**SUSTAINABLE**	**218**	**FARM**	**131**	**STUDY**	**128**
1978-2013	principle	67	practice	96	system	204	garden	124	support	74
	approach	66	people	50	agriculture	150	agricultural	32	environmental	48
Complete	development	66	book	49	land	106	forest	16	ecology	37
	sustainability	45	work	40	create	65	chemical	14	education	28

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3

Grassroots engagement with transitions to sustainability: diversity and modes of participation in the international permaculture movement[2]

INTRODUCTION

Increasing concerns about the pace of environmental degradation, including climate change, biodiversity loss, and profligate and unequal consumption of increasingly scarce resources, have been met with incremental responses from large institutions across multiple sectors of society (Assadourian et al. 2013, Grantham 2012, Beddoe et al. 2009). With the substantive failure of governmental regulatory approaches and top-down market-based initiatives to address these issues, increasing attention is being paid to the contributions of actors from outside of large state and non-state institutions (Seyfang and Haxeltine 2012, Ernstson et al. 2008, Leach et al. 2012, Bergman et al. 2010). Grassroots actors and their aggregates – networks, communities, and movements – are increasingly looked to as critical agents in the transition to sustainability, helping forestall, mitigate, and adapt to environmental degradation. Scholarship on these issues is spread across multiple disciplines, theories, and terminologies, most saliently in the literature of sustainability transitions, socio-ecological systems, and in studies of environmentalism spanning political science, social psychology, and environmental sociology. Emerging scholarship on grassroots innovation networks is helping balance a preponderant focus on top-down technocratic processes in the literature of sustainability transitions (Lawhon and Murphy 2012, Smith and Stirling 2010). At the same time, the focus on grassroots innovation networks bridges a gap between scholarship on sustainability transitions and research on environmentalism – drawing our attention to bottom-up processes of transition that may not look like traditional environmental movements. Our understanding of the forces driving participation in grassroots networks remains limited, however, and there has been little crossover so far with the literature on environmentalism.

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Permaculture is an international grassroots network focused on the sustainable design of human settlement (Mollison 1998). Permaculture has a very public profile, with an extensive internet presence and projects on every inhabited continent (Ferguson and Lovell 2014). While permaculture has historically been isolated from conventional scientific research, recent studies have identified permaculture as a potential contributor to the sustainability of farm practices, (Ferguson and Lovell 2014, Conrad 2014, Suh 2014a, Ferguson 2013b, Ingram et al. 2014), as well as ecological literacy and sustainability-relevant behaviors more broadly (Burton 2013, Ferguson 2013a, Guitart et al. 2013, Lewis 2014). We address permaculture both a useful case study to help shed new light on in grassroots networks and transition processes, and to provide some foundational assessment of a potentially impactful international network that so far has received little systematic scrutiny (Ferguson 2013a).

Based on our extensive review of the literature, no study of the makeup of the network has been published (Ferguson and Lovell 2014). Very little is known about who, in socio-demographic terms, is participating and what forms participation takes. Without previous research on permaculture to draw on, our study is necessarily exploratory in nature, and we cast our analytical net widely in the interest of identifying promising themes and questions for future research. While the broad spread and substantive content of the permaculture movement suggest potential contributions to sustainability transitions, our ignorance of who is participating limits our ability to assess permaculture's actual and potential impact or to identify barriers to efficacy and growth. The international distribution of permaculture makes it an ideal case for investigating not only the factors shaping participation, but how those factors vary across social and environmental contexts.

We structure this paper as follows: the next sections review relevant perspectives on participation in grassroots networks and environmental movements. We then introduce permaculture, highlighting the factors that make permaculture a useful and timely case study for investigating grassroots participation in sustainability transitions. Following the introduction we present our methodology, which includes the collection of data with an international web survey, followed by exploratory factor analysis, and fitting a multilevel multivariate regression model. In

the following section we present our results, discussing broad geographic and socio-demographic distributions and how they interact with national context to shape modes of participation. Finally we discuss the meaning of these results for understanding grassroots sustainability transitions in general and permaculture in particular. With the intention of addressing both scholars and participants of grassroots networks, we identify key implications of our findings and promising avenues for research and growth.

Participation at the grassroots: networks and movements

Researchers and non-governmental organizations increasingly regard grassroots networks as important sources of innovation and as engines for mobilizing needed resources in support of societal transitions to sustainability, as well as reducing the severity of environmental change (Seyfang 2007, Seyfang and Smith 2007, Ernstson et al. 2008, Bergman et al. 2010, O'Brien 2012, Dellapenna et al. 2013, Pansera and Owen 2014). Grassroots networks do this, broadly, by generating technical and social innovation in response to perceived problems, and by mobilizing around alternative approaches to management and consumption of resources. The appeal of grassroots actors and networks as agents of socio-technical transition is multifold. Grassroots actors may be able to innovate and adapt to changing conditions in ways and at a pace that the inertia of large institutions rarely permits (Seyfang and Smith 2007, Leach et al. 2012). By mobilizing resources in support of preferred technologies, grassroots networks create cultural and economic niches that buffer novel technologies (including forms of social organization) from the market and policy pressures of hostile socio-technical regimes (Smith 2006, Seyfang 2007, Seyfang and Haxeltine 2012). Support for innovation may also become more explicitly and conventionally political, as grassroots networks mobilize political capital to put pressure on existing institutions (Ernstson et al. 2008, Dellapenna et al. 2013).

The characteristics of grassroots networks can also present hazards to effective action. Grassroots efforts can be especially vulnerable to suppression and co-optation by state and business actors (Fressoli, et al., 2014, Feola and Nunes 2014, Gerlach 2001). Grassroots networks may be insular and/or exclusive, failing to include stakeholders with critical perspectives on the problem at hand, or failing to extend their influence to relevant constituencies (Ernstson, et al., 2008). When grassroots networks focus on local, bottom-up, and

project-based solutions, their impact may be constrained by their particularity, limiting their capacity to develop solutions that are generalizable beyond a specific context. Place-based and practical projects are vulnerable to a problem of scalar mismatch, when narrow technical solutions are offered as remedies for problems such as poverty or environmental degradation that are driven by structural rather than technical issues (Smith, et al., 2014).

The manifest political dimensions of grassroots networks – including the question of how participation is shaped by socio-demographic and structural factors – have received rather less attention in the literature on innovation and sustainability (Smith and Stirling 2010). There has been little crossover so far between the emerging literature on bottom-up eco-innovation and the expansive literature on participation in environmentalism. This is a critical gap, as our ability to assess the capacity of grassroots actors to support meaningful ecological transition hinges on our understanding of the factors that drive and constrain inclusive participation. Whether transition is viewed as a political or technical problem (or both), transitioning to sustainability will require profound changes, and broad and substantive participation across all sectors of society. Such participation is especially important in the case of frontline communities and politically marginalized populations, which are frequently impacted first and most severely by environmental issues even as they are excluded from meaningful democratic participation (Burleson 2010, Conant 2012, Smith and Stirling 2010).

An extensive body of research investigates the ways in which gender, ethnicity, and socio-economic status, shape engagement with environmentalism – including both formal movement activity and everyday environmentally relevant behaviors. For the purposes of this study we broadly categorize theories of socio-demographic differences in participation into cultural and material explanations. The former look to differences in in beliefs, norms, and perceptions, to explain differences in participation across groups, while the latter look to differences in access to material resources. In the case of gender, several studies indicate women are more likely to express concern about environmental issues and to engage in private environmental behaviors, but less likely to engage politically (Mohai 1992). The literature offers both material and cultural explanations for these effects. Biographical availability theory proposes that the socio-economic and political marginalization of women reduces their access to discretionary time and money,

and thereby curtails their capacity to act outside the household (Xiao and McCright 2014). A complementary cultural explanation holds that the gendering of caregiving as women's work encourages women to be especially vigilant for threats to the safety and wellbeing of the members of their households (Davidson and Freudenburg 1996, MacGregor 2002). Other studies have failed to clearly show these gendered patterns (Tindall et al. 2003), highlighting the need for a better understanding of the ways in which gender effects are mediated by social and structural context. Studies of the agrarian Landcare movement in Australia, for example, have shown that groups with high levels of women's participation are more effective than those without (Lockie, 1995).

Explanations of gendered participation have parallels in studies of ethnicity and environmentalism. Emerging from research in the U.S., subcultural explanations look to differences in beliefs and values between minority ethnic groups and the white majority to explain patterns in participation (Parker and McDonough 1999). This body of research offers few definitive answers, however, and many contradictory findings. Some scholars link this confusion to the wide variety of definitions, framings, and scales being deployed in these studies – suggesting the unsurprising irony that differing beliefs and values are embedded in the design of research intended to address differences in beliefs and values (Johnson et al. 2004, Tao Li and Wehr 2007). Barriers to participation theories integrate aspects of cultural and material explanation, by assuming that environmental values are similar across groups, and that differences in participation are driven by histories of oppression and exclusion, bias within white-dominated environmental movements, and feelings of powerlessness among marginalized groups (Adams 1992, Parker and McDonough 1999). Barriers theories thereby shift attention to the culture of majority-white environmentalism as a force excluding or limiting non-white participation (Kalof et al. 2002).

Drivers of participation do not operate strictly at the level of individual socio-demographic factors. Broader social, political-economic, and environmental context also shape engagement with environmental issues in ways that invoke cultural and material explanations. Environmental concern has long been identified as a facet of 'post-materialist' values and thereby a luxury of the industrialized nations (Kemmelmeier et al. 2002) who are themselves the lead contributors to

global environmental crises. This view is the subject of vigorous debate, with some studies showing opposite effects – i.e. an inverse relationship between environmental concern and national affluence (Gelissen 2007, Dunlap and York 2008). The 'objective problems – subjective values' theory attempts to reconcile seemingly contradictory findings by proposing that environmental concern in the highly-developed nations is driven by values, while that in the less-developed nations is driven by direct experience of environmental degradation (Brechin 1999). We must assume that individual- and structural-level forces interact to drive engagement. To our knowledge no research has addressed such interactions (cf. Nawrotzki, 2012, which uses examines the influence of such cross-scale interactions on a single measure of environmental concern). Examination of cross-scale interactions holds the potential to bolster and clarify both individual-level and structural effects. For example, material barriers to participation should have greater effects in countries with greater levels of distributional inequality. Cultural (and cross-cultural) effects which presume environmental context – such as women's socialized vigilance for threats to the household – should have stronger effects where environmental degradation is greater.

While it is important to identify the ways in socio-economic and cultural forces suppress diverse participation (Verba et al. 1995), apparent differences in level of engagement may obscure qualitative differences in style of engagement. The participation of members of marginalized communities can pass unrecognized if research questions are informed only by the environmentalism of elites. Research on innovation for sustainability tends to direct our attention to top-down processes of policy and technocratic management (Seyfang and Smith 2007, Bergman et al. 2010) rather than bottom-up innovation and mobilization. Despite evidence to the contrary, the literature often situates individuals and communities with little access to resources largely as markets for innovation flowing from the top down, rather than sources of innovation that can benefit not only themselves but also the wider world (Pansera and Owen 2014).

Research on environmentalism does distinguish between public/political and private/personal engagement forms of engagement (Mohai 1992, Coffé and Bolzendahl, 2010). While valuable, this dichotomy still threatens to obscure or undervalue forms of engagement that don't look like conventional movement politics (Lockie 1995, Lewis 2014). Recent studies have highlighted the

complex relationship between race, gender, and socio-economic status, and non-movement forms of engagement including land use planning (Villamor et al. 2014), relational activism – which might in another context be called social innovation (O'Shaughnessy and Kennedy 2010), and eco-innovation (Pansera and Owen 2014). This quantitative survey-based research is complemented and challenged by qualitative research that takes the engagement of women and people of color as a starting point and explores the ways in which identity shapes participation (Bell and Braun 2010, Taylor 1997, Einwohner et al. 2000, Taylor 1997, Rainey and Johnson 2009, Culley and Angelique 2003). Taken together these studies suggest that as we identify the forces of exclusion shaping forms of action associated with elites, we should also expand our conceptions of participation to encompass multiple dimensions of bottom-up engagement.

Objectives

This study directs these questions about drivers of bottom-up participation in sustainability transitions to an examination of the permaculture movement. In doing so we address several intersecting gaps in the scientific literature. The first is highlighted by the emerging literature on grassroots innovation, which has brought attention to the importance of extra-institutional actors and networks to the processes of sustainability transition. This literature has so far, however, paid little attention to the socio-demographic constraints on participation in these networks. The influence of socio-demographic factors on the dynamics of inclusion and participation is critical for understanding the capacity of grassroots networks in transition to sustainability.

The second gap is the lack of any systematic examination of the permaculture movement. As a network and a set of ideas, permaculture appears to have something to offer to sustainability transition, but our ignorance of who is participating, and how, inhibits our ability to assess its potential and identify barriers to efficacy and growth. This study attempts to remedy that gap by conducting a broad international – though English-only – survey of permaculture participants and analyzing the socio-demographic characteristics of the network. The analysis explores the relationships between multiple participant roles identified by respondents, as well as the relationships between those roles and individual and structural forces.

In investigating the influence of socio-demography on dimensions of participation in permaculture, this project also extends the existing literature of personal, socio-economic, and structural influences on grassroots environmentalism, with an emphasis on exploring the interactions between structural and individual factors.

Our objectives were to: (1) provide a foundational description of permaculture as a grassroots innovation network; (2) describe the socio-demography of participants; (3) identify the ways in which personal, social, and structural factors shape the roles played by participants, with special attention to gender, race, and socioeconomic factors at the individual and structural level; and (4) identify questions for future investigation. This exploratory research is driven by the overarching questions of: Who is participating in permaculture? What roles are they playing? How do socio-demographic factors shape participant roles?

Permaculture

In this section we will critically outline key concepts and characteristics of the permaculture literature and the network, including apparent strengths and liabilities. A recent systematic review organizes analysis around four strata, assessing permaculture as design system, best practices framework, worldview, and movement (Ferguson and Lovell 2014). Across these strata, permaculture offers a distinctive perspective on socio-ecological transition, with key principles that parallel or prefigure themes in sustainability-oriented scholarship, such as landscape multifunctionality, ecosystem mimicry, ecoagriculture, intervention ecology, and adaptive management (Nudds 1999, Blann et al. 2003, Folke et al. 2003, Ferguson and Lovell 2014, Hobbs et al. 2011, Lefroy 2009, Scherr and McNeely 2008). It is a direct antecedent to the international Transition Town movement that is receiving significant scholarly attention for its decentralized and populist approach to grassroots transition processes (e.g. Feola and Nunes 2014).

Permaculture's central concept is that humanity can reduce or replace energy- and pollution-intensive industrial technologies – especially in agriculture – through intensive use of biological resources and thoughtful, holistic, design, patterned after wild ecosystems (Holmgren 2002). Founded in the late 1970s by White Australians Bill Mollison and David Holmgren,

permaculture's broad geographic spread today is largely due to Mollison, who spent the decades following permaculture's founding teaching internationally at an ambitious pace (Grayson 2010). The permaculture movement today consists of a loosely affiliated network of individuals and projects, connected through permaculture courses and workshops, online forums, and local projects, as well as through and regional, national, and international convergences (Ferguson and Lovell 2014, Grayson 2010). Groups generally display a low level of institutionalization, and projects encompass a wide variety of functions, commonly including community gardens, campus greening initiatives, educational efforts, and less commonly, demonstration and/or research sites, periodicals, and farming-focused education and support efforts. While permaculture has a strong focus on productive landscapes, it does not appear to be a generally rural/agrarian phenomenon. The concerns of permaculture's literature and web presence are spread across the urban-rural gradient, and discussion of production have focused primarily on home- and market-garden scale.

Transition requires not only socio-technical innovation, but also the narratives and values that motivate adoption and advocacy (Fressoli, et al., 2014, Dellapenna et al. 2013, Philippe and Bansal 2013, Paschen and Ison 2014). Though popular discussions of permaculture often focus on questions of practice and technique, the contributions of such grassroots networks to sustainability transitions may be through the worldview they disseminate (Kemmelmeier et al. 2002, McFarlane and Boxall 2003). The permaculture worldview incorporates a theory of human-environment relations that positions humans as ecosystem managers, highlighting the potential for holistic design and management to meet human needs while increasing ecosystem health (Toensmeier and Bates 2013). Like contemporary theories of socio-ecological systems (Berkes et al. 2002, Gunderson and Holling 2002), this notion contradicts both traditional, preservation-oriented conservation, and growth-oriented development, each of which invokes a fundamental contradiction between human well-being and ecosystem health (Pálsson 1996, Strongman 2012).

It is likely that participants' level of engagement (Parker and McDonough 1999) with permaculture is driven by an experience of empowerment (Smith 2002). The "simple solutions populism" of permaculture (Ferguson and Lovell 2014 p. 267) suggests that the best responses to

global crises can be implemented immediately with readily accessible materials and skills. As a theory of change, simple solutions populism shifts the perceived locus of control over environmental crises toward the individual (Hines et al. 1987) and ameliorates the inverse relationship between the scale of environmental problems and individuals' sense of efficacy (Uzzell 2000).

The worldview of permaculture is reflected in model of change that mostly spurns systematic engagement with existing institutions in favor of direct intervention into the means of subsistence, reintegrating production and resource management under the stewardship of local individuals and communities (Grayson 2010). This strategy for social transformation seeks to re-work human-environment relations from the ground up and avoid the 'long march through the institutions' (Cornils 1998). The flat network structure that accompanies this mode of action appears to be a conscious strategy to avoid the avoid the twin dangers of cooptation and outright suppression to which grassroots efforts are vulnerable (Feola and Nunes 2014, Gerlach 2001, Mollison 1997). This model has met with some success, as evidenced by its international distribution and positive influence on urban land use, horticultural and agricultural practices, and other sustainability-relevant behaviors across contexts (Lewis 2014, Guitart et al. 2013, Ferguson 2013a, Burton 2013, Conrad 2014, Yuen et al. 2001, Soares 2005, Ventura and Andrade 2011, Suh 2014b, 2014a).

The evident successes of the permaculture network are balanced by problematic assumptions and implications that evoke the hazards of insularity, exclusivity, particularity, and scale mismatch to which grassroots networks are prone. The emphasis on individual responsibility, and the proposed abandonment of existing civic and civil institutions, provide uneasy parallels with neoliberalism, the dominant political-economic ideology of our time (McCarthy and Prudham 2004, Guthman 2008). Like other versions of localism and voluntarism, these aspects of permaculture threaten to engender a depoliticized naiveté concerning the scale of responses needed to address global and regional crises (Mohan and Stokke 2000, Allen and Guthman 2006).

Especially salient for this study is the notion, entrenched in permaculture thinking, that a lack of formal hierarchies ensures equitable access and democratic governance to and of the network:

> "As permaculture is open to new information, and to every person, it results in highly individual expressions of projects everywhere. As we are largely self-funded, we cost very little, and are not controlled by outside monies. Thus we are not subject to any external controls beyond our own ethics, or our own will to act. As we are a non-hierarchical network joined only by volunteer [sic] or the user-pays principle, we have no internal status differences, and we relate as equals. As we never need to vote, we are democratic; each acts as they see beneficial." (Mollison 1997 pp. 30–31).

In dismissing the possibility of constraints on participation other than individual interest, Mollison encourages a 'demography blind' perspective that ignores the forces of privilege and exclusion embedded in race, gender, and class relationships (Bonilla-Silva 2006). The conflation of a lack of formal hierarchy with the absence of hierarchy in general is not unique to permaculture, and has been the subject of critique since the years of permaculture's founding – first in the context of the emerging second-wave feminist movement (Freeman 2013), and most recently in criticism directed specifically at permaculture's sibling movement Transition Towns (Trapese Collective 2008). An alternate view is that socio-demographic constraints on diverse participation can only be remedied through programmatic mobilization of resources and strategic policy initiatives requiring some level of institutionalization. Formal and bureaucratic hierarchies often constitute pernicious barriers to transition, but these effects can be ameliorated through participatory democratic structures and processes (Fung and Wright 2001, Menegat 2002). Informal hierarchies of rank and privilege, on the other hand, lack such concrete points of leverage and are often invisible to their beneficiaries (Sue 2004).

Low levels of institutionalization may also constrain capacity for program development, systematic tracking of outcomes, and engagement with potential allies. Recent research suggests that the permaculture network in the UK is vulnerable to insularity, and thereby to a lack of capacity to influence relevant institutions and communities (Ingram et al. 2014).

We will here primarily use the term grassroots network to describe permaculture, rather than the more specific "grassroots innovation network" or "global action network." We use this term in the interest of simplicity, to situate our investigation in relation to the literature on sustainability

transitions, and because it better conveys the generally low levels of institutionalization associated with permaculture. We will also use the term movement to reflect the permaculture literature itself, and when it serves clarity and readability.

METHODS

Data Collection

We administered the survey using the online service Surveymonkey from July to October. The survey was only available in English. We solicited respondents through a variety electronic and social media, including regional, national, and international permaculture-related email lists and online forums, through permaculture interest groups on social media, and through the researcher's website. We also asked respondents to refer the survey within their own networks. We invited response people who "participated in permaculture in any way," and was restricted to respondents 18 years of age and older. A total of 1,055 respondents began the survey. By virtue of web access and language, our sample excludes important sectors of participants in permaculture (see below), and this exploratory study pertains only for those sector of the permaculture network with web access and facility in English.

To screen out respondents with no connection to permaculture, only respondents who first indicated involvement with permaculture were given access to the survey. We additionally removed respondents that did not select any roles and those that explicitly indicated ignorance of permaculture in open-ended responses. In the data cleaning phase we eliminated responses with less than 70% completion and responses without geographical location information. These screening steps left 731 responses for analysis. Results are concentrated in the United States (59%), Australia (15%), Canada (8%), and the United Kingdom (5%). The rest of the responses were distributed among 42 countries, with 1-9 responses per country.

In addition to standard socio-demographic questions, the survey contained sections addressing roles played by participants, participation in network activities, the influence of permaculture on sustainability-relevant lifestyle behaviors, experiences in permaculture education, prior understanding of permaculture, and understanding gained from exposure to permaculture on a

number of broad social and ecological themes. The survey also contained a section addressing levels of participation in permaculture projects and institutions, civic institutions, and social movement activities, and the level of integration of permaculture with the latter two categories of activity. The survey included separate sections on professional permaculture work in design, farming (and other agricultural/horticultural production occupations), and education. Only socio-demographic data and roles are assessed in this paper.

To assess participant roles, we asked respondents to check all applicable terms in a list following the question "What role have you played in permaculture?" Choices consisted of community member, activist, teacher, organizer, professional, practitioner, designer, consultant, and student. The role categories were arrived at based on expert knowledge, grounded in extensive review of the literature and a decade of personal experience in the permaculture network.

Data analysis

We carried out data analysis in four stages: cleaning and preparation, descriptive analysis, factor analysis, and multilevel modeling. We carried out preliminary cleaning and processing of data, including regularization of open-ended questions and geocoding, using the spreadsheet application Numbers (v. 2.3) and Google Refine (v. 2.5, now OpenRefine). We performed subsequent analyses in the R software environment (3v. .0.2).

Explanatory variables were divided into personal factors, socio-economic status indicators, and structural factors. Personal factors included gender (M/F/Other), age, and race/ethnicity (White/Caucasian, Native American, Hispanic, Asian/Pacific Islander, Black/African-American). Socio-economic status indicators included highest level of education completed, relative income (annual income as a proportion of the national median annual income), and residential status (rent/own/live with family/other).

Structural factors consisted of national-level indices drawn from secondary sources, including measures of overall human development, socioeconomic inequality, and ecosystem vitality (Figure 3.1). The Human Development Index (HDI) is a composite index created by the United Nations Development Programme, intended as a multidimensional measure of human wellbeing

and a substitute for Gross Domestic Product. It includes measures of life expectancy, education, and gross national income per capita (Sen 1994). HDI scores were available for all countries except Japan (N=2) and Saudi Arabia (N=1).

The Inequality-Adjusted Human Development Index (IAHDI) calculates a penalty for each dimension the dimensions of the HDI based on distributional inequality (Hicks 1997, Alkire 2010). We used the aggregated penalty (expressed as the percent loss to HDI) as an index of national-level inequality. Of the countries in the sample for which HDI scores were available (i.e. excepting Saudi Arabia and Japan), the inequality score was available for all except South Africa (N=8).

To investigate the effect of environmental quality we used the Ecosystem Vitality (EV) component of the Environmental Performance Index generated by the Yale Center for Environmental Law & Policy as a predictor variable. The Ecosystem Vitality index includes dimensions of air quality, water resources, biodiversity and habitat, natural resources, and sustainable energy (Emerson et al. 2010). This index was available for all countries represented in the sample.

Imputation of Missing Data

After assessing descriptive statistics and prior to model fitting, we imputed missing values in the predictor variables in order to retain information in cases with complete sets of response variables and partial sets of socio-demographic predictors. Multivariate imputation with chained equations, using a random forest prediction algorithm, was performed with the mice function in the R package of the same name (Buuren and Groothuis-Oudshoorn 2011). A small number of missing structural variables were imputed with the same approach, but calculated separately and prior to personal variables, using 50 national-level variables drawn from the combined datasets of the Inequality-Adjusted Human Development Index and the Environmental Performance Index as predictors for imputed values. Insufficient data were available to justify the imputation of otherwise national-level indices for the territories of Bermuda (N=3) and Puerto Rico (N=1), and these responses were therefore left out of the model.

Factor Analysis

We then performed exploratory factor analysis on the nine role variables, with the goals of identifying relationships between roles and extracting a smaller number of new variables, thereby reducing dimensionality. We used the fa.poly function from the psych package, which computes tetrachoric correlations and is therefore suitable for use in factor analysis of binary data such as the role variables (Fox 2009, Revelle 2012). We assessed factor adequacy with the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and extracted factor scores for each using the ten-Berge method.

Model Fitting

We then fitted a multivariate multilevel model using the extracted variables from the factor analysis as response variables and socio-demographic and structural variables as predictors. Prior to model fitting we confirmed the absence of multicollinearity for all continuous predictor variables. We aggregated groups within categorical variables to produce binary variables, with the intent of reducing model complexity, using a heuristic of contrasting traditional power-holding groups with historically marginalized groups (despite the real differences in kind and scope of marginalization that these groups experience). We aggregated ethnicities other than White/Caucasian (Asian or Pacific Islander, Hispanic, Black/African American, and Native) under the category People of Color (POC). We will refer to the simplified variable as race, and continue to refer to the original variable as ethnicity. We merged the gender categories female and other on the grounds of sharing marginal status in patriarchal societies. We assume that the observed effects of the simplified Female/Other category are driven by the supermajority of female-identified respondents, so we will refer to that category as women and/or female when discussing the model. We aggregated residential status into two categories, contrasting homeowner and "other" residential status (including renting, living with family, and other). We specified interaction terms between select national-level structural variables and individual-level socio-demographic variables: between the environmental index and gender, and between the inequality index and gender, race, and income.

The survey, while only available in English, received responses from both anglophone and non-anglophone countries. In order to control for any effects of the relationship between the language

of the survey and national language, we included a binary variable indicating whether the national language(s) of respondents' country of residence included English.

As our data consists of individuals nested within countries, with variables at both levels, traditional regression would violate assumptions of independence. Regression methods that are appropriate for nested data are referred to by multiple names, including multilevel modeling (MLM), mixed effect modeling, random coefficient modeling, and hierarchical modeling. MLM approaches are increasingly chosen for their flexibility, as they naturally accommodate unbalanced data, and for their power, as they "borrow strength" across group, estimate parameters through partial pooling of variation (Gelman et al. 2004).

We selected a Bayesian modeling strategy to fit our model for several reasons. Practically speaking, few statistical packages can accommodate multilevel multivariate regression models. In the R environment, the most mature and flexible function for fitting multivariate MLMs is MCMCglmm, which is Bayesian in approach (Hadfield, 2010). Bayesian MLMs have been used effectively in cross-national studies of attitudes toward (thought not engagement with) environmentalism (Nawrotzki 2012, Mostafa, 2013). The Bayesian approach is also theoretically suitable. Model fitting in a Bayesian framework does not rely on assumptions about sampling distributions and allows for probabilistic examination of model parameters based on posterior distributions. It therefore naturally lends itself to model-based inference, which is more appropriate for our non-probability (i.e. convenience) sample than the more conventional design-based inference (see below) (Koch and Gillings 2004). Bayesian model fitting follows the following steps: (1) Prior knowledge is used to assign distributional assumptions (priors) to model parameters. (2) A likelihood function is calculated based on the priors and the data. (3) Priors are multiplied by the likelihood function to produce a posterior distribution of parameter values. (4) Posterior distributions are then iteratively sampled and updated using using Marcov Chain Monte Carlo (MCMC) simulation. With sufficient sample size and/or the specification of uninformative priors, the MCMC algorithm will produce estimates of model parameters comparable to frequentist approaches, as the data overwhelms the influence of the priors (e.g. Mostafa 2013).

Using the MCMCglmm package, we followed the standard practice of using uninformative priors, specifying an inverse-Wishart distribution for variances with a mean of zero and low degree of belief. Following Hadfield (2010), we fit a parameter expanded model, incorporating redundant working parameters that are not identified in the likelihood function, in order to improve mixing of the sampling chains and speed convergence. We ran the final model for 500,000 iterations, discarding the first 60,000 draws as burn-in to reduce the influence of starting values, and retaining every 80th draw thereafter to protect against autocorrelation within the chains. These conditions produced an effective sample size of at least 4790 for all parameters of interest. We verified low levels of autocorrelation within chains (< 0.04 at any lag) (Congdon 2014). In order to assess convergence we visually inspected trace plots and kernel density plots of the simulation draws for all parameters, and verified that trace plots appeared as random noise and kernel density plots appeared approximately normal. We used visual posterior predictive checks to assess model fit, confirming that all observations fell within the 95% credibility interval of the mean of the posterior predictive distribution (Gelman et al. 2004).

Model-based Inference for Exploratory Research

In an exploratory context, with no systematic knowledge of the target population, and a convenience sample generated by the uncontrolled web-based distribution of the survey instrument, the most appropriate approach to inference is model-based rather than design-based (Sterba 2009). Conventional design-based inference relies on randomized sampling from a finite population to reduce sampling bias and support inferences about the population. Model-based inference is a complementary approach that focuses on the relationship between variables in the model rather the relationship between the sample and the population. It is often used for web-based research and other scenarios when randomized samples are not feasible (Schonlau et al. 2002, Anderson 2008, Bethlehem and Biffignandi 2011, Clarke 2011).

This study is relevant to a specific sector of permaculture participants – those with web access and facility with English. This sector warrants investigation in its own right, and we must also note that those excluded from our sample by technology or language include important sectors of the permaculture network, in the developing world particularly, including smallholder farmers and other subsistence producers (Terui 2000, Meigs 2004, Felix-Romero 2010, Conrad, 2014).

RESULTS

Description

Personal Variables

Personal socio-demographic variables included gender, race/ethnicity, and age (Table 3.1). Gender responses across all 731 respondents were 389 female, 328 male, and 14 other. Female respondents were the largest category in most groupings, including the four countries with 38 responses (USA, Australia, Canada, and UK, N=643). Reported age of respondents had an overall median of 40.

Racial/ethnic identification among respondents was overwhelmingly White/Caucasian (661), followed by Hispanic (16), Asian or Pacific Islander (10), Black/African American (9), Native American (6), and 29 non-responses. Of the top four responding countries, responses from Canada were the most diverse, with most numerous responses from White/Caucasian (56), followed by Asian or Pacific Islander (2), and Black/African-American (1) and Native American (1). The least diverse set of responses were from the UK, with no respondents identifying as other than White/Caucasian. Responses from outside the top responding countries, though still showing a super-majority of White/Caucasian respondents (74), followed by Hispanic (8), Asian or Pacific Islander (3), and 3 non-responses. In Figure 3.2a, ethnicity in the sample is plotted alongside national statistics for ethnic demographic distribution for the top responding countries. In each country the sample was less diverse than the national context. The USA is the most diverse of the four, had the largest number of responses, and showed the most severe underrepresentation in the Hispanic and Black/African categories. For these comparisons, note that we cannot formally distinguish between lack of diversity in the permaculture movement and bias in our sample. The degree of difference, however, makes it highly plausible that diversity is a real issue in the permaculture network.

Socio-Economic Status Indicators

Indicators of socio-economic status (SES) included level of education, status of current residence (own/rent/family/other), relative income (annual income as proportion of the national median). For education, the most numerous responses overall, in descending order, were 4 Year College

(300), Masters (158), High School (125), 2 Year College (114), PhD (34), and Primary School (1 – not displayed in plots). Of the top four responding countries, Australia had the highest percentage of respondents who had not completed any post-high school degree (27%), followed by the UK (24%), the USA (14%), and Canada having the lowest percentage (12%). Across all other countries, 26% of respondents had not completed any post-high school degree. Education level in the sample is plotted alongside national education statistics for the top four responding countries (Figure 3.2b). As above, note we cannot formally account for bias in our sample in making this comparison.

In the overall sample, 433 respondents indicated that they own their current residence, 200 rent, 69 live with family, 75 in some other arrangement, and 43 non-responses. The USA respondents reported the highest percentage of ownership (60%) and the UK the lowest (29%). The overall ratio of homeowners to renters (ignoring the other categories) was 1.7:1, suggesting intermediate to high socioeconomic status.

For relative income, missing data were generated both by non-response (accounting for the majority of missing entries) and by the lack of national income data for a small number of countries, leaving 584 responses for analysis (USA N=363, Australia N=102, Canada N=54, UK N=28, all others N=37). The sample-wide median value for relative income was 0.8.

Response Variables

The most commonly identified role was community member (501 responses), followed by student (489), practitioner (488), designer (309), activist (306), teacher (283), organizer (281), consultant (235), and professional (159). Respondents were asked to check all applicable roles. The median number of roles selected was four.

Factor analysis

Parallel analysis and optimal coordinates analysis both indicated the retention of three factors (Raîche et al. 2013). Factor adequacy was confirmed with the Kaiser-Meyer-Olkin Measure of Factor Adequacy, using the KMO function in the R psych package (Kaiser 1974, Revelle 2012). The Overall Measure of Sampling Adequacy was 0.88 (‘great’, cf. Kaiser 1974 for this and

following). The largest item sampling adequacy score was for the role of activist (0.92, 'superb', ibid.) and the smallest was student (0.76, 'good', ibid.). The first factor was labeled "professional," and the included the variables for consultant (1), designer (0.9), professional (0.7), and teacher (0.5) (Figure 3.3). The second factor was labeled "relational", and its loadings included organizer (0.9), community member (0.7), and activist (0.7). The third and final factor was labeled "practice," its loadings were practitioner (0.7) and student (-0.4). Note the single negative loading of student on the practice factor: identifying as a student lowers respondents' score on this dimension, and vice versa.

Fitted Model

Model results are displayed as a coefficient plot (Figure 3.4). Posterior means are plotted as points, and are analogous in practice to estimated coefficients in a frequentist framework. Error bars represent 95% Highest Posterior Density, and are analogous in practice to 95% frequentist confidence intervals (Hadfield 2010). In keeping with the exploratory nature of this study, for the purposes of discussion we relax the threshold for predictors that were significant within 90% credible intervals or that displayed an effect size commensurate with other credible predictors (Kirk 1996, Coe 2002, Maher et al. 2013).

Personal variables

Age and gender both had significant positive effects on the practice dimension. The strongest effect among the personal variables was the positive effect of male gender on the professional dimension. None of the effects of race were significant, but the size its negative effect on the relational dimension was commensurate with other significant effects.

Socio-economic Status Indicators

The effects of SES indicators were highly varied. Income had no significant effects. Homeownership negatively impacted professional and relational dimensions, and had a positive effect on the practice dimension. Level of education had a positive effect on all three response variables, with the strongest effect from two years of college (contrasted with high school

education only) on practice. The strongest effect among all SES indicators was the negative effect of homeownership on the relational dimension.

Structural variables and national language

The strongest effects among the national-level variables were from national language, with residence in a non-anglophone country having a negative effect on the relational dimension, and a strong positive effect on the practice dimension. Inequality had a significant positive effect on the practice dimension. Ecosystem vitality had a significant negative effect on the professional dimension.

Cross-scale Interactions

The model displayed several significant interactions between national- and individual-level predictors. Gender displayed significant interactions with the structural variables of inequality and ecosystem vitality (Figure 3.5). For both professional and relational dimensions, the relationship between men's and women's scores inverted across the gradient of ecosystem vitality, with men's scores negatively correlated with ecosystem vitality. Gender also interacted with national-level inequality to affect the practice dimension, such that as inequality increases, the practice gender gap increases.

Inequality also had a significant interaction with relative income, and sizable observed interactions with race, affecting the practice dimension.. As inequality increases, relative income shifts from a slight downward slope to a strong upward slope (Figure 3.6). In other words, at high levels of inequality, practice increases with relative income. The strength and direction of the observed interaction between inequality and race suggests that as inequality increases, POC identity has an increasingly negative influence on both professional and practice dimensions.

DISCUSSION

This project offers a first look at the socio-demographic characteristics of participation in the international grassroots network known as permaculture. Our approach focuses on variation within the movement, with coarser look at the degree to which survey responses resemble

national demographic distributions. Factor analysis and regression modeling illustrate the effects of gender, race, and SES on participation within the movement across multiple dimensions of participation. By including national-level indices in the model, our approach also offers an opportunity to further investigate the interactions between individual factors and larger-scale forces in an international context. Our findings show that gender and class are interacting with dimensions of participation in complex ways that vary across international socio-environmental context. Our findings complicate both cultural and material explanations of environmental action, and highlight the need for a perspective that emphasizes multiple dimensions of participation, and addresses the multiple levels and locations at which social forces shape grassroots involvement in sustainability transition.

Socio-demographic Overview

Survey responses show high/representative levels of diversity in age and gender and very low levels of diversity in ethnicity. The good news of proportional gender participation is moderated by our findings of gendered differences in participation. The bad news of disproportionately low ethnic diversity is compounded by observed (though non-significant) effects that suggest racial disparities in participation. The size of racial effects in the model, compared to other significant effects such as gender prompt us to take these effects seriously despite their lack of statistical significance (Coe 2002, Maher et al. 2013). The observed effects suggest that people of color are overall less likely than Whites to participate in relational roles, and that racial disparities in the professional and practice dimensions appear and grow as structural inequality increases. These constraints may be due to increasingly limited access to the resources required to participate (such as time), increasing feelings of powerlessness that accompany marginalization, or increasing cultural alienation between privileged and marginalized subcultures, or some combination of these factors. Determining which is beyond the scope of this project.

The socio-economic make-up of the permaculture network remains somewhat ambiguous. While relative income does not itself suggest disproportionately high SES, respondents do show higher than representative levels of education and intermediate to high levels of homeownership. For an environmentally-focused counterculture, such as that associated with permaculture, income may not be as meaningful an indicator of socio-economic status as other factors, owing to conscious

lifestyle choices among participants which may restrict income but do not necessarily alter other aspects of SES (Halfacree 2001, Hamilton and Mail 2003).

Modes of Participation

The clustering of the raw variables within the three extracted factors of professional, relational, and practice, illustrate multiple distinct dimensions of participation. The dimension we labeled professional is associated with high-status, public, and professional roles, while the dimension we labeled relational is associated with the work of generating and maintaining the network – roles that are less likely to be high-status, professional, or paid positions. The correlation of professional and relational, however, suggests that these dimensions are mutually compatible. We interpret the dimension we called practice to indicate engagement with some biophysical dimension, whether in the form of (for example) shifts in lifestyle, environmentally relevant behaviors around the household, horticultural or agricultural activities, or some other activity that is not purely social/relational. The weaker and absent correlation of either relational or professional with practice, respectively, points toward a degree of the autonomy between social (professional, relational) and biophysical (practice) modes of engagement. Participation in the form of practice could either bolster the two social modes of participation or compete with them, depending on the context and circumstances of the practitioner. The fitted model reinforces this picture of autonomy between social and biophysical participation.

Gender, Environmental Threat, and Sexism

Women are represented in the sample at or above their presence in the general population, but their participation in professional and practice roles, when compared to men, is not proportional to their presence in permaculture. The significant interaction with ecosystem vitality creates an interesting commentary on gendered differences in environmental participation. Women's socialization as caregivers has been hypothesized to heighten their vigilance against potential threats to the members of their household – and thus to care more about environmental issues (Mohai 1992). The intensity of women's involvement should therefore be highest at low levels of ecosystem vitality, especially in the dimension of practice, as they respond to visible and

imminent environmental threats. But this is not the case, and rather it is men's responses that are higher in more ecological degraded environments.

On the other hand, the relative exclusion of women from access to economic resources has been offered as an explanation of lower levels of women's participation in public sphere. The theory of biographical availability supposes that women are less available than men to participate in environmental activity outside of the private sphere due to the demands of the household and reduced discretionary resources (Xiao and McCright 2014). This would lead us to expect an interaction women's public involvement was more constrained higher levels of structural inequality, while potentially private roles such as practice would remain unaffected. Instead, we see a contrasting pattern: inequality does not appear to modulate the effect of gender on relational or professional dimensions, but does amplify the gender gap in the practice dimension.

These results confound the cultural and biographical explanations for gendered differences in participation. In the absence of support for these theories, the evidence points toward the more general explanation of ubiquitous gender bias – both external and internalized sexism – on gendered differences in participation. Women consistently receive less support and more criticism for taking on professional roles (Eagly et al. 1995, Eagly and Karau 2002), and the worth of their contributions is systematically underestimated by others (England 1992) and by themselves (Kray and Babcock 2006). These forces are likely driving both the roles that women actually perform in permaculture as well as how they identify their roles.

Costs and Yields of Practice

It is a foundational assumption that the practice of permaculture should be beneficial for individuals across a wide swath of SES, yielding a net material benefit to the practitioner without extensive capital investment. Participation as a practitioner, however, appears to be constrained by access to resources. At the individual level, the practice dimension is positively and significantly correlated with age, male gender, college education, and homeownership. These individual-level associations are reinforced by structural and cross-scale effects. Increasing inequality at the national level exacerbates gender disparity in the practice dimension. Higher practice scores are associated with respondents from non-Anglophone countries, who are likely

to have increased access to resources – either as highly educated native citizens of their countries of residence, or as immigrants or visitors from anglophone countries. Lastly, under high levels of structural inequality, practice becomes positively correlated with income, and has a stronger observed (though not significant) correlation with White racial identity.

Theories of barriers to participation appear to explain this aspect of our results well: practice is constrained by access to resources, and as the distribution of social and economic goods becomes increasingly unequal, the capacity of marginalized groups to practice permaculture is progressively curtailed (Parker and McDonough 1999). This is an unsurprising but nevertheless important finding for practitioners and advocates of grassroots transition networks such as permaculture. These are not, however, grounds to reject the notion of material benefits for practitioners. First, the effects described above may reflect initial barriers (i.e. start up costs), rather than longer term potential benefits. Second, as noted above, those excluded from our sample (by lack of internet access and/or lack of facility with English) include important sectors of permaculture practitioners – especially smallholders and other subsistence producers in the developing world, for whom the limited evidence available suggests permaculture may offer concrete benefits (Terui 2000, Meigs 2004, Felix-Romero 2010, Conrad 2014). Third, we should exercise caution in our interpretation of the interaction between income and inequality, as it is possible that in highly unequal countries, the practice of permaculture drives income rather than vice versa.

Subjective Values, Objective Buffers

In light of theories of biographical availability, barriers to participation, and post-materialist values, we might expect that increasing indicators of socio-economic status and human development would drive increasing intensity of involvement along professional and relational roles as well, i.e. more affluence equals more participation (Parker and McDonough 1999, Dunlap and York 2008, Xiao and McCright 2014). The variation in the effects of relative income, homeownership, and education, across dimensions of participation and structural factors, supports a framework that distinguishes between cultural and material components of SES on one hand and dimensions of engagement on the other. It would appear that some types of affluence promote engagement with environmental issues, while others act as a buffer between

affluent communities and the socio-ecological consequences of affluence (and its attendant consumption).

Implications

For both scholars of permaculture and participants, this study is intended to ameliorate the tendency to regard permaculture as unique phenomenon – a movement sui generis. While permaculture possesses its own distinctive characteristics, it is in many ways much like other environmental movements of the industrialized world – especially in that its participants are largely White and of intermediate to high SES. Like other environmental movements, the factors limiting diversity and equality in permaculture must be addressed thoughtfully and systematically if permaculture is to make a meaningful contribution to societal transition to sustainability. Researchers addressing permaculture should consider the ways in which permaculture can fit into existing theoretical frameworks of movement and network as well as the ways in which it does not sit easily into any Ferguson, & Lovell, 2012. The literatures of environmental movements and innovation networks are both useful resources for identifying key questions.

For scholars of grassroots innovation networks, this study demonstrates the need for attention to questions of access, diversity, and the socio-demographic constraints that shape them. The focus on informal networks of innovation (rather than traditional forms of mobilization around political and environmental campaigns) cannot be a reason to elide the political dimensions of grassroots sustainability efforts. For social movement scholars that are already steeped in analysis of drivers of participation, this study offers both a call to continue expanding investigation of the dimensions of participation, and to translate theory and methodologies geared toward classic environmental movements and apply them to networks and related forms of organization.

The parallels and contrast between the effects of gender, race, and SES, point the way toward a perspective that takes into account the multiple levels and loci at which socio-demographic and structural factors shape the capacity of grassroots actors to participate in innovation networks and environmental movements. It is clear that related but distinct constraints act differentially on (1) entry, or simple encounter and engagement with the movement and (2) the kind and intensity

of involvement once engaged. For example, the comparisons between sample and national demography show that whatever factors exclude POC do not also exclude women. Once engaged with the movement, however, being a woman depresses the professional dimension more than being a person of color (though both are affected negatively). It is possible that for those POC who manage to become involved with a White-dominated movement such as permaculture, the cultural and socio-economic barriers to entry act as a filter – selecting for qualities and capacities that mitigate, but do not eliminate, barriers to involvement in professional roles.

The diagram in Figure 3.7 illustrates a theoretical framework of boundary and terrain that attempts to integrate the forces that shape participation operating at multiple levels and loci. We don't intend that this framework fully address grassroots participation in all its psychological and social complexity (Kitts 2000, Bamberg and Möser 2007), but rather illuminate the role of socio-demographic and structural factors and their most explicit cultural aspects. We continue to use the term network in this discussion, but intend that this model should apply equally to movements.

It should be uncontroversial to observe that, in general, the interaction between an individual actor and a grassroots network is shaped by the resources and position of the actor (including psychological and material factors), and the distribution, cultural characteristics, and material resources of the network. Our model of participation proposes four main elements: actor, boundary, terrain, and landscape. The set of individual actor characteristics we identify is intended to be fairly standard, in relation to the literature of social movement studies. We use the term boundary to refer to processes that shape encounter and basic involvement with the network. For any given actor and their capacity, the possibility of encountering and entering a network is determined by the relationship between their own interests and capacities, and that of the network: accessibility (location, timing, and publicity of meetings), personal relevance, and cultural competency (the degree to which information about the network is conveyed in a way that is welcoming and inoffensive). Boundary processes at the grassroots have received considerable scholarly attention in multiple disciplines (Pachucki et al. 2007, Newell et al. 2000), including in the limited body of scholarly research on permaculture (Ingram et al. 2014).

Once an actor encounters and becomes involved with the network – passes or is admitted by boundary processes – an overlapping but distinct set of forces operates to shape the actor's participation. We refer to these processes as the terrain. The dimensions and scope of participation are determined by their interaction between actor characteristics, and the interplay of cultural attitudes (such as bias and support), material resources and their disposition, and other characteristics of the network. We refer to the larger socio-environmental context as the landscape, in which structural factors directly and indirectly influence participation, both shaping the prospects of the network as a whole and modulating the effects of individual socio-demographic factors. The factors shaping participation must be regarded as multi-level and multi-loci because participation itself is multidimensional and multi-local: from personal to public, from social to biophysical, and from relational to instrumental.

Limitations of this Study

This study is based on a convenience sample, so exact inference about the population of permaculture participants is not possible. The survey sample is likely skewed in both predictable and unpredictable ways by several factors: as a non-random sample, by English-only survey availability, and by web-only administration. As noted above, this survey entirely excludes important sectors of the permaculture movement that lack web access and/or facility with English. Within industrialized countries, the web-only format would predictably cause a skew toward high SES, and within non-anglophone countries in the developing world, the English language format and web-only format likely produce an even more pronounced bias. We should not assume that the influences of socio-demographic factors on modes of participation in permaculture within the developing world, in non-English speaking populations, and in lower SES groups, are well-demonstrated by this study. This study also relies solely on self-report of roles as a single (if multidimensional) index of engagement. Other metrics to quantify engagement may be more informative.

Future Directions

This study suggests several avenues for future research. The questions driving this study should be extended to encompass other dimensions of participation beyond role identification, including

environmentally relevant behaviors and involvement in network activities (e.g. hosting and attending events, giving and receiving aid, etc.). In order to understand permaculture's actual and potential contributions to transitions to sustainability, we must assess exogenous influence or outcomes. How does permaculture influence participant's public and/or professional lives? How, if at all, do participants integrate the permaculture worldview and principles into their relationship with institutions, their activism, or their life in civil society? Each of these questions can be addressed in an exploratory fashion with the remainder of the dataset used for this study – though interpretation will necessarily be constrained by the same limitations of the sample discussed above. Studies based on this dataset should inform further research making use of random and/or stratified sampling, multiple language availability, and multiple format administration, that can eliminate sampling bias and create a basis for strong statistical inference about the population of the permaculture movement.

Another key avenue is highlighted by those respondents that are participating in modes that are unusual for their socio-demographic group, and points to questions best addressed through qualitative research: What is the experience of women in professional and practice roles in permaculture, and what are the forces that facilitate their participation? What is the experience of the small number of people of color who do participate, and what facilitates their participation? How can the permaculture movement, and grassroots networks and movements generally, support diverse and representative participation?

CONCLUSION

With the slow pace of institutional change in response to global environmental crises, further attention to the capacity of grassroots actors to foster transitions to sustainability is needed. This article is intended to address both scholars of grassroots sustainability transitions and participants (particularly in the permaculture movement). To transition scholars, we have made the argument the cross-scale interaction between socio-demographic and structural factors points the way toward a perspective that stresses the multiple levels and loci at which these forces exert themselves, and thereby shape and constrain the participation of grassroots actors. Any such perspective must take into account the multi-dimensionality of participation, and seek to avoid

the simple dichotomies that threaten to obscure the richness and variety with which people engage with the task of transitioning to sustainability.

In addressing scholars of permaculture and the permaculture movement itself, we have shown that despite its distinct strengths, permaculture faces many of the same struggles around inclusion and diversity as other environmental movements with their origins in the global North. Expanded racial and economic diversity in movement participation overall, and expanded gender diversity in public professional roles, are critical for permaculture to contribute substantively to a transition to sustainability. Despite a lack of formal hierarchy, the network structure of permaculture demonstrably fails to create an inclusive and diverse movement. Permaculture participants and advocates should consider strategies to build institutional capacity in ways that enable systematic efforts to expand meaningful diversity while maintaining safeguards against co-optation.

Some permaculturists are taking up this challenge, as evidenced in the USA by recent discussion of gender bias in permaculture and strategies for correcting it (Olson-Ramanujan 2013), the emergence of regional women-only permaculture gatherings, and the formation of the Black Permaculture Network, a POC-led organization with a mission of soliciting and directing funding to provide scholarships to support students of color in attending permaculture courses (http://blackpermaculturenetwork.org/). While these developments are encouraging, there is much more to be done. The permaculture movement and its advocates face a complex dilemma in negotiating between two conflicting imperatives: that of conserving the model of change that has accompanied their international spread and successes to date, and changing that model in the face of the constraints it imposes on participation. This dilemma is not, of course, unique to permaculture – but it is critical. Currently, the lack equitable diversity across participant roles casts a long shadow over the relevance of permaculture in the global context. If participants can successfully address the dilemma of grassroots diversity, then as a set of ideas and practices, and as an international movement, permaculture will have much to offer the formidable task of transitioning to sustainability.

TABLES AND FIGURES

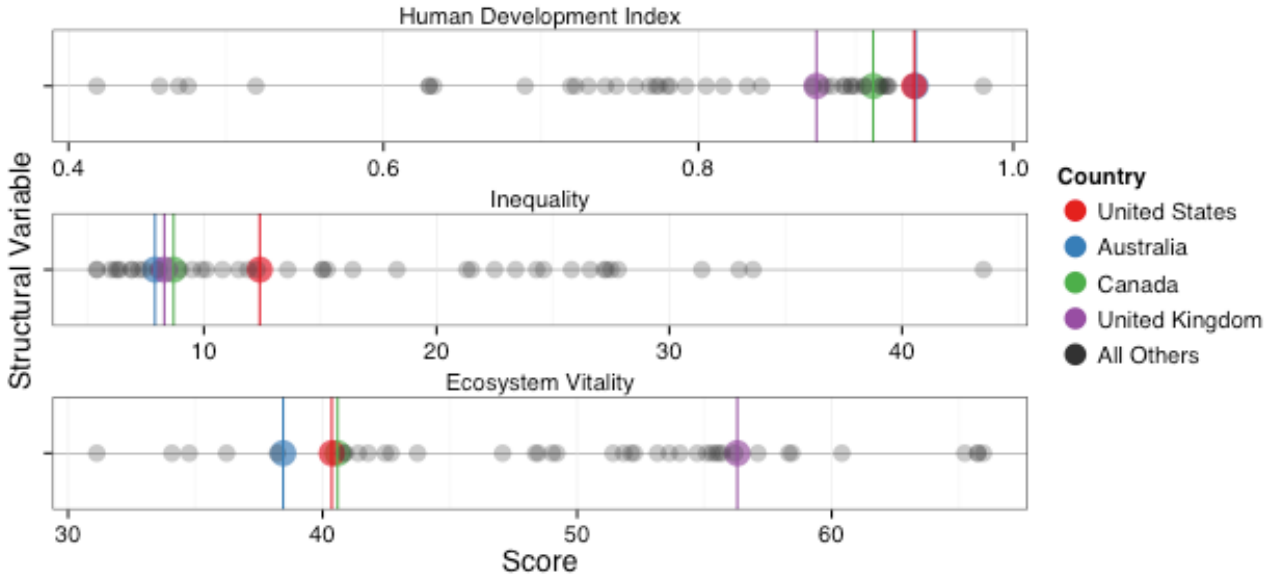

Figure 3.1. Structural variables: national indices of development, inequality, and ecosystem vitality across 45 countries. Distribution of scores on three national-level indices for the 45 countries in the sample. The four top-responding countries are shown in color, and the remaining 42 countries are in grey. The indices are each multidimensional, and derivied from the following sources. Human Development Index (HDI) is compiled by United Nations Development Programme (UNDP), Inequality is the penalty to HDI calculated as part of the Inequality-Adjusted Human Development Index (also compiled by UNDP), and Ecosystem Vitality is part of the Environmental Performance Index complied by Yale University and Columbia University. While the four top-responding countries represent the bulk of the responses, they only represent a small portion of the range of national-level conditions represented in the sample.

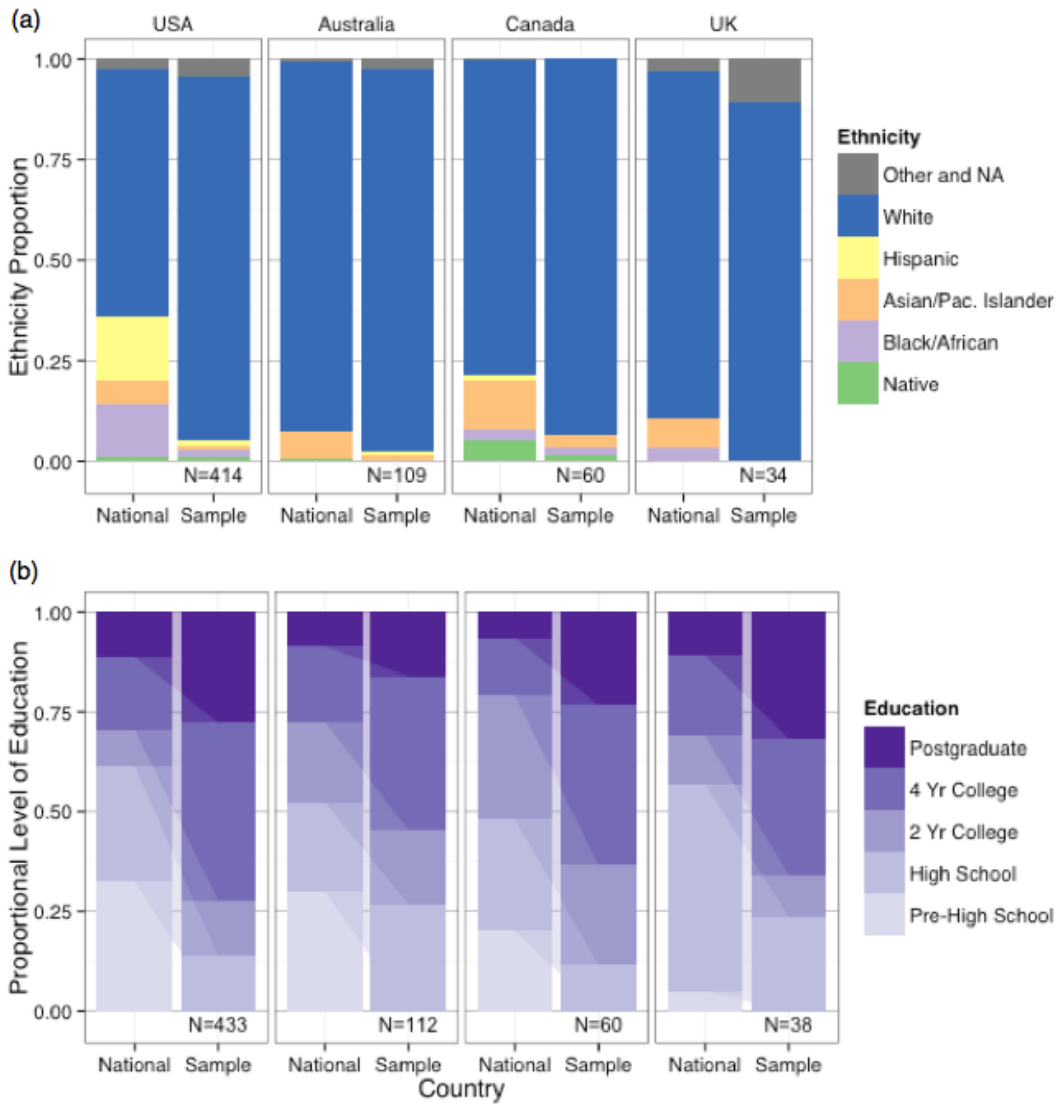

Figure 3.2 (a) Permaculture lacks ethnic diversity. The figure shows a comparative plot of proportional ethnicity, contrasting sample with national distribution for each of the four top-responding countries. In addition to non-responses, grey blocks here include ethnic categories in national data that do not match with survey categories. In each country the sample is less diverse than the national context. The most diverse of the four countries - the USA - also has the largest number of responses, showing conspicuous underrepresentation in the Hispanic and Black/African categories. (b) Permaculturists have received more schooling than average. The figure shows a comparative plot of level of education, contrasting sample with national distribution for each of the four top-responding countries. Transparent bars connect corresponding levels to aid interpretation. The sample lacks any responses in the lowest level of pre-high school education. Overall, the darker colors in the sample columns show higher levels of education than the national distribution for each country.

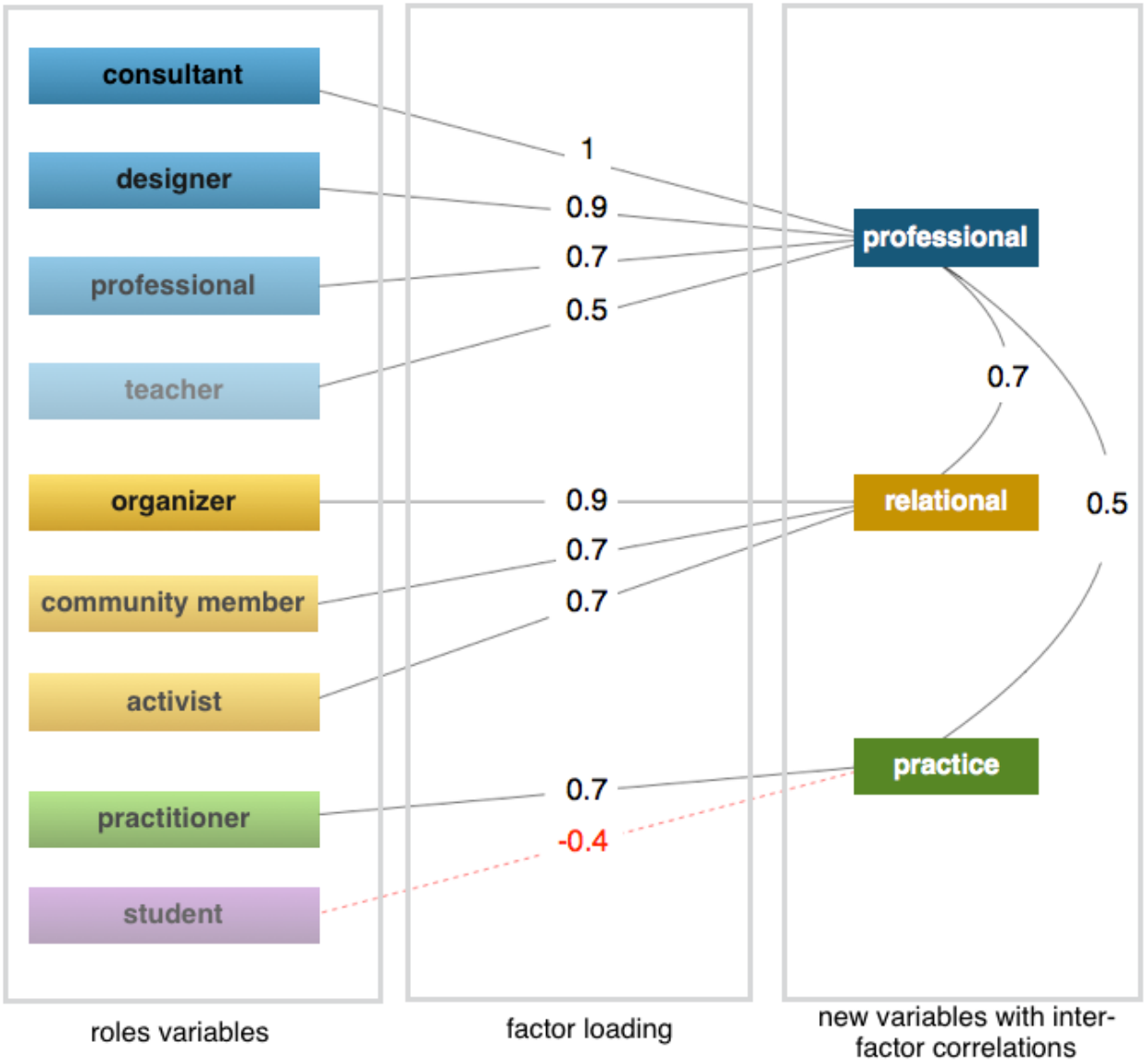

Figure 3.3. Factor structure of nine role variables to three dimensions. This figure shows the loading of the original 'check all that apply' role variables onto three factors, with the color and transparency of original variables showing grouping and strength of association. Factor structure shows distinct dimensions of participation, delineating between social and biophysical roles, and between higher- and lower-status roles. Within social roles, high-status, professional, public-interface roles, loading on the factor labeled 'professional,' and lower-status, relational, and likely unpaid roles loading on the factor labeled 'relational.' Biophysical participation is captured in the third factor, labeled 'practice,' which is loaded only by the roles of practitioner and student. Note that the loading of student is negative, so checking off the student role lowers a respondents score on the practice factor, and vice versa.

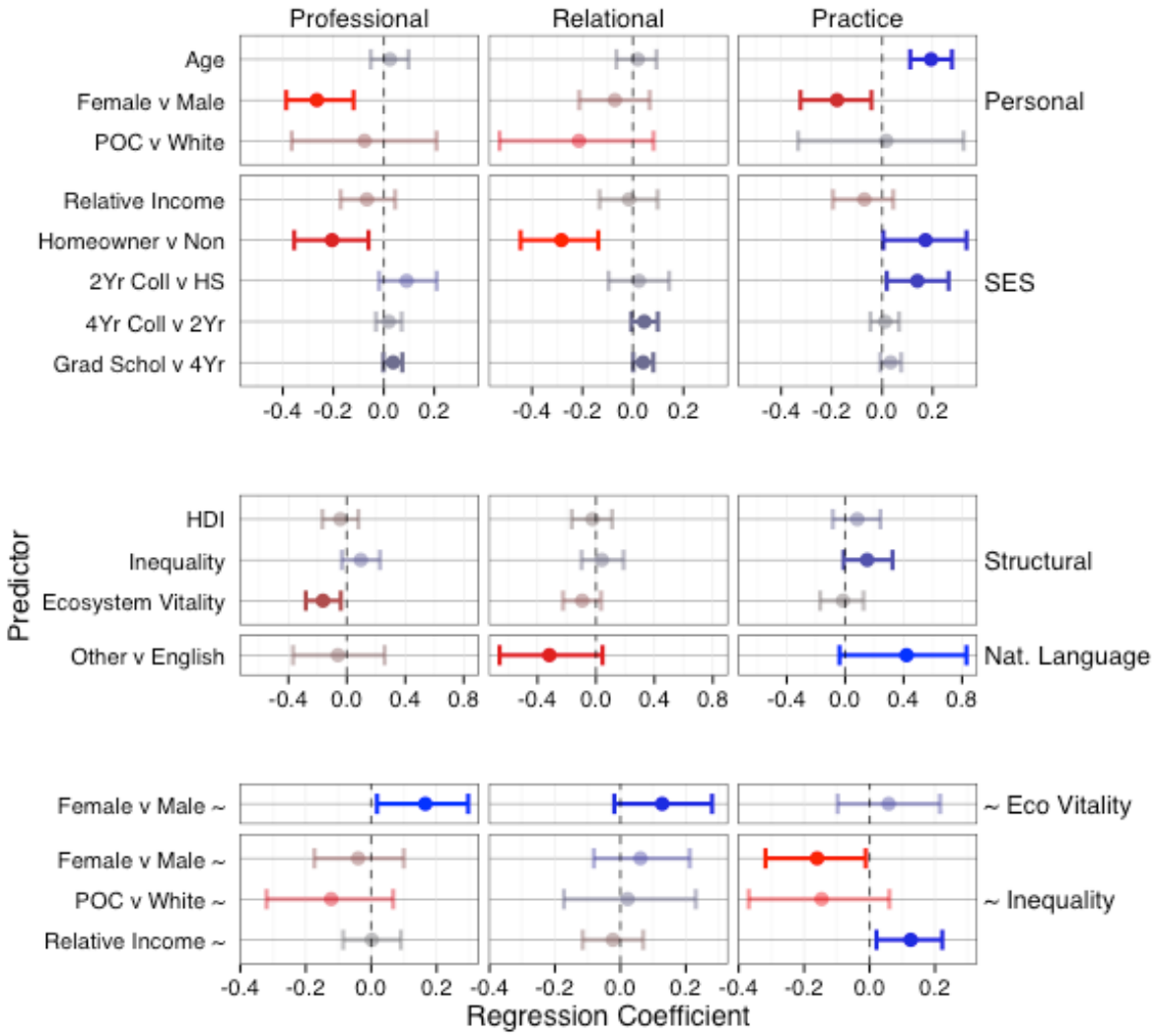

Figure 3.4. Model results show effects of socio-demographic and structural factors on dimensions of participation. The position of points for each predictor across three x-axes shows the mean of the posterior distribution - analogous in practice to estimated coefficients in a frequentist framework. The zero line indicates no effect of the predictor. Error bars represent 95% Highest Posterior Density, and are analogous in practice to 95% confidence intervals in a frequentist framework. Points and error bars are colored to show effect size (as the absolute value of the coefficient). Predictors not significant at 90% credibility are shown at 50% transparency.

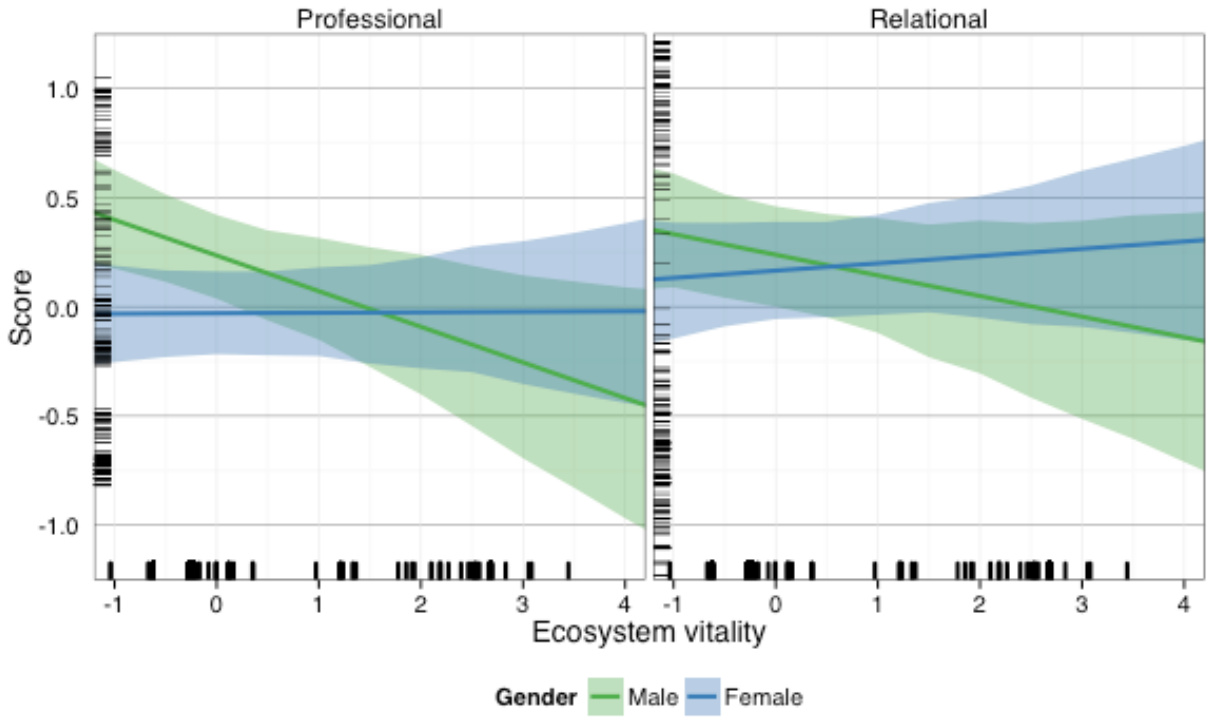

Figure 3.5. Women's participation in professional and relational dimensions is only slightly affected by ecosystem vitality, while men's participation on these dimensions declines as ecosystem vitality increases. Dimensions of participation are plotted on the y-axis and conditioning variables on the x-axis. Plots show model predictions (with unplotted variables held at constant values) and 95% Highest Posterior Density bands. Rug plots along each axis show the distribution of individual responses.

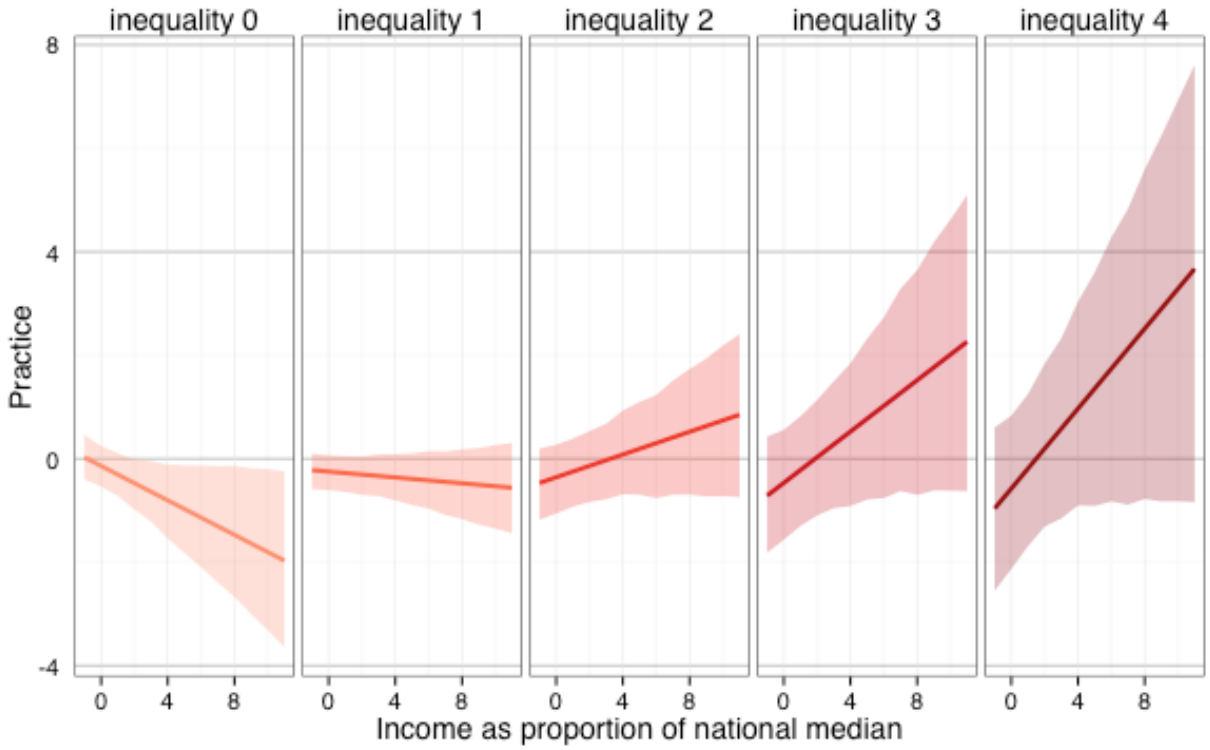

Figure 3.6. Income drives participation in practice roles, and the strength and direction of the effect is determined by national-level inequality. Plot shows model predictions (with unplotted variables held at constant values) and 95% Highest Posterior Density bands. Rug plots along each axis show the distribution of individual responses.

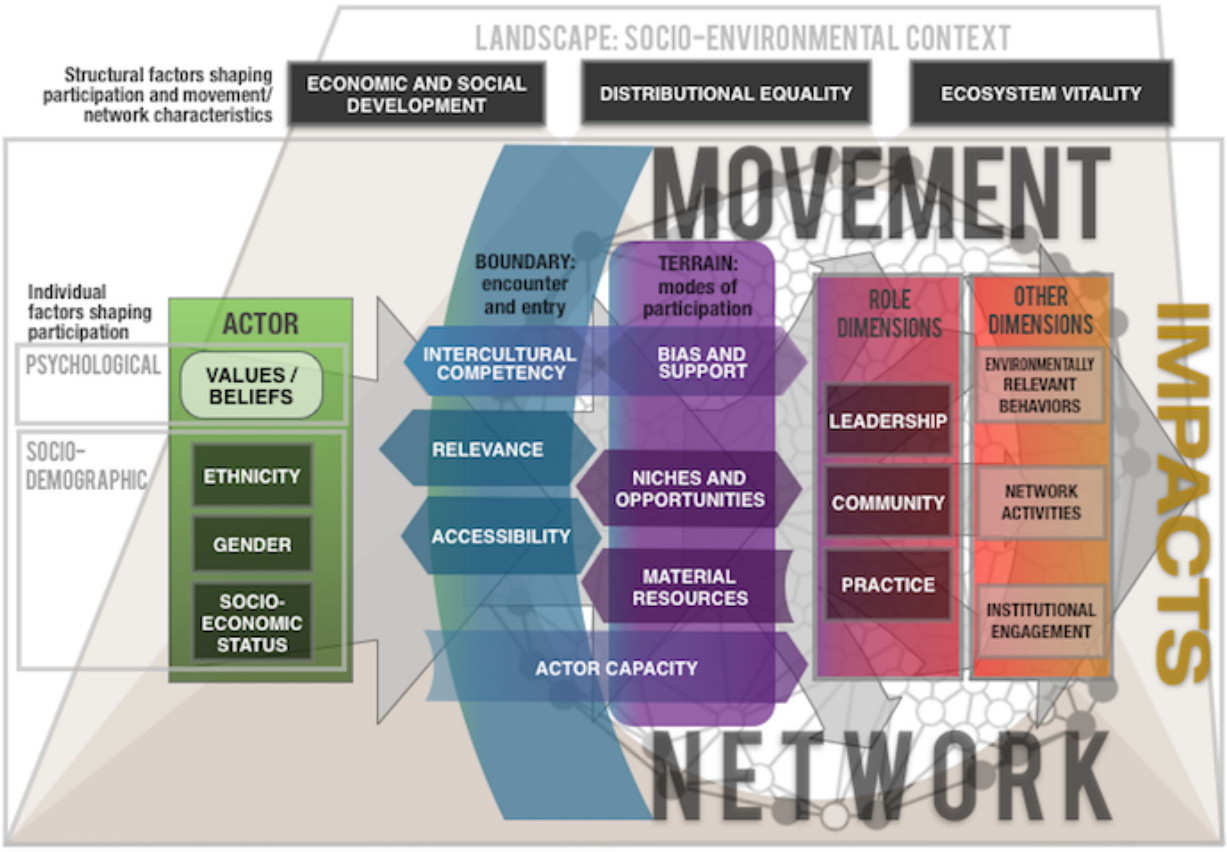

Figure 3.7. Boundary and terrain: a multi-level, multi-loci model of the influence of socio-demographic and structural factors on participation in movements and networks. Movement and network characteristics interact with socio-demographic factors to shape participant demography at two thresholds or loci: (1) simple encounter of the movement/network by the potential participant, and entry of the participant into the movement/network, and (2) a multidimensional participation profile. Participation is also affected by socio-environmental context, both directly and indirectly, as structural factors act directly on participation while also modulating the effects of participant demography.

Table 3.1. Demographic distribution among 731 permaculture survey respondents. The leftmost column shows distribution in the total sample. The other two blocks of columns show responses from the four top-responding countries, and all other responses divided into three categories accorded to Human Development Index, respectively. (a) Gender responses are within 10% of a 1:1 male:female sex ratio for the total sample and most subgroups. No respondents identify their gender as other in either the low or middle other/HDI grouping. Of the top 4 responding countries, the highest level of respondents identifying gender as other are UK and USA (.03 and .02, respectively), and the lowest is Australia (.01). (b) Ethnicity. Every subgroup shows a white supermajority. The most diverse responses come from each of the three subgroups outside of the 4 top-responding (and white majority) countries. Despite white demographic dominance across subgroups, the proportional ethnicity of the permaculture movement appears to shift with regional ethnic context. (c) Education. Of the top four responding countries, Australia had the highest percentage of respondents who had not completed any post-high school degree (27%), followed by the UK (24%), the USA (14%), and Canada having the lowest percentage (12%). (d) The overall sample ratio of homeowners to renters (ignoring family and other categories) is 1.7:1, suggesting intermediate-to-high socio-economic status. Among the four top-responding countries, Australia has the highest ownership:rental ratio at 2:1, and the UK the lowest at .73:1. (e) Relative income, or income as a proportion of the national median income. Missing values are created both by non-response and by lack of data on national median income, and thus all 15 potential responses in the lowest other/HDI category are missing. The median for the total and for 4 of the 6 subgroups is below the national median. This contrast with the other socio-economic status indicators (that suggest intermediate-to-high SES) highlights the ways in which income may not be a powerful indicator of socio-economic status in this context, due to conscious lifestyle choices among participants that may restrict income but do not necessarily alter other aspects of SES.

	Total	USA	Australia	Canada	UK	41 other countries by HDI		
						0.42-0.63	0.69-0.84	0.87 - 0.98
Responses	731	433	112	60	38	15	30	43
Number of countries	45	1	1	1	1	8	17	16
Gender								
Female	389	230	66	28	29	8	14	14
Male	328	193	45	31	8	7	16	28
Other	14	10	1	1	1	0	0	1
Ethnicity								
White/Caucasian	661	391	106	56	34	12	23	39

Table 3.1 (cont.)

	Total	USA	Australia	Canada	UK	41 other countries by HDI		
						0.42-0.63	0.69-0.84	0.87 - 0.98
Hispanic	16	7	1	0	0	1	4	3
Asian or Pacific Islander	10	3	2	2	0	1	2	0
Black/African American	9	8	0	1	0	0	0	0
Native	6	5	0	1	0	0	0	0
NA	29	19	3	0	4	1	1	1
Education								
High School	125	60	30	7	9	4	8	7
2 Year College	114	60	21	15	4	4	6	4
4 Year College	300	193	43	24	13	6	6	15
Masters	158	99	17	12	9	1	8	12
PhD	34	21	1	2	3	0	2	5
Residence								
Own	344	208	62	32	11	5	12	14
Rent	200	114	31	17	15	2	3	18
Family	69	36	8	5	4	3	7	6
Other	75	44	9	5	7	1	5	4
NA	43	31	2	1	1	4	3	1
Relative Income								
Max	22.5	22.5	11.79	5.26	3.13	NA	15.3	7.19
Median	8	0.77	1.01	0.885	0.555	NA	2.025	0.85
Min	0	0.02	0.03	0.03	0.06	NA	0.08	0

Table 3.1 (cont.)

	Total	USA	Australia	Canada	UK	41 other countries by HDI		
						0.42-0.63	0.69-0.84	0.87 - 0.98
NA	147	70	10	6	10	15	20	16

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4
Livelihood Diversity and Labor Productivity on US Permaculture Farms

INTRODUCTION

The trajectory of agricultural industrialization toward large-scale, specialized, input-intensive farms has generated tremendous gains in productivity (Dimitri, et al., 2005) and profits for agribusiness corporations (Magdoff, et al., 2000), along with an array of increasingly negative social and ecological consequences (Altieri & Nicholis, 2005; Lobao & Meyer, 2001; McIntyre, et al., 2009). The market and policy shifts that are the causes and consequences of industrialization have also generated formidable challenges for diversified farming systems (DFS) and the farmers who manage them (Bowman & Zilberman, 2013). Over the past 80 years, farmers in industrializing agricultural systems have had to choose between scaling up and specializing, leaving farming entirely, or adapting to an increasingly hostile political-economic context (Van Der Ploeg, 2010). Facing a lack of governmental and institutional support, farmers of DFS turn to alternative, grassroots support networks through which they can share production, marketing, and planning strategies (Ingram, 2007; Fernandez, et al., 2012). Such alternative agroecological networks, from informal farmer-to-farmer knowledge sharing (Kroma, 2006; Isaac, et al., 2007) to semi-institutionalized regional networks (Warner, 2006), to highly coordinated national and international movements (Martínez-Torres & Rosset, 2010; Petersen, et al., 2012; Rosset, et al., 2011; Fernandez, et al., 2012), have been identified as important sources of technical and socio-political support for farmers managing DFS.

Permaculture is a one such movement that has received increasing popular attention but little systematic assessment. Permaculture is an international network with broad sustainability goals (Mollison, 1988) and a core focus on diverse productive landscapes (Holmgren, 2002). Recent research has shown a substantial overlap between the themes and proposals of permaculture and those of agroecology (Ferguson & Lovell, 2014). Despite a high public profile, permaculture has received very little attention in the scientific literature - though recent publications may indicate a shift. While historically associated with subsistence production rather than commercial

production, public awareness of permaculture as *farming* (rather than gardening) appears to be growing alongside the increasing focus within permaculture on commercial production (Frey, 2011; Holzer, 2011; Shepard, 2013). This trend is echoed in the recent increase of scholarly literature addressing permaculture, that also focuses primarily on permaculture's relevance to agriculture (Soares, 2005; Ferguson & Lovell, 2013; Conrad, 2014; Ingram, et al., 2014; Suh, 2014; Ferguson & Lovell, 2014).

This paper reports on exploratory research investigating permaculture as it exists on diversified farming systems the US. We conducted field research at 36 permaculture-identified farms in order to build an understanding of permaculture in relation to the larger context of diversified farming systems and to characterize diversity in farm livelihoods and production. We used hierarchical cluster analysis to develop a preliminary typology of permaculture farms. Recognizing labor productivity as a critical issue for DFS, we fit a multilevel model to investigate the associations between diversification, involvement with permaculture, and labor productivity.

The Decline of Diversified Farming Systems

For the past 80 years, the US has been at the forefront of the agricultural industrialization - leading the way domestically while aggressively exporting technological and policy packages that favor fewer, larger, increasingly mechanized, and increasingly specialized farms. This has resulted in a drastic reduction in the number of farms, from a peak of 6.8 million in 1935 to 2 million today (MacDonald, et al., 2004). As farms have grown fewer, they have also become less diverse, shifting over the same timeframe from an average five commodities produced per farm to an average of only one (Dimitri, et al., 2005).

While diversified farming systems are typically defined by their diverse production activities, recent scholarship has defined DFS in terms of biophysical rather than agronomic characteristics. Kremen et al. (2012:1) identify DFS by their intentional maintenance of "functional biodiversity at multiple spatial and/or temporal scales in order to maintain ecosystem services critical to agriculture." Other approaches to the study of non-industrial farming systems define their focus differently - though considerable overlap remains. Farms identified as DFS are likely to be

described with equal fidelity as multifunctional, organic, agroecological, family, or peasant farms (Brookfield, 2008; Ploeg, 2008; Wilson, 2008; Kremen, et al., 2012). As such, DFS are likely to exhibit high levels of livelihood diversification along with biological diversity. Pluriactivity, or the wide range of strategies by which farmers generate income from non-production enterprises, is a nearly ubiquitous feature of non-industrialized farm households (Brookfield, 2001). Regardless of distinct emphases among the assorted rubrics, DFS and other non-industrial farms face a formidable set of challenges in an industrialized agriculture system - and have been in collective decline for nearly a century.

The stakes of the decline of DFS are high in both ecological and social terms. As biologically diverse agricultural landscapes disappear, so do the critical environmental services on which agriculture ultimately depends (Zhang, et al., 2007; Kremen & Miles, 2012). Broad-scale mechanized farms require a far more drastic process of ecological simplification than do DFS, as diverse, spatially heterogeneous landscapes in a mosaic of annual- and perennial-dominated patches that include cultivated and uncultivated zones, are replaced by large uniform blocks of a few genetically homogenous annual crops under constant disturbance (Barthel, et al., 2013; Perfecto & Vandermeer, 2010; Vandermeer, 1995). Ironically, while industrialization has reduced agriculture's spatial footprint, it has multiplied its ecological footprint. The trajectory of environmental simplification has parallels in industrialization's social outcomes. As industrialization replaced the labor of farmers with agri-chemicals and machinery, the contraction of the farm labor market triggered a sharp decline of the number of farmers - from nearly 40% of the US population 1900, to now less than 1% (Dimitri, et al., 2005). As farmers go, so go the rural communities rooted in agrarian livelihoods. Over the same period the percent of the US population living in rural areas dropped from nearly 60% to ~22% today (Dimitri, et al., 2005).

While the non-industrial farms of which DFS are a subset occupy a minority of cropland in the US, they still comprise the vast majority of farms (Macdonald et al. 2013). Throughout the process of industrialization, as a small number of farmers scaled up and mechanized, and many more left the agricultural sector, others have found ways to adapt to the increasingly hostile environment. Through multiple forms of pluriactivity, farmers have developed strategies for

maintaining an agrarian livelihood, including off-farm employment to supplement farm earnings, developing new non-production enterprises on and off the farm, and diversifying production to hedge against risk and tap new markets. As the same time, recent years have seen a surge of interest in farming and the entrance of new farmers to the agricultural sector - 22% of farmers today have been farming less than 10 years (2012 Census of Agriculture).

Strategies and Challenges for Diversified Farming Systems

Farmers managing DFS face formidable challenges, including exclusion from governmental incentive programs, loans, and subsidies (Bowman & Zilberman, 2013); increasing capital and input costs (Iles & Marsh, 2012); the disappearance of intermediate-scale markets and economic institutions (Lyson, et al., 2008); and the lack of appropriate decision and planning support (Becot, et al., no date). At the same time, DFS must either compete with the industrialized farms that are the intended targets of government programs and market policy or develop novel products and markets outside of the mainstream agricultural system.

Numerous frameworks have been proposed to help understand the strategies through which farmers endeavor to survive the hostile environment. The schemas of conventional agronomic research, however, have limited utility for characterizing the strategies used by the farmers of DFS to navigate through an industrialized agricultural system. Historically, pluriactivity has been regarded reductively as a shift away from farming (Loughrey, et al., 2013). Many non-production enterprises, however, on and off the farm, are rooted in the farm and in agrarian livelihoods (van der Ploeg, et al., 2009). Given the challenges that non-industrial farms face in an industrialized system, researchers have begun to regard pluriactivity as a set of strategies for continuing to farm, rather than as an abandonment of farming.

Pluriactivity appears as a variety of livelihood diversification strategies (Dries, et al., 2011). Income diversification is a strategy practiced by the vast majority of US farm households, who depend on off-farm employment for some portion of their livelihood (Dimitri, et al., 2005). Through the strategy of structural diversification, farmers develop new ways to generate farm-based income independent of any shifts in production, such as bypassing distributors to sell direct-to-consumers. Structural diversification also includes using the farm as a site for

generating non-production income, through cultural enterprises like agritourism and education (Barbieri, 2013), or through material products and services, such as value adding or custom machine work. The extension of farm-centered livelihoods into a diverse set of off-farm activities is highlighted by the theory of activity systems, which frames farm-based livelihoods as complex assemblages that are not circumscribed by the boundaries of the farm (Terrier, et al., 2013).

Strategies of Agricultural Diversification

Scholars of DFS are particularly interested in the strategy of agricultural diversification. Diversification of production can be attractive to farmers for several reasons. For farmers globally, now and throughout history, spreading income across multiple production systems is a strategy to build resilience and minimize against risk, securing some income and/or subsistence in the event of a crop or market failure that could wipe out a single production system. Diversification also creates the potential for synergies in production (Altieri & Nicholis, 2005). Synergies occur when two or more complementary systems are more productive in combination than in isolation. Researchers have identified synergy effects at multiple scales. Synergies at the field scale, or overyielding, may be generated by facilitation and/or resource partitioning between annual crop species when grown in arrangements that are mixed in space (polycultures) or time (crop rotation) (Altieri & Nicholls, 2004; Smith, et al., 2008; Picasso, et al., 2011). Moving from field to farm scale, researchers have identified a broad range of potential synergies across functional groups, including the integration of trees and annual crops (Schoeneberger, et al., 2012), animals and annuals (Devendra & Thomas, 2002) animals and tree crops (Sharrow, et al., 1999), and aquaculture systems with diverse land-based production (Dey, et al., 2010; Murshed-E-Jahan & Pemsl, 2011).

Agricultural diversification, however, does not guarantee such synergy. Even carefully planned integration of multiple production systems can result in competition and interference effects between systems. Furthermore, biophysical synergies may not translate into economic synergies when they require increased management and labor. This was the finding of one the few scientific studies to explicitly invoke permaculture. Suh (2014) investigated rice-duck polycultures, a system that is much favored in the permaculture milieu (Furuno, 2001). This

study found that despite demonstrable biophysical synergies in the crop/animal integration, the labor intensive nature of the polyculture rendered it unattractive for most producers.

Labor efficiency is an especially critical consideration for farms that must compete with industrial agriculture, which has managed to largely replace human labor with mechanical and chemical inputs (Wang & Ball, 2014). Where fossil fuel and its derivative agrichemicals are cheap, relative to human labor, labor requirements and costs will be higher for organic production (Pimentel, et al., 2014; Delate, et al., 2003). Labor costs are the largest component of production costs for organic farming in the US (US Census 2008 Organic Production Survey). Not all DFS are organic, however, and more to the point, many organic producers are highly specialized. Diversification may compound the increased labor of organic practices. Because of their complexity, DFS are more difficult to manage than specialized farms, and present fundamental challenges in planning and decision (Chavas, 2008). The same complexity also limits farmers' ability to make use of labor saving technologies, as the spatial and structural variation of DFS is less amenable to mechanization (Bowman & Zilberman, 2013).

Permaculture and Agricultural Diversification

While policy continues to favor industrialized operations, farmers managing DFS must turn to agroecological networks for support. Permaculture is a grassroots network and ecological design system that emphasizes an integrated, systems-thinking approach to the design of productive landscapes and infrastructure. Since its origins in the 1970s in Australia, it has spread widely and is associated with projects on every inhabited continent (Ferguson & Lovell, 2014), but has little in the way of institutions or coordinated activity beyond the regional scale. The last several years, however, have seen permaculture receiving increasing attention across scholarly disciplines for the ways in which it embodies, in a popular context, concepts of sustainability that parallel the concerns of emerging science-based frameworks (Ferguson & Lovell, in press; Veteto & Lockyer, 2008; Pickerill, 2010; Morris, 2012; Ferguson, 2013; Feola & Nunes, 2014). Recent scholarly interest has focused increasingly on permaculture as it is relevant to farming systems (Ferguson & Lovell, 2013; Conrad, 2014; Ferguson & Lovell, 2014; Ingram, et al., 2014; Suh, 2014).

Agroecological networks such as permaculture may provide support for DFS in multiple ways. Where extension services are often ill-equipped to deal with complex diversified operations or unconventional crops, farmer-to-farmer knowledge sharing can provide practical and technical support (Warner, 2008; Kroma, 2006). Involvement with alternative 'agri-food' movements can help connect farmers with potential direct-sale customers in their local community (Seyfang, 2007), draw visitors for agri-tourism enterprises (Holloway, et al., 2006), and attract volunteer or intern labor (Yamamoto & Engelsted, 2014). Not least, agroecological networks can promulgate the norms and narratives that motivate farmers to maintain DFS, and inspire new farmers to develop them in the face of a hostile environment (Carolan, 2006; Jordan, et al., 2008; Sanford, 2011; Ferguson & Lovell, 2014; Meek, 2015).

The permaculture perspective on agriculture is similar to that of agroecology and agroforestry, emphasizing principles of diversity and multifunctionality in order to minimize risk, exploit synergies between systems, and reduce inputs (Mollison, et al., 1997; Bane, 2012; Falk, 2013). The permaculture orientation toward farming also places distinctive emphasis on perennial and polyculture production systems (Shepard, 2013; Toensmeier, 2011; Ferguson & Toensmeier, 2014), integrated water management (Lancaster, 2005; Lancaster & Marshall, 2008), and the use of new and underutilized crops, as practical extensions of agroecological principles (Ferguson & Lovell, 2014).

Adherents propose that the permaculture perspective on design and practice can support DFS in meeting the challenge of a hostile environment that overwhelmingly favors industrial agriculture. Based on widely available permaculture literature, we distill the permaculture agricultural model as follows (Mollison & Holmgren, 1978; Mollison, 1979; Mollison, 1988; Frey, 2011; Holzer, 2011; Bane, 2012; Falk, 2013; Shepard, 2013). Farms should be highly diversified, integrating annual, perennial, and animal production systems. Perennial crops should be used extensively, especially in polycultures, both for their environmental value and as highly productive and low-maintenance systems. Farmers should use the whole-systems design tools of permaculture to carefully read the landscape, select land uses and crops, and place them in strategic relationships in the landscape. This process will enable farmer-designers to leverage the diversity of these

systems and generate synergies between components that will reduce or eliminate the need for inputs and drastically reduce labor.

It is clear that permaculture shares many principles and norms in common with agroecology and agroforestry. Permaculture's differential emphasis and integration of agroecological principles is provocative, and in some cases - such as the focus on design process and configuration - directs attention to topics that are overdue for systematic inquiry (Cavazza, 1996; Veldkamp, et al., 2001; Hatfield, 2007; Osty, 2008; Benoit, et al., 2012).

Questions and Controversies

Little is known, however, about what happens when permaculture's universal principles and whole-systems design approach touch down in the particular and concrete socio-environmental contexts in which farmers are working to earn their livelihood. By the admission of its founders, permaculture has been criticized for being impractical since its inception (Mulligan & Hill, 2001; Holmgren, 2002). A recent systematic review found that the permaculture literature makes overreaching and oversimplifying claims about diversified agroecosystems, and consistently downplays the complexity and risk faced by producers in managing highly diversified systems (Ferguson & Lovell, 2014). Permaculturists' enthusiasm for perennials and polycultures has been criticized on the basis of ecological naiveté and the conflation of primary productivity with agricultural productivity (Williams, et al., 2001; Ferguson & Lovell, 2014; Smaje, 2015). A common criticism among working and aspiring farmers is that permaculture is a 'pyramid scheme,' i.e. that permaculture education only prepares students for teaching permaculture, and not for farming or other occupations (Trought, 2015; E. Toensmeier, personal communication April 7 2015).

While permaculture has been largely ignored by researchers and academics (Veteto & Lockyer, 2008), recent studies suggest that this situation may be changing. On the question of the practicality, Conrad (2014) found that permaculture training had positive outcomes for resource-poor Malawian smallholders, helping them diversify production and significantly improve nutritional diversity and seasonal food security. The research of Ingram et al. (2014) in the UK revealed strong social learning processes in the permaculture community of practice, along with a tendency toward insularity that limits the potential for engagement with the broader

agricultural community. Recent studies aside, permaculture as a farming system remains poorly understood. The literature of permaculture has historically focused largely on homestead- and garden-scale production. As a result, even the informal and anecdotal case-studies of that literature offer little insight into the real-world outcomes of production operations.

We help remedy these gaps in our understanding by conducting the first (to our knowledge) systematic assessment of permaculture farms. Our first objective is to characterize US permaculture farms based on type and diversity of sources of income, and to develop a preliminary typology based on those characteristics. Our second objective is to assess the determinants of labor productivity at the level of individual enterprises across farms, focusing on the effects of (1) the type of enterprise and (2) agricultural diversification at the farm level, as measured by the distribution of labor across all production systems and between crop and animal systems specifically.

METHODS

Data Collection

Research site selection

There is no registry or formal network of permaculture farms. We identified prospective farms through several methods, including iterative state-by-state internet searches, snowball referrals, and searching an online farm database oriented toward local food consumers (localharvest.org). We also posted solicitations to email lists and online forums, and posted a referral form on the project website. Using these methods, between May 2012 and June 2013 we assembled a list of 170 prospective farms. In order to identify and select research sites, from September to May 2013, we administered a short preliminary survey using a commercial online survey hosting service. The survey was designed to take 5 minutes or less to complete, and gathered basic demographic information as well as assessing scale of production, level of influence by permaculture idea on farm management, and level of participation in the permaculture network. Responses were solicited from farms on the list, and a link to the survey was also made available with the referral form on the project website.

In May 2013, the survey had received 122 complete responses, of which 110 indicated interest in participating in future research. These 110 farms were grouped into four categories based on scale, and farms with the highest level of influence by permaculture were selected from within each category to produce a target sample of 57 farms.

Farm Research

Between June 2013 and January 2014, a researcher visited 48 sites distributed widely across the contiguous United States. Site visits were scheduled in advance, and all participants were emailed an agenda for the visit and an explanation of questions and methods. Participants were advised that the site visit agenda could be completed in a minimum of four focused and uninterrupted hours, but that the researcher was available for a full day if the farmer was interested broader discussion or required breaks to attend to other activities. The amount of time each farmer made available, as well as the time required to complete different parts of the research agenda, were highly variable. Not all methods could be applied at every site, and therefore our analysis includes data from 36 of the visited farms. The field researcher guided each farmer through a process of identification and ranking of enterprises, and allocation of labor, income, and expenses, across farm enterprises through four seasons. Farmers considered their last completed season in their responses.

Like other non-industrial farms, DFS are likely to display a broad range of practices for record-keeping and documentation. Our approach to dealing with the complexity and variety of DFS livelihoods is informed by the methodologies of Participatory Rural Appraisal - particularly through the use of ranking and allocation questions (Riley & Fielding, 2001). Our primary instrument was a spreadsheet workbook, administered on a tablet, that allowed input of data using checkboxes, sliders, and drop-down menus, and iteratively adjust their responses as necessary (Figure 4.1). This approach allowed farmers to aggregate up from small, easily estimable quantities ("How many hours a week do you work, on average, in the winter?"), and disaggregate down from large well-known quantities ("What was your gross income last year?"). For all allocation questions, farmers could adjust their responses based on multiple channels of feedback, as the spreadsheet offered continually-updating displays of data both numerically (as quantities and/or proportions) and graphically (as pie charts and/or stacked bar charts). This approach helped accommodate farms with records and documentation ranging from extensive to

none, as farmers could base their response on both their knowledge of time and financial quantities, as well as their understanding of proportions across seasons and enterprises.

Using the spreadsheet, farmers built up estimates of aggregate labor for each season from granular estimates of weekly person-hours for different laborer categories, including household full-time, household part-time, hired full-time, hired part-time, and volunteer/intern full-time and part-time. Farmers then allocated seasonal labor totals across six categories: the top five income-producing enterprises and 'everything else.' Farmers supplied figures for gross and net farm income, and then allocated gross income across categories - first between four seasons and then, within each season, across the same six categories as the labor allocation procedure above.

Data Analysis

Enterprise Classes

After cleaning and preprocessing the livelihood data, we sorted enterprises into a two-level hierarchy of categories and calculated farm totals for labor and gross income with each category. The top level included five categories: production-based enterprises were placed into categories of animal, perennial, and annual production, and non-production enterprises were placed into the categories of cultural services (including knowledge-based service enterprises such as education, design, consultation, etc.) and material products and services (including value-adding and some service enterprises). For the second level categorization, enterprises were classified as annuals, tree crops, other perennials, large animals, small animals, horticultural, funding, services, teaching/consultation, and value-adding. For both levels of classification, the sixth 'everything else' category (when present) was classified as mixed/minor. In most cases the two levels of the hierarchy are fully nested, though the horticultural category at the second level gathered enterprises from several 1st level categories. This did not affect any aspect of the analysis, as the two levels of categorization were largely dealt with separately.

Livelihood Diversity

We quantified livelihood diversity in three ways, including diversity of income across all farm enterprises, diversity of labor across all production enterprises, and the evenness of labor across all crop vs. all animal enterprises. Whole-farm (all enterprise) income diversity was calculated to

assess overall level of pluriactivity, while production labor diversity was used to investigate the effects of spreading labor across multiple production systems. We chose the Simpson index as a baseline diversity score, which is equivalent to the Herfindahl index used in econometric analysis (Villano, et al., 2010). Following procedures for calculating effective species richness used in numerical ecology, we also converted the Simpson index to effective number of enterprises for descriptive purposes. In order to assess the presence of more specific economies (or diseconomies) of scope, we used Simpson's index of evenness to model the distribution of labor between aggregated cropping systems and aggregated animal systems, normalized to a 0-1 range so that 0 indicates only crop or only animal enterprises (or neither), and 1 indicates an even division of labor across crop and animal enterprises (Smith & Wilson, 1996).

Typology Development

To generate a preliminary typology of permaculture farms, we clustered farms based on their distribution of (log-transformed) income across the 6 top-level enterprise categories of annual, animal, perennial, cultural (services), material (products and services), and mixed/minor. As the mixed/minor category was less informative than the other enterprise classes, we down-weighted it by multiplying by .5 prior to log-transformation to reduce its influence on subsequent clustering. We performed hierarchical clustering using the *hclust* function from the R stats package, based on Euclidean distances and using Ward's minimum variance algorithm for agglomeration (Legendre & Legendre, 2012). Clusters were validated graphically using a silhouette plot (Rousseeuw, 1987). To assess the relative importance of the six variables in the clustering solution, we performed descriptive linear discriminant analysis (Huberty, 2005).

Modeling Labor Productivity

We assessed enterprise-level partial labor productivity using a multilevel modeling approach, using the *lmer* function in the lme4 R package to fit a random-intercept model with Restricted Maximum Likelihood on 195 individual enterprises nested within the 36 farms (Bates, et al., 2012). The use of a multilevel model, specifying farm as a random effect, allows for the assessment of the drivers of labor productivity at the enterprise level while accounting for farm-level variability driven by unmodeled or unmeasured variables such as capitalization, farmer skill, and local economic conditions. The significance of the random effect was assessed with a

permutation-based exact likelihood ratio test using the *exactLRT* function in the R package RLRsim (Scheipl, et al., 2013). The significance of predictors was estimated using the *confint.merMod* function of the lme4 package, via a 10,000 iteration semiparametric bootstrap, which resamples response residuals with replacement while maintaining the initial estimates of random effects. We calculated model effect size in two ways: marginal r^2, which treats fixed effects only and ignores the random effect, and conditional r^2, which accounts for the variance of the random effect (Shinichi Nakagawa, 2013).

Multilevel models have not been widely used in the analysis of efficiency in agricultural economics, but have been applied successfully in efficiency analysis in education (Johnes, 2003) and health care (Grassetti, 2005). We took this approach for several reasons, in place of the frontier methods most commonly used in econometric approaches to efficiency analysis, i.e. stochastic frontier analysis (SFA) and data envelopment analysis (DEA). Conceptually, our research questions are grounded in agroecology and political ecology, rather than the neoclassical production theory from which production frontiers emerge (Debertin, 2012; Francis, et al., 2013). Frontier approaches invoke a set of assumptions concerning the motivations and behavior of farmers, and the homogeneity of conditions across sites that do not reflect the research interests and have been criticized from within the discipline of agricultural economics as inappropriate for observational research (Debertin, 2012). While frontier approaches have proven themselves useful for multi-input/multi-output analyses of total factor productivity, our model focuses on the simpler metric of partial labor productivity - involving only the single input of labor and the single output of gross income. SFA and DEA also impose statistical constraints that limit their application for this project. Most importantly, methods for comparing individual enterprises nested within a relatively small sample of farms are not well developed for either DEA or SFA. Additionally, SFA-based inference depends on the correct specification of a (parametric) production function as well as strong assumptions about the distribution of the compound error term (Kumbhakar & Lovell, 2003). The non-parametric approach of DEA makes no such assumptions, but is very sensitive to finite sample size such as that found in our study (Simar & Wilson, 2007). Additionally, methods for modeling the effect of exogenous factors on DEA efficiency scores are a highly controversial topic around which no clear

consensus has emerged (Simar & Wilson, 2007; Simar & Wilson, 2011; McDonald, 2009; Hoff, 2007).

Response variable. Our response variable was the log-transformed gross income for each enterprise. Table 3.1 shows the level (i.e. enterprise-level or farm-level) and numeric range of all variables used in the model, along with any transformations applied.

Enterprise-level predictors. As our interest is in understanding the determinants of labor productivity, we included as a predictor the log-transformed total labor inputs (as the year total person hours) for each individual enterprise. Also at the enterprise level, we also included the variable representing the 2nd-level categorization of enterprises into 11 classes, specifying treatment contrasts and using annual vegetable production as the reference level.

Farm-level predictors. We included farm-level predictors to assess the effects of overall production diversity and crop/animal diversity, and involvement with permaculture, on labor productivity.

We assume that the level of involvement with permaculture varies between farms, and that this may shape important differences in the degree to which permaculture concepts are being applied. We included network participation to help account for that variation. In the preliminary survey farmers answered six questions concerning their mode and frequency of involvement with the permaculture network. They were asked how many times in the previous six months they had participated by giving advice to, and receiving advice from other permaculturists, giving or receiving aid in the form of labor or materials, and attending and hosting events. In the interest of reducing dimensionality, we conducted a principal components analysis on these 6 variables using the *prcomp* function in the R base package R Development Core Team (2013). After conducting parallel analysis using the nScree() function in the nFactors package (Raiche & Magis, 2010), we retained the first component for inclusion in the model.

We included the production diversity score as a measure of the effects of spreading labor out evenly across multiple types of production rather than concentrating mainly on one or few. In

order to assess whether involvement with permaculture is supporting farmers in managing diverse production, we specified an interaction between production diversity and involvement with permaculture. In order to assess the effects of crop/animal diversity on different kinds of production, we specified an interaction between crop/animal diversity and each production enterprise class.

RESULTS

Demographics and Farm Characteristics

We gathered data on household income and off-farm income from 27 farm households. Of the remaining 9 farms, four were owned by organizations rather than individuals and an additional 5 did not supply an answer. Total household income varied from $6,060 to $445,000 (Table 3.2). The contribution of farm-based income to total household income for these farms ranged from 0 to 100%, with 10 farms reporting 75% of household income or more from farm-based activities, and 10 farms reporting 10% or less household income from farm-based activities. Farmers ranged in age from 26 to 70, with a median of 44. The farmers interviewed were 65% male, with 17 women to 32 men. All farms with two primary farmers had one male and one female farmer.

Farms ranged from 1 year old to an intergenerational family farm of 100 years. Eleven farms occupied the first quartile of 4 years old or younger, and 11 farms occupied the third quartile of 16 years old or older. The median age was 7.5 years. The levels of experience of the farmers (averaged and treated as a single response in cases of two primary farmers) ranged from 2-37 years. Eleven occupied the first quartile of 5 years or less of experience as a lead farmer, and 10 occupied the third quartile of 16 years experience of greater.

We assessed the scale of farm operations in terms of gross revenue, net revenue, and acres in production (Table 3.3). Gross income is a more useful measure than net in this instance for two reasons. One, many of the newer farms showed negative net revenue despite high gross and apparent productivity, reflecting early investment in infrastructure and land improvement. Second, due to very different levels and styles of business accounting across farms, the farmers' own earnings were sometimes included in net revenue and sometimes counted as expenses.

Gross revenue ranged from $2000 to $800,000, with a median value of $43,700. Net revenue ranged from -$4000 to $60,000, with a median value of $4400. Eleven farms occupied the first quartile of zero or negative net revenue. Production zones ranged from 2 - 1500 acres in size, with a median value of 10 acres. Nine farms were 30 acres or larger, and 11 farms were 5 acres or smaller.

Farm Livelihoods

Enterprises

Farms reported 60 different enterprises among their five most important sources of farm-based income (Table 3.4). The 10 most frequently reported enterprises overall were annual vegetables (N=17), on-site adult education (N=12), pork (N=11), consultation (N=8), tree fruit (N=8), off-site education (N=7), grants (N=6), nursery sales (N=6), poultry (eggs) (N=6), and culinary herbs (N=5).

Labor inputs

When farmers identified the most significant enterprises in terms of labor inputs, the most frequent enterprises selected were annual vegetables (11), adult education (4), and nursery (4). The most frequent selections for the category of second-highest labor inputs were annual vegetables (7) and nursery (7), and for third-highest were pork (5), tree fruit (5), on-site adult education (3), and eggs (3).

The total labor inputs ranged from 1,755 - 27,790 person-hours for the year of the study. This is the equivalent of 0.84 - 13 full time positions, with a median of 3.2. Between 0 and 91% of the total of total labor inputs were allocated to production enterprises. For non-production enterprises, 0 - 70% and 0 - 71% of labor went to cultural and material services, respectively. Note that the production category only includes that production labor which is oriented at least in part towards sale, and excludes production labor for crops that are used entirely within a service or value-adding enterprise or for strictly subsistence production. Several farms with very low or zero allocation to production enterprises are actually involved in significant production activities.

Sources of income

When farmers identified their five most important farm-based enterprises for income, the five most frequent enterprises were annual vegetables (9) and on-site adult education (5). For the second-most important income-producing enterprise, the two(?) most frequent enterprises were annual vegetables (4) and consultation (3). The enterprises for third-place importance were culinary herbs (3) and seeds (3).

Diversification

Livelihood diversity for all farm-based enterprises by income, rendered as effective number of enterprises, ranged from 1.1 to 5.6, with a median of 3.6. Note that that the maximum possible score would be 6, as the distribution of income was assessed across the top 5 grossing enterprises and a 6th category containing all other sources of revenue. A score of 6 would indicate that gross revenue was evenly distributed across all 6 categories. If the 6th category was disaggregated into individual revenue sources the effective enterprises for most farms would be higher.

Production diversity, calculated by labor for production enterprises only, ranged from 0 (no revenue directly from production) to 4.2. Note that the maximum possible score here was 5 (for revenue distributed evenly across 5 production enterprises) as the 6th 'everything else' category contained an unknown mix of enterprise classes and was therefore not included in the calculation. It is important to note that for several farms, significant production activities were subsumed within value-adding or service enterprises, and therefore are not included in the calculation.

Clustering and Typology

We chose a 5-cluster solution based on interpretability, and validated the result graphically using a silhouette plot (Figure 4.2). The silhouette shows how well each farm lies within its cluster, based on the comparison of distances between the farm and its within-cluster neighbors and and farms in other clusters (Rousseeuw, 1987). The figure shows a generally strong clustering result, with two negative values indicating probable misclassification of 2 out of 36 farms. Figure 4.3 allows us to inspect the clustering in detail, showing the dendrogram produced by the clustering algorithm, with the categorical distribution of log-transformed income for each farm displayed at the terminal nodes of each branch. The final clusters are bounded by red rectangles.

Interpretation of the clustering results is facilitated by joint examination of the detailed results of Figure 4.3 and the averaged raw (un-transformed) categorical income within each cluster (Figure 4.4). Based on individual and average income distributions within and across clusters, we assigned descriptive names to each group: cultural/production (N=7), animal base (N=5), service base (N=9), small mixed cropping (N=10), and integrated production (N=5). The results of the descriptive discriminant analysis showed that variables representing production income were the most influential on the clustering. In descending order of influence, the variables were perennial, annual, animal, cultural, mixed/minor, and material. Table 3.5 shows the results of the discriminant analysis with correlation ratios, Wilk's lambda, and F statistic as measures of influence, all of which indicate the same order of influence. Note that p value is included as a supplemental measure of influence, but should not be interpreted in a conventional manner, as it is not appropriate to test the significance of variables on clusters those variables were used to create.

Selected characteristics for each cluster, including farm age, acres in production, gross and net income, years of farming experience, whole-farm effective diversity by income, effective production diversity by labor, and crop/animal evenness by labor, are displayed in Table 3.6. Minimum and maximum values for the mean and median of each measure are in boldface to facilitate comparison between clusters. Examination of these measures deepens and supports the clustering result. The integrated production cluster has the highest mean and/or median value for every measure *except* for two of the measures of diversity: whole-farm diversity (income), and crop/animal diversity (labor).

Modeling Labor Productivity

Overall model fit

We fit the model first with 198 enterprises, and then identified outliers with standardized residuals greater than 95% of the second quantile of the standard normal distribution. After removing 3 outliers from the sample we re-fit the model. No further pruning of outliers was required. The final model overview is displayed in Table 3.7. The permutation-based exact likelihood ratio test showed that specifying farm as a random effect - as opposed to ignoring farm as variable and fitting an ordinary linear model - significantly improved the model fit (LR =

165, $p < 2.2e-16$). Model marginal r^2 (fixed effects only) was 0.26, and conditional r^2 (accounting for farm-level variance) was 0.85 (Table 3.7). The difference between these two measures of goodness-of-fit provides further support for the value of including farm as a random effect.

Effects of Predictors

Using the semiparametric bootstrap to generate 95% confidence intervals, we identified multiple significant associations between the predictors and labor productivity. All coefficient estimates and confidence intervals are shown in Figures 4.5 (continuous predictors) and 4.6 (enterprise classes). Effects are considered significant when the 95% confidence interval does not span zero.

Enterprise-level predictors. As expected, labor inputs have a significant positive effect on income (Figure 4.5). Of the non-production enterprise classes, the negative influence of value adding is the only significant effect (Figure 4.6). Of the production enterprise classes, the negative influence of perennial production is the only significant effect (Figure 4.5). As the production classes are involved in a higher-order interaction with crop/animal diversity, their conditional effects require caution in interpretation.

Farm-level predictors. Production diversity and permaculture network involvement both have significant positive effects on returns to labor. The significant negative interaction between these two predictors means the positive effects of production diversity disappear at high levels of involvement, and vice versa (Figure 4.7). The strongest effect in the model is the positive interaction between crop/animal and tree crops (Figures 4.5 and 4.8). It is the only significant interaction between crop/animal diversity and any production class.

DISCUSSION

By adapting methods from international development research for the industrialized world, we have generated new insights into the character and dynamics of permaculture-identified farms in the US. The digitization and adaptation of ranking and allocation questions, inspired by methods of Participatory Rural Appraisal, has been helpful in dealing with the diversity and complexity of livelihoods in our sample, and allowed us to conduct enterprise-level analysis, generating livelihood profiles that may not have been feasible by other means. By situating the farms in our

sample within the larger context of diversified farming systems, we are helping to remedy the gap in our understanding of permaculture farms and contributing to a larger effort to address the paucity of research on DFS in the industrialized word.

Our sample included a very high level of diversity across most parameters: age of farm, experience of farmer, gross revenue, and production acreage. Within that diversity, several patterns emerge, notably a large number of relatively new farmers, new farms, and small-scale operations. Enterprise-level analysis of production and non-production activities showed highly diverse livelihoods within farms, while the cluster analysis produced a typology of farms that reveals patterns in how permaculture-identified farmers assemble livelihoods from diverse farm-based enterprises. Our preliminary typology of permaculture farms identifies 5 different types of farm livelihood profile: cultural and material services, animal production, mixed annual and perennial production, cultural services and production, and integrated production dominated by animal and perennial systems.

Identifying labor efficiency as a critical parameter for DFS operating in competition with industrial agriculture, we fit a multilevel model to assess the relative efficiencies of different classes of enterprises, and the effects of production diversity, crop/animal integration, and involvement with permaculture, on economic returns to labor. Our model revealed significant positive effects of crop/animal integration on the labor productivity of tree crops, and of diversified production on returns to labor generally. The model also revealed a complex negative interaction between overall production diversity and involvement with the permaculture network, such that high levels of participation negate the benefits of diversified production.

We found that the farms we visited fit squarely within that category of farms variously identified as DFS, family farms, and smallholders (Kremen, et al., 2012). The farms we visited exhibit modes of pluriactivity that suggest that they face challenges shared in common with DFS generally, and adapt to these challenges using a familiar set of strategies (Blad, 2010). They exhibit structural diversification through the development of on-farm non-production enterprises including agri-tourism and value adding, as well as diverse methods of marketing directly to consumers and retailers (Dries, et al., 2011. While there is no data with which to compare, it is

likely that they could be distinguished from non-permaculture DFS by higher levels of education-related services in addition to more conventional agri-tourism activities. Like other non-industrial farms, they display high levels of income diversification through off-farm income - both unrelated to the farm and through the development of activity systems that generate off-farm income through enterprises that are nevertheless rooted in the farm (Terrier, et al., 2013). Observed components of such activity systems include cultural services such as education and consultation, and material services such as custom machinery work and ecological landscaping services.

In addition to structural and income diversification, farms also exhibited diverse agricultural production. While pluriactivity has historically been regarded as a transitional process out of farming (Loughrey, et al., 2013), the farms we visited are in line with recent research that describes pluriactivity as a stepping stone into commercial production (Loughrey, et al., 2013) and/or a steady-state mode of operation (Kinsella, et al., 2000). For farmers involved in alternative grassroots networks such as permaculture, it seems likely that diversified production is not itself a strategy for adaptation or survival, by which farm resources are diverted into new ventures (Meert, et al., 2005; Blad, 2010), but rather a norm embedded in the motivations for farming.

Economies and Diseconomies of Scope

Our model shows evidence of synergies derived from spreading labor investments out across more production operations rather than concentrating investments unevenly among fewer. Our measure of overall production diversity - combining the number of production enterprises classes and evenness of labor distribution among them - shows a significant positive conditional effect on returns to labor. There is not, however, evidence that involvement with permaculture provides support to farmers in generating synergies from highly diverse production. Rather, at high levels of participation, the benefits of diversification disappear. Farmers managing diverse production systems *and* participating heavily in the network are likely experiencing diseconomies of scope, passing beyond a point at which the strategic and effective allocation of labor resources becomes less and less likely (Chavas, 2008).

Neither Utopia nor Scam

The permaculture notion that the integration of animals can reduce the labor requirements of perennial production systems receives some support from our model, through the positive interaction between crop/animal diversity and tree crops. This good news for permaculture advocates is mitigated by the negative relationship between production diversity and involvement with permaculture, which reinforces a criticism of permaculture as a 'pyramid scheme' that prepares participants to teach permaculture more effectively than it prepares them to farm. The low median net income of the sample ($4400) would seem to lend strength to that critique - though the significance of that figure is thrown into question by the relative newness of many farms (11 under five years) and the differences in accounting between farms (such that net income included farmer salaries for some farms and not for others). Ultimately, the force of this critique depends on whether the legitimacy of permaculture depends on whether it empowers farmers to overcome the mismatch between diversified production and an industrialized agriculture system. This might be too much to ask. If the question of permaculture's value instead hinges on whether involvement with permaculture supports farmers in navigating a hostile environment while maintaining (or developing) diversified production, then the answer changes. The positive impact of network participation at low levels of production diversity suggests that permaculture may act as a form of cultural capital that facilitates the development of cultural service enterprises. In light of a broader perspective on pluriactivity, we should resist the impulse to classify such forms of pluriactivity as an abandonment of DFS.

The practices and techniques advocated for by permaculture, like those of agroecology, are largely drawn from traditional practices embedded in very different cultural and political-economic contexts than that of industrialized agriculture. In particular, they are drawn from contexts in which labor is inexpensive relative to food and other commodities, and in which the cultural fabric of reciprocity - the 'moral economy' - is largely intact (Altieri, 1999; Meert, et al., 2005). It should not surprise us that farmers have difficulty supporting themselves on production alone when attempting to deploy diverse agroecological production techniques in the context of expensive labor, cheap commodities, and a largely disintegrated moral economy. Nor should it prompt us to reject the efforts of grassroots efforts to inspire and inform such production. The question of whether the content of programming offered by permaculture farms reflects an

honest appraisal of the challenges and risks of diversified production is a separate and important question - but one that is not possible to address in this study.

The fact that permaculture-identified farms fit squarely into the frameworks of pluriactive and diversified farming systems should act as a moderating influence on permaculture's most enthusiastic advocates and vociferous detractors. If the high levels of pluriactivity on permaculture farms proves that the forms of production advocated for by permaculture are impractical, the same must be said of small, diversified, and agroecological farms operating in an industrial context, generally. The practicality of a form of production is determined in large part by the political-economic context in which it operates - the only 'practical' forms are those supported by the status quo. If we are to criticize permaculture, it should not be on the basis of failing to demonstrate a pathway to out-competing industrialized agriculture on its home turf. We can and should criticize permaculturists when they mis-represent the possibility of doing so. National agricultural policy and international trade agreements will not be replaced simply by action at the level of individual farms - or even regional food systems. The task of modeling alternatives is useful, if not critical, but the difficulty of modeling 'ideal' diversified production systems within the existing system is formidable if not utopian. It is reasonable to expect that DFS will incorporate varying levels of pluriactivity, including off-farm income, to maintain their livelihood.

Limitations of this Study

This project is exploratory and is more suitable for identifying questions for further investigation than coming to firm conclusions. Statistical inference is limited by its small sample size, as well as likely selection bias. In the process of soliciting and scheduling farms - most of which in the summer and fall - there seemed to be a pattern of greater difficulty scheduling with more intensive production-oriented farms, such that our sample is probably biased toward farms with non-production livelihoods.

Our methods obscure significant elements of production happening on farm sites. First, we categorized as production only those enterprises that generated income directly from the sale of agricultural products. Production that fed into value adding and/or service enterprises could not

be effectively tracked with our survey instrument. Second, we did not assess subsistence production. Many of the farm enterprises classified as value adding and services were connected with significant production activities, and many of the farms managed diverse and sometimes extensive production for on-farm consumption.

In this study, we are only able to address one of two critical questions relating to permaculture and diversification. The first question involves biophysical productivity, and whether permaculture farms are able to exploit complementarity between crops and land uses to design overyielding polycultures. This question remains within the black box of biophysical productivity, unaddressed by this study. We address the second question, of whether permaculture-identified farmers are able to translate production diversity into synergies in financial returns. As important as the questions of biophysical synergy remain, here we can only address the (equally critical) question of how DFS are able to navigate the political-economic context of industrialized agricultural systems - and whether permaculture offers meaningful support in doing so.

Future Directions

More research is needed to remedy the limitations of this study with a larger sample, and through a systematic sampling plan and visitation schedule that will allow the participation of more production-oriented farms. Farms that show evidence of biophysical and economic synergies should be studied in greater depth to build understanding of the combinations of species, farm and farmer characteristics, planning strategies, and contexts that support farmers in generating such synergies. In particular, qualitative research is needed to identify how the conceptual tools of permaculture are involved in this process. Given the distinctive focus of permaculture on design and spatial configuration, the integration of spatial analysis into future farm research - on and off permaculture-identified farms - is a fruitful avenue for inquiry.

CONCLUSION

In this study, we conducted the first systematic research into permaculture farming, helping to remedy the lack of any systematic understanding of permaculture as farming practice and agroecological network. We identified patterns in livelihood profiles across permaculture farms, and helped contextualize permaculture-identified farms as diversified farming systems. Like

other small and diversified agriculturalists, permaculture farmers face formidable obstacles and employ a familiar variety of strategies in order to develop or maintain diversified production landscapes. Through non-production enterprises on and off the farm, permaculture farmers create a buffer between the agroecosystems they manage and the vicissitudes of the market. The exorbitant claims of some permaculture authors and practitioners are not supported by this study. Neither does this research offer support to permaculture's most ardent detractors who claim it is fundamentally fraudulent. Until the political and economic trajectory of US agriculture changes, a reliable path to economically robust and diversified production is likely to remain elusive.

Figure 4.1. Allocating seasonal labor across enterprises on the tablet, using the spreadsheet-based research instrument. Weekly labor inputs for each season are piped in from an earlier section of the instrument. The total height of each column, representing the seasonal labor inputs, stay constant while the proportions within the columns are iteratively adjusted by the farmers using the touchscreen.

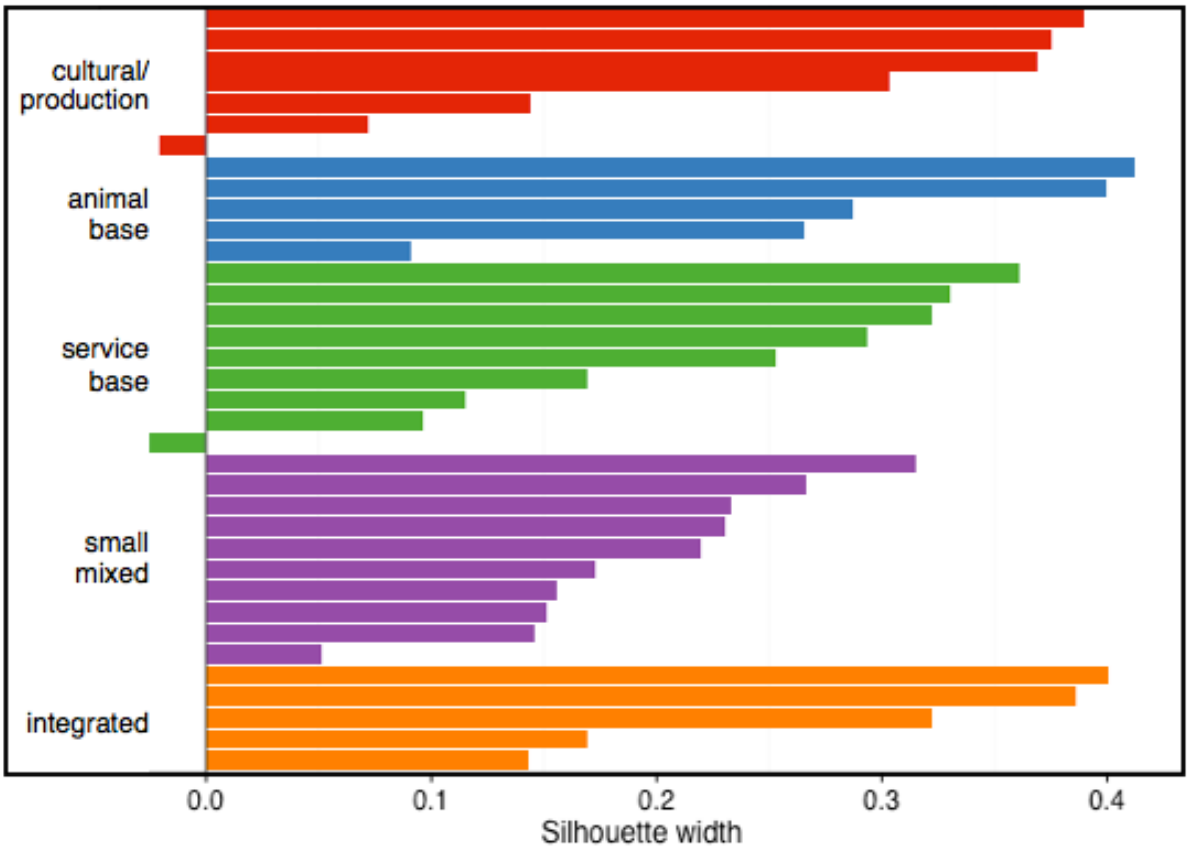

Figure 4.2. Silhouette plot of 5-cluster solution after hierarchical cluster analysis based on Euclidean distances and Ward's minimum variance algorithm. The silhouette shows how well each farm lies within its cluster, based on the comparison of distances between each farm and it's within-cluster neighbors, and with farms in other clusters.

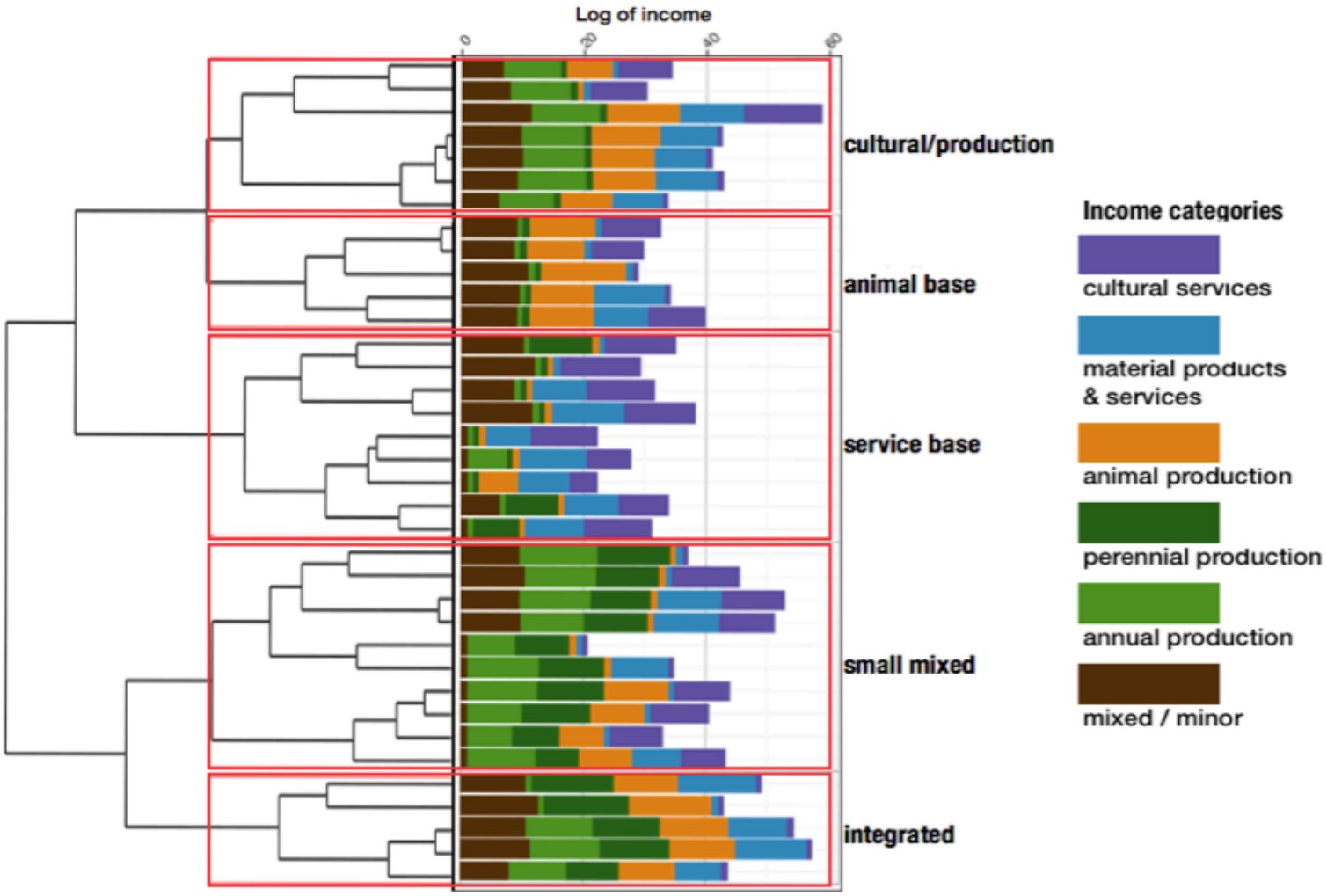

Figure 4.3 Cluster dendrogram with the categorical distribution of log-transformed income for each farm displayed at the terminal nodes. Final clusters are indicated by red rectangles.

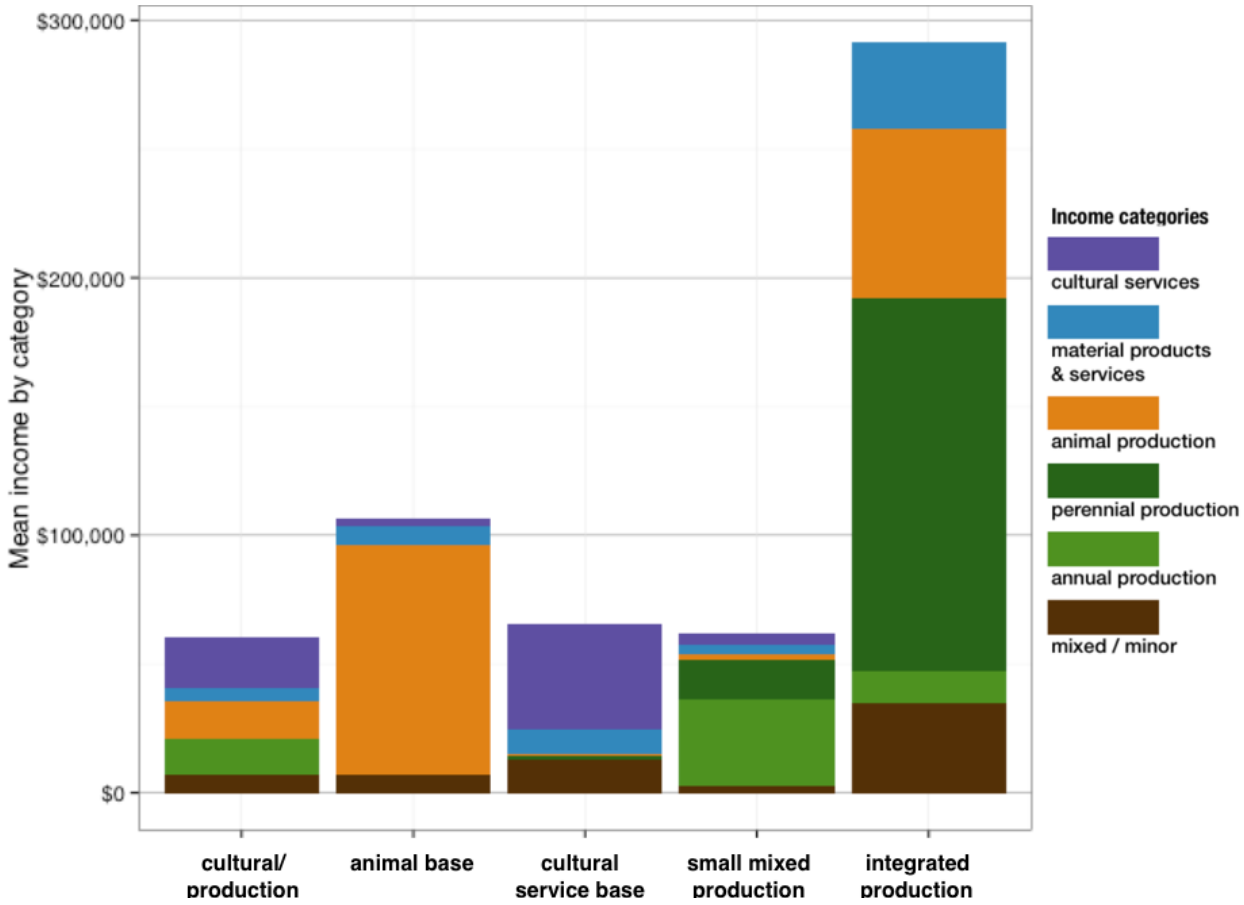

Figure 4.4 Stacked bar chart of mean raw (un-transformed) income within each cluster by category.

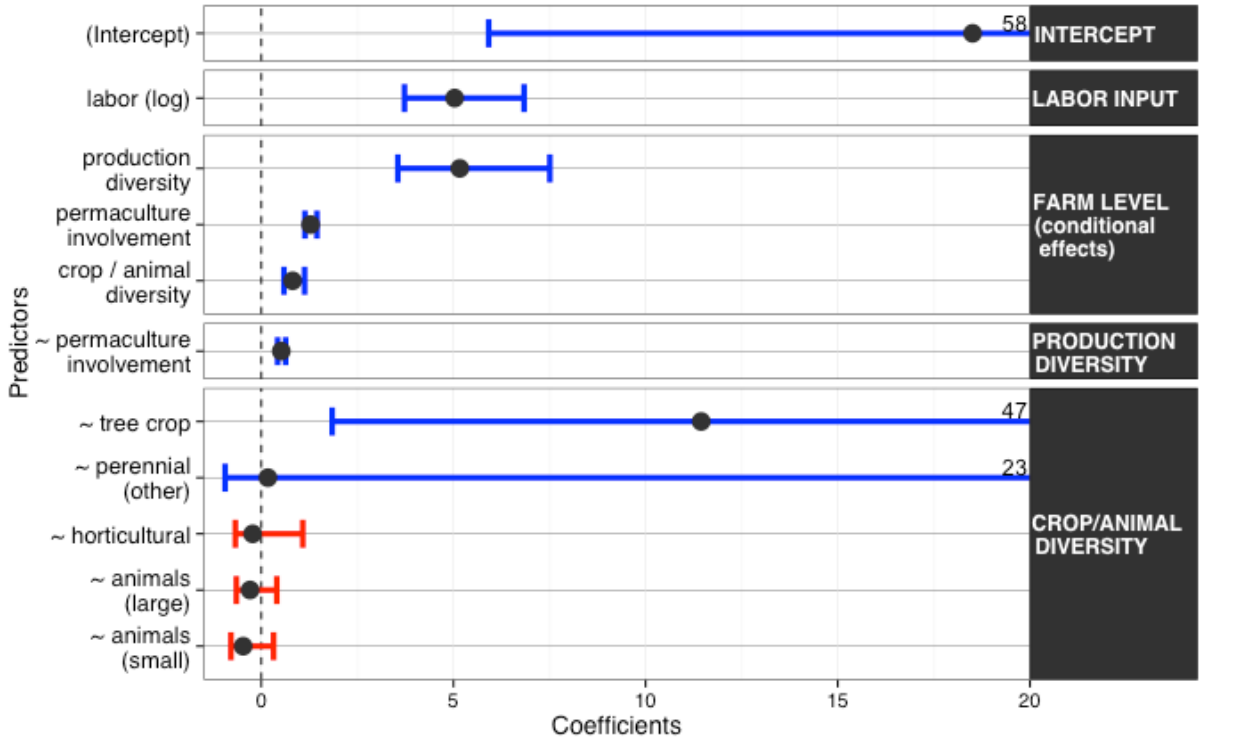

Figure 4.5. Coefficient plot for all continuous predictors from multilevel model with semiparametric bootstrapped 95% confidence intervals. As the response variable was log-transformed, all coefficients are back-transformed. Numeric value for out-of-bounds confidence limits is indicated in text annotations.

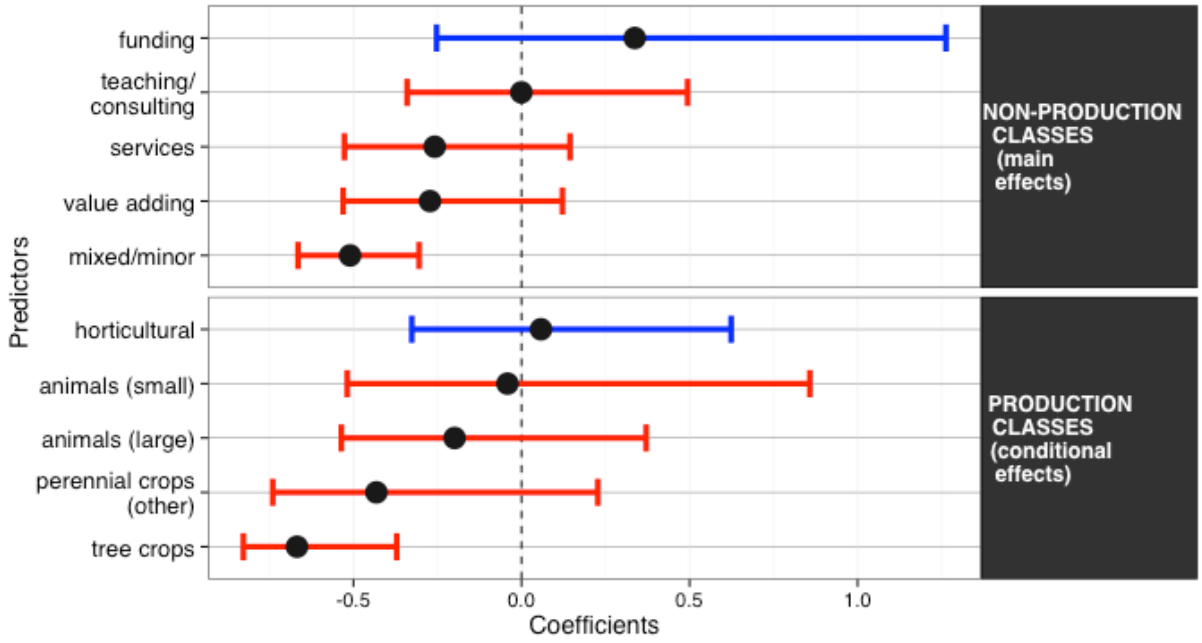

Figure 4.6. Coefficient plot for all categorial predictors from multilevel model with semiparametric bootstrapped 95% confidence intervals. Annual vegetable production was set as the reference label, which is represented by the zero line. As the response variable was log-transformed, all coefficients are back-transformed.

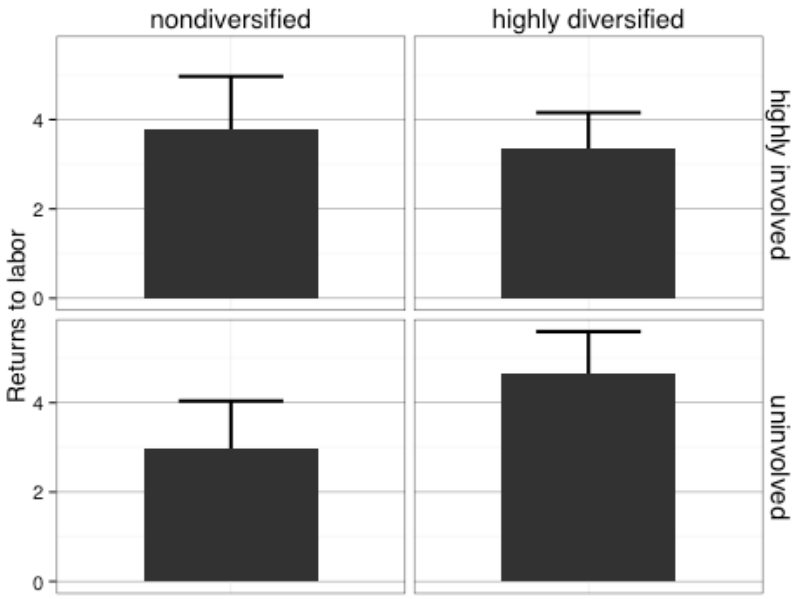

Figure 4.7. Model predictions show the interaction between production diversity and involvement with the permaculture network. At low levels of involvement, diversification has a significant positive effect on labor efficiency. At high levels of involvement, the observed negative effect of diversification is not significant.

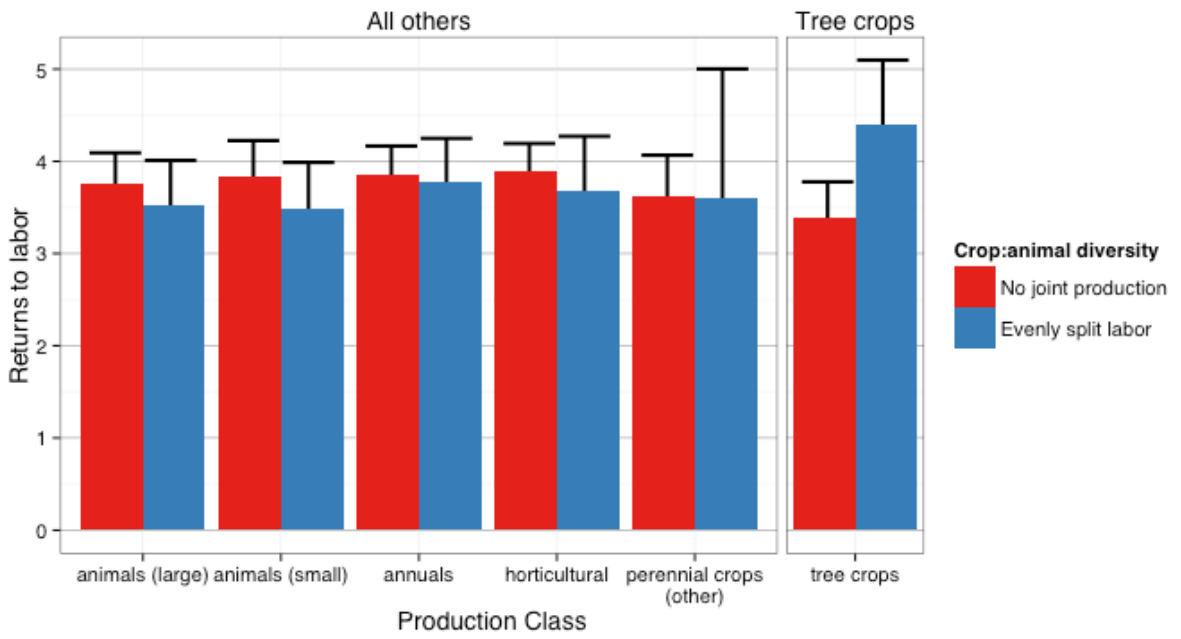

Figure 4.8. Model predictions show the effect of crop/animal diversity on returns to labor for each production class. The only significant effect is for tree crops. Results show that labor efficiency increase for tree crops when farm labor inputs are shared with animal systems.

Table 4.1. Level, numeric range, and transformation (if any) of variables used in the model.

	level	variable	description	median	range	trans.
response	**enterprise**	gross	year total income from enterprise	5840	40 - 417,000	log10
predictors	**enterprise**	labor	year total person-hours to enterprise	1764	96 - 4500	log10
		class	*11-level categorical variable*			
	farm	production diversity	Simpson's Index of Diversity of distribution of labor across enterprises	0.56	0 - 1	none
		crop-animal diversity	evenness of distribution of labor between all crop / all animal enterprises	0.1	0 - 1	none
		network involvement	1st component PCA of 6 network participation questions	0.16	-3.4 - 4.0	none

Table 4.2. Household and demographic characteristics of participating farmers.

	household characteristics			age		gender				education		
	size	total income ($)	off-farm income ($)	farmer 1	farmer 2		farmer 1	farmer 2	total		farmer 1	farmer 2
min	1	6,060	0	26	23	**female**	11	6	17	**some HS**	2	4
median	2	38,750	18,900	44	37	**male**	25	7	32	**HS**	0	3
mean	2.8	57,463	45,342	43.79	40.82					**some college**	3	1
max	11	445,000	445,000	70	66					**Bachelors**	23	3
										Masters	7	0
missing	*3*	*4*	*5*	*2*							*1*	

Table 4.3. Scale, age, income, and debt of participating farms.

	land (acres)		age of farm	gross income ($)	debt ($)
	owned	in production	(years)		
minimum	0	1.5	1.0	$2,000	$0
mean	153.4	87.3	15.2	$100,625	$129,593
median	40.0	10.0	9.5	$43,750	$10,000
maximum	2000.0	1500.0	100.0	$800,000	$2,600,000
std. deviation	348.8	263.4	18.5	$159,026	$496,670
missing					*9*

Table 4.4. All enterprises occurring more than once and their classification, times occurring, mean and standard deviation of gross, and mean gross/labor.

CLASS	enterprise	count	mean gross	std dev	mean gross/labor
TREE CROPS		**8**	**$92,700**	**$154,700**	**$34**
	tree fruit	8	$92,700	$154,700	$34
FUNDING		**9**	**$21,200**	**$31,100**	**$21**
	grants/gifts	1	$94,900	NA	$45
	donations/membership	2	$31,400	$23,100	$37
	grants	6	$5,500	$4,400	$12
ANIMALS (large)		**24**	**$25,500**	**$42,000**	**$16**
	meat (large ruminants)	5	$59,300	$70,600	$40
	meat (small ruminants)	3	$35,000	$51,800	$16
	dairy (large)	3	$23,400	$26,000	$12
	pork	12	$11,600	$21,600	$8
	stock (pigs)	1	$1,800	NA	$2
ANIMALS (small)		**14**	**$18,600**	**$27,200**	**$15**
	poultry: meat	5	$31,300	$37,900	$23
	poultry: eggs	7	$14,400	$19,700	$12
	poultry: stock	1	$2,600	NA	$4
	wool	1	$700	NA	$1
SERVICES		**18**	**$10,100**	**$13,800**	**$14**
	event hosting	2	$23,700	$33,000	$58
	rental properties	1	$17,400	NA	$27
	overnight stays	2	$31,800	$11,400	$27
	pollination services	1	$5,700	NA	$8
	local food events	2	$9,800	$6,700	$6
	marketing products of other producers/processors	3	$3,700	$3,200	$4

Table 4.4 (cont.)

CLASS	enterprise	count	mean gross	std dev	mean gross/labor
	custom machine work	2	$2,500	$2,100	$3
	gardening	4	$3,100	$4,400	$2
	custom grazing	1	$200	NA	$0
TEACHING/CONSULTATION		**36**	**$10,600**	**$19,400**	**$11**
	adult education (on site)	12	$20,200	$30,100	$14
	education (off-site)	8	$7,300	$12,800	$12
	youth education (on site)	6	$2,900	$3,700	$10
	consultation	9	$6,800	$5,100	$6
	book publication	1	$700	NA	$2
HORTICULTURAL		**21**	**$12,500**	**$12,600**	**$9**
	cut flowers	1	$10,400	NA	$32
	hive products	1	$24,100	NA	$30
	culinary herbs	5	$4,400	$4,600	$9
	mushrooms (grown indoors	1	$35,800	NA	$8
	nursery	6	$16,200	$16,500	$7
	seeds	4	$12,800	$12,600	$5
	mushroom spawn	1	$14,100	NA	$4
	mushrooms (grown outdoors)	1	$7,500	NA	$2
	medicinal herbs	1	$600	NA	$1
VALUE ADDING		**16**	**$10,400**	**$16,800**	**$7**
	crafts	1	$12,000	NA	$33
	cheese	2	$49,100	$16,700	$15
	perennial pasture seedmix	1	$2,400	NA	$13
	brewery	1	$24,300	NA	$10

Table 4.4 (cont.)

CLASS	enterprise	count	mean gross	std dev	mean gross/labor
	wild harvest	2	$5,200	$600	$6
	canning/preserving	1	$2,000	NA	$6
	firewood	2	$2,800	$2,000	$3
	tanning	1	$700	NA	$3
	bakery	1	$6,800	NA	$2
	canning / preserving	1	$900	NA	$1
	herbal medicines	1	$1,600	NA	$1
	hand split fence posts	1	$500	NA	$1
	mushroom logs	1	$1,000	NA	$0
PERENNIAL (other)		**5**	**$4,300**	**$4,400**	**$6**
	shrub/bramble fruit	1	$3,300	NA	$8
	perennial vegetables	4	$4,500	$5,100	$6
ANNUALS		**21**	**$19,000**	**$25,300**	**$5**
	annual vegetables	18	$22,000	$26,300	$6
	dry legumes	1	$2,000	NA	$1
	grains	2	$1,100	$1,200	$0
MIXED/MINOR		**26**	**$15,500**	**$24,900**	**$8**

Table 4.5. Results of descriptive linear discriminant analysis showing relative influence of input variables on the clustering result. In descending order of influence, the variables were perennial, annual, animal, cultural, mixed/minor, and material. Measures of influence include correlation ratios, Wilk's lambda, and F statistic, all of which indicate the same order of influence. Note that p value is included as a supplemental measure of influence, but should not be interpreted in a conventional manner, as it is not appropriate to test the significance of variables on clusters those variables were used to create.

income variables	correlation ratios	Wilk's lambda	F statistic	p values
perennial	0.80	0.20	31.26	1.77E-10
annual	0.78	0.22	27.18	9.54E-10
animal	0.65	0.35	14.10	1.16E-06
cultural	0.38	0.62	4.78	4.05E-03
mixed/minor	0.30	0.70	3.37	2.12E-02
material	0.13	0.87	1.13	3.62E-01

Table 4.6. Farm characteristics by cluster. Maximum and minimum values in each mean and median row are in bold to facilitate comparison.

	clusters				
	cultural / production	**animal base**	**service base**	**small mixed cropping**	**integrated production**
N	7	5	9	10	5
age of farm (years)					
minimum	3	2	3	2	1
median	10	**5**	14	8	**16**
mean	13	**8**	16	13	**29**
maximum	35	25	42	37	100
stand. deviation	11	10	15	11	40
missing	*0*	*0*	*0*	*0*	*0*
production area (acres)					
minimum	2	2	2	2	10
median	10	**30**	**4**	9	**30**
mean	62	179	**7**	15	**319**
maximum	230	450	26	50	1500
stand. deviation	94	225	8	18	660
missing	*0*	*0*	*0*	*0*	*0*
gross income					
minimum	$6,000	$10,000	$2,000	$4,000	$12,000
median	$30,000	**$27,000**	$30,000	$60,000	**$155,000**
mean	**$60,071**	$106,400	$65,722	$62,150	**$291,400**
maximum	$260,000	$420,000	$270,000	$180,000	$800,000
stand. deviation	$90,371	$175,890	$87,972	$50,923	$319,257
missing	*0*	*0*	*0*	*0*	*0*
net income					

Table 4.6 (cont.)

	clusters				
	cultural / production	**animal base**	**service base**	**small mixed cropping**	**integrated production**
minimum	$0	$2,000	$0	$0	$4,000
median	$7,750	$7,000	**$4,800**	$7,500	**$40,000**
mean	$12,064	$10,800	**$9,033**	$9,050	**$39,800**
maximum	$55,000	$30,000	$30,000	$20,000	$60,000
stand. deviation	$19,526	$11,122	$10,422	$8,315	$23,026
missing	*0*	*0*	*0*	*0*	*0*
farming experience (years)					
minimum	3.0	3.5	3.0	2.0	2.0
median	9.0	6.0	**5.0**	7.0	**16.0**
mean	10.3	**9.1**	**9.1**	**14.7**	13.8
maximum	20.0	25.0	26.0	50.0	18.0
stand. deviation	6.5	8.9	7.7	16.4	6.7
missing	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
whole-farm diversity (effective # by income)					
minimum	2.6	3.5	1.1	1.3	2.4
median	**4.2**	4.0	3.7	**3.0**	3.9
mean	**4.0**	3.9	3.2	**3.1**	3.9
maximum	5.5	4.5	4.7	5.1	5.2
stand. deviation	1.0	0.4	1.5	1.3	1.2
missing	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
production diversity (effective # by labor)					
minimum	1.4	2.0	0.0	1.5	1.4
median	2.8	2.0	**1.0**	2.3	**3.4**
mean	2.5	2.5	**0.6**	2.6	**3.0**
maximum	3.3	4.4	1.7	4.7	4.1

Table 4.6 (cont.)

	clusters				
	cultural / production	**animal base**	**service base**	**small mixed cropping**	**integrated production**
stand. deviation	0.8	1.1	0.7	1.0	1.1
missing	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
crop/animal diversity (evenness by labor)					
minimum	0.00	0.00	0.00	0.00	0.00
median	**0.84**	**0.00**	**0.00**	**0.00**	0.60
mean	**0.70**	**0.00**	**0.00**	0.19	0.56
maximum	1.00	0.00	0.00	0.88	0.97
stand. deviation	0.38	0.00	0.00	0.29	0.39
missing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*

Table 4.7. Model summary values and goodness-of-fit measures.

R2		**residual standard error**	**log-likelihood**	**AIC**	**deviance**	**df.residual**
marginal	**conditional**					
0.26	0.85	0.29	-102.2	250.4	159.0	172

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5
Conclusion

THE STATE OF PERMACULTURE

Through systematic review, survey, and on-farm field research, the investigations discussed in the preceding chapters help to establish a foundation and framework for multi-disciplinary inquiry into permaculture. To summarize these investigations, we return to the guiding questions introduced in Chapter 1 (Introduction).

How credible and plausible are the proposals emerging from the permaculture perspective on agriculture?

The framework permaculture promotes is, in broad strokes, extensively supported by contemporary science. Principles and themes largely complement, and in many cases provide a useful extension of, those in the agroecology literature. Permaculture's focus on site specificity in design, and on principles like diversity and multifunctionality, are widely echoed across a broad swath of agroecological research and theory. There is very rich empirical support for the importance of perennials, polyculture, integrated water management, and land-use diversification. Permaculture also offers something dis-tinctive and critical to that body of research, as an integrating framework that makes explicit how all of these elements are meant to work together. The strong emphasis on the transformative potential of these elements is provocative and useful.

And in some cases, permaculture does indeed shine a light on a neglected topic. The *design of agroecosystems* is a subject that receives very little attention in the agroecology (in English-language publications, at least). Our rich discussion of the integration of multiple components in a specific site does not have any parallel in the scientific literature. For instance, we present a set of tools for thinking strategically about *configuration*, or arrangement in space, that is unique. The hypothesis behind Relative Location, Zones and Sectors, and related principles, is that it's not just how we decide on land uses, but how we arrange them in the landscape, that drives all kinds of functions and whole-farm outcomes. This is a reasonable and testable hypothesis that is simply not addressed in any systematic way in the agroecological literature.

There is ample material for a rich dialog between permaculture and agroecology. Given the legacy of resistance to criticism in permaculture, this will likely require permaculturists to experiment with new models of development and ways of thinking. I would argue that permaculture can only benefit from movement in this direction. The permaculture literature demonstrates a weakness for extrapolating from ecological principles in a way that oversimplifies mechanisms and glosses over variation, and for making overreaching claims and prescriptions based on those principles. Much of this involves what is, at best, confusion around the relationship between different kinds of productivity: namely, net primary production (NPP) on one hand, and production of harvestable yields on the other. This shows up in discussions of forest gardens, polycultures, perennials, the edge principle, and diversity (and possibly elsewhere). Higher net primary production will not necessarily produce more human-edible materials. Even when higher NPP does translate to increased production of harvestable yields, factors like increased harvest labor can easily swamp production gains. At best, it is confusion - at worst, it is a smoke-and-mirrors sales pitch.

At a larger level, the permaculture literature also underplays the complexity and risk involved in developing and managing diversified farming systems (DFS). Starting or transitioning to DFS is an incredibly complex task - especially in the industrialized world, where farmers must compete directly with the cheapest commodities in the world (Kremen et al. 2012; Bowman and Zilberman 2013). Very little of the wealth of farm planning and decision-support materials out there are appropriate for diversified farms, and even less so for those that incorporate perennials. So far, permaculture has offered little to fill that gap.

The major points of our analysis were as follows: (1) principles and topics largely complement and even extend principles and topics found in the agroecological literature; (2) distinctive approaches to perennial polyculture, water management, and the importance of agroecosystem configuration exceed what is documented in the scientific literature and thus suggest promising avenues of inquiry; (3) discussions of practice consistently underplay the complexity, challenges, and risks that producers face in developing diversified and integrated production systems; (4) the movement is mobilizing diverse forms of social support for sustainability, in geographically

diverse locations; and (5) scholarship in permaculture has always been a diverse marginal sector, but is growing.

Who, in socio-demographic terms, is participating in the permaculture network, and how do socio-demographic factors shape participation?

The findings discussed in Chapter 3 show that gender and class are interacting with dimensions of participation in complex ways that vary across international socio-environmental context. The effects of gender on professional and relational roles varied with ecosystem vitality, with women scoring higher than men in countries with high levels of ecosystem vitality, and the reverse where ecosystem vitality was low. The observed effect of race on practice varied with national inequality, such that the scores of respondents of color were equivalent to white respondents in countries with the least inequality, but descended as inequality increased, while whites were unaffected.

Results showed the participation of women at or above parity (53%). Women, however, were less likely than men to identify with professional and practice roles. Our sample also displayed a white supermajority (96%). Lack of diversity was most pronounced in the country with the largest sample, the USA, which also showed the greatest underrepresentation in Black and Latino respondents. Through race and gender, we are losing out on critical contributions from groups whose leadership permaculture needs badly in order to thrive and expand.

What happens when the principles and ideals of permaculture touch down in production landscapes – or in other words, what is happening on permaculture farms?

Permaculture farmers in the US, like anyone else attempting to manage a diversified farm in this context, face serious political-economic barriers. Permaculture farms that were visited displayed a remarkable range of strategies in order to create niches and buffers to shelter them from hostile policy and market forces, helping to maintain the style of production and agrarian livelihood to which they are called.

Permaculture farms exist across a broad range of scales, and are very diverse in terms of land use and enterprise configuration, farm structure, market strategy, and social context. Nevertheless,

some patterns emerge from observation across many sites. Many farms are organized around goals other than straightforward economic production, prioritizing other strategies making change. None of the patterns discussed here are mutually exclusive, and virtually all the farms exhibited several of them to varying degrees. Some farms prioritize **informal direct exchange and consumption,** using subsistence production, barter, and direct exchange to facilitate reduce the importance of money in human relations rather than optimize income. Other farms focus their energies on regenerating **permanent production landscapes,** such as restoring clearcut hill-sides and denuded rangeland using production practices, thereby helping increase the long-term productive capacity of the regional landscape. For some farms, **education and community building** functions are central, and the focus is on fostering opportunities to share knowledge and develop relationships providing resources for community meetings, running workshops, hosting farmer in cubation programs, and other programs. These programs can also bring in money to invest in developing production systems. Some permaculture farms, of course, focus on **financially robust production,** demonstrating working models of diversified farming systems that incorporate organic market gardening, mixed orchards, rotational grazing systems, and other land uses, in a site-specific patchwork. To achieve financially robust production demands extremely strategic allocation of resources, especially labor. This pattern is also the least common among among the farms visited. While each of the above strategies is crucial for transforming the food system, the critical gap right now is in the pattern of **financially robust production.**

SYNTHESIS

We can now turn back to the overriding question guiding this investigation:

To what extent, and how, does permaculture represent a force for positive change toward socio-environmental transformation?

One thing we can say with complete confidence is that permaculture is neither static nor monolithic. It is a grassroots utopian project founded by thoughtful and iconoclastic White men of the Global North. As such, it emerges from the confluence of tendencies that are radical and emancipatory with others that are dangerously naïve and sometimes reactionary. In as much as permaculture supports an engaged form of ecological literacy and mobilizes people to make and support change – especially in collaboration with their communities – we should celebrate it.

When it supports narrowly conceived (and privilege-blind) goals of 'self-sufficiency,' or the belief that changes in lifestyle are themselves a viable strategy for socio-environmental transformation, we should call out and critique these tendencies. When permaculture's advocates help foster the norms and narratives that inspire farmers to evolve and maintain diversified farming systems, and inspire consumers to seek out the products of those farms, they are making a meaningful contribution. The opposite is true when permaculture advocates gloss over the challenges of diversified production, ignore the political-economic context, and give the impression that thinking permaculture thoughts and applying permaculture practices will empower farmers to magically transcend the hostile market and policy environment they face.

Public discussion of permaculture is often polarized, as opposing parties each focus on certain aspects of a complex reality and ignore others. After years of navigating these unhelpful debates, this author composed a short story to help illustrate the nature of the conflict, and the neglected alternatives in the discussion.

The Parable of the Canoe

> So this guy has a canoe for sale. It's a good thing too, because the river is flooding. The water is rising fast and you're going to need to navigate it. You need a good boat. You go to check out the canoe, and it's clear that it's something special. They spent years refining their design – for speed, weight, stability, practicality, aesthetics. They searched far and wide for the strongest, lightest, wood, to painstakingly mill and shape and sand. They researched the finest adhesives and resins that modern technology has to offer, to bind it together and seal it. This is a boat that could last a lifetime, with proper care. It's versatile, powerful, and durable. It's not perfect, but it's beautiful. Just as you are getting ready to shake hands and seal the deal, the guy says: 'And if that's not enough, buddy, get this – the canoe can *fly*.

Debates about permaculture tend to consist of lot's of back-and-forth between one group focused on the quality and timeliness of the canoe, and another group that is very annoyed that (some) people) are still saying the damn thing can fly.

Permaculture is growing, and thereby changing, at a rapid pace. There are tendencies developing within the permaculture movement to build inclusion and diversity, to offer grounded and substantive support to diversified farmers, and to foster critical scientific literacy. At the same time, permaculture will continue, in many respects, to reflect its cultural context - in a phase of rapid expansion. In that sense, it is very likely that the permaculture movement will continue to be challenged by low levels of scientific literacy and persistent, witting and unwitting, sexism and racism. The degree to which permaculture can meet and surmount these challenges depends largely on the choices we make through our own engagement.

Appendix
Additional data and outputs
and anticipated outputs

ADDITIONAL DATA

The projects in Chapters 3 and 4 gathered much broader sets of data than were presented in the analyses. The so-far unanalyzed data gathered in these projects represents several opportunities for additional analysis. The analyses presented in this investigation therefore represent the first pass at each of these data sets. All data described below are shared with the major professor supervising the dissertation, Dr. Sarah Taylor Lovell.

International Survey

The international web survey collected data on multiple additional dimensions of engagement with permaculture, and the outcomes of participation, in addition to the data analyzed here. Questions were grouped roughly into different dimensions of engagement, along scale from endogenous (internal to the movement) to exogenous (external to the movement). At the endogenous end, categories include conceptions of permaculture, movement/network participation, educational experiences (in permaculture), and participation in permaculture-identified organizations. Categories for personal dimensions of engagement include educational impacts from permaculture (gains in understanding), and experience of empowerment (or disempowerment). Individual categories include changes in lifestyle and sustainability-relevant behaviors, effect on the built environment, and effects on the immediate natural environment. Moving toward the movement-external end of the spectrum are professional categories, with separate questions sets around professional work as teaching (and event organizing), farming, and design. Finally, at the exogenous end is the category of civic and institutional engagement and integration.

Questions addressing the respondents' conception of permaculture included the open question "How do you define permaculture, when asked by someone who doesn't know anything about it?" This category also included questions asking the respondent to rate their agreement with

statements identifying permaculture as a social movement, philosophy/worldview, profession, set of garden/farm practices, and a framework for design/planning. Further open questions asked participants to identify: defining practices of permaculture; most important individuals, organizations, and sites in permaculture today; and their most valued sources of information on permaculture, including web, periodicals, books, and other.

To investigate the level and type of movement/network participation, respondents were asked how many times in the previous six months they had interacted with other permaculturists by giving advice, receiving advice, giving labor or materials, receiving labor or materials, attending an event, hosting an event, and by following or participating in online discussion. Respondents were also asked to identify any permaculture-identified institutions or projects in which they were involved, and estimate the percent of their social time they spent with people they knew through their involvement with permaculture. To assess the trajectory of involvement, respondents were asked to compare their present level of involvement with their past involvement on a four-point scale (much less, less, greater, much greater), and to compare their predicted future involvement with their present involvement on the same scale. Respondents were provided with an open-text response to explain their answers to the trajectory questions.

One set of questions addressed respondents' experience of the permaculture design course, the semi-standardized 72-hour curriculum that is one of the primary entry points for involvement in permaculture. Respondents identified the year, location, organizational host, principal teachers and any secondary teachers, cost, and the length of the course. Respondents additionally estimated the balance, as percentages, between lecture-based and activity-based learning, and assigned letter grades (A, B, C, D, F) to the course on the lectures, activities, build infrastructure, outdoor setting, human/emotional elements, and other (open question).

To assess the perceived impacts on knowledge and understanding of involvement with permaculture, respondents were asked to rate their prior level of understanding of several broad themes, and to rate their level of agreement with statements that their understanding of these same themes had increased because of their involvement with permaculture. Themes included the natural world, the production and consumption of energy, the function and construction of

buildings, the global economy, food production, waste treatment and disposal, design process, and how communities work. Shifting focus from areas of understanding to efficacy and empowerment, participants rate their level of agreement with a set of statements concerning the effects of their involvement with permaculture, namely that it: enables them to be a more effective advocate for sustainability, makes the world more overwhelming, has given them new and useful skills, makes it harder to support themselves in their chosen profession, and provides them with a sense of community and mutual support.

Questions on sustainability-relevant behaviors remain at the scale of the individual, but expand beyond the strictly internal/personal dimensions described above. Respondents were asked to rate their level of agreement with sentences stating that their involvement with permaculture had triggered changes in the following behaviors: gardening, landscaping, recycling, traveling (more), traveling (less), traveling (form), composting, reducing energy use, reducing general consumption. An open text field was also provided for "Other" responses. Perceptions of impacts on the built environment were assessed with three questions in which respondents rated their level of agreement with statements concerning the influence of permaculture on the design, construction, and maintenance, of the buildings and built infrastructure of their daily life. Similarly, perceptions of impacts on the natural world were assessed through similar questions/statements that because of their involvement with permaculture, their natural environment was more diverse, more abundant, harder to garden in, less toxic, more wild looking, and more pleasant to be in.

Separate sets of questions were made available for respondents that indicated that they were permaculture teachers (or organizers of courses), farmers/orchardists, and designers. Teachers (and course organizers) were asked about time spent on courses of various lengths, the number of permaculture design courses (PDCs), average length of PDCs, average pay of teachers for PDCs, and an open-ended question "who are your students?" Farmers were asked how many years they had been farming, gross farm-based income, and number of workers at varying levels of employment: full time-full year, full time-seasonal, part time-full year, part time-seasonal, and volunteer/intern. Farmers were also asked to identify their most important crops/products and the most important markets for their products. Designers were asked how many clients they had

worked with over the previous six months, and whether this number was low, average, high, or unknown (due to newness of enterprise). Further questions for designers asked their hourly and/or daily rate, and an open-ended question "who are you clients?" These open-ended questions were coded to identify the following non-exclusive categories: rural, urban, residential, farms, educational, private, civic, and public clientele.

At the exogenous end of the spectrum, questions were asked to support an understanding of whether and how the permaculture is insular, or engaged with the public sphere. Respondents were asked about their participation in non-permaculture activism and/or social movements, and their engagement with civic/public institutions. Respondents rated the level to which permaculture was integrated into each of these forms of public-sphere engagement.

The survey concluded with an opportunity for respondents to provide feedback or commentary on the survey. An open text field was provided for respondents to identify any problems they encountered in filling out the survey, and/or important questions that were missed.

Farm Field Research

In addition to the data analyzed in Chapter 4, the farm field research gathered several types of additional data. To begin with, some of the data that did appear in Chapter 4 analyses were presented in aggregated form, but were collected at a finer grain. Labor and income were analyzed as annual values, while the data were collected at the seasonal level. Disaggregation and analysis at the seasonal level will support for the investigation of additional questions, such as whether and how diversification allows farmers to spread labor and income more evenly across the year. Seasonal labor inputs were broken up by source, including household, hired, and volunteer-intern, and level of employment, including full-time, part-time, and project-based, to produce 9 sources/level categories of labor input for each season - thereby producing a potential total of 36 categories. For all hired positions, the position name was given, the number holding that position, and the level of compensation. Respondents also indicated the number of workers supplying the hours for each source/level of labor input.

For all production systems, respondents indicated whether the products were intended for home consumption/on-farm use, sales, value-adding, and/or use in a service enterprise. For all value-adding enterprises, respondents indicated whether products were intended for home consumption/on-farm use, sales, and/or use in a service enterprise. All service enterprises were identified. In addition to seasonal income and labor inputs for the top five income-producing enterprises, enterprises were ranked (to 8th position) for income, labor, and expenses. To assess production of home/on-farm use, the respondents estimated the amount of home food consumption that was produced on-farm (as a percent). Food production systems were ranked (to 8th position) based on their contribution to home consumption. Food and non-food production systems were ranked (to 8th position) for ranked for impact on home/farm budget.

Farmers estimated the proportion (as percent) of biological and material inputs that were produced on-farm (rather than purchased/imported). Biological inputs included annual seeds and starts, perennial propagules, chicks/eggs for poultry, young ruminants, piglets, young of aquatic species, mushroom spawn, mushroom substrate, and young fiber animals. Material inputs included compost, manure, animal feed, mulch, wood products (including trellis, fenceposts, and the materials), and other soil amendments.

We also gathered data on quality of life, markets for products, and spatially explicit data on land use and practice. Aspects of quality of life that we investigated included self-rating of social connection, access to information, feelings of the self-direction and efficacy, and the distribution of labor across loved, indifferent, and hated tasks. For markets, farmers allocated their gross sales income across different types of markets, including distributors, farmers markets, community support agriculture (subscription farming), on farm sales, retail stores, restaurants, processors, web sales, and other. They also allocated their total marketing effort across the same categories.

Spatial land use and practice data was also gathered at each site visit, through farm tours and open-ended discussion during and after the tours. Copious pictures were taken and tagged with geographic coordinates during farm tours, generating rich visual and spatial documentation at each site. Land use and land cover analysis classification and analysis of this data is ongoing. At

the patch level, land cover and land use are being used as proxies for ecological functionality and production functionality, respectively. Land cover types are assigned on the basis of eight classes (in approximate rank of ecological functionality): annual, mixed annual/perennial, mixed intensive, herbaceous perennial, water, mixed herbaceous/woody perennial, woody perennial, and forest. The class "mixed intensive" was used to designate the intensively mixed-cover areas surrounding homes and farmsteads. The classes "woody perennial" and "forest" were used to distinguish cultivated perennial cover (i.e. orchards) from forest, respectively. Land use was assigned to eight classes (in approximate rank of economic functionality): establishment phase, boundary/buffer, minimal management area, managed woodlot, farmstead (corresponding to the mixed intensive land cover class), orchard, pasture, and intensive production zone (including annual and mixed annual-perennial crops cultivation areas).

The additional data collected affords the opportunity for multiple additional publications. The following papers are anticipated as additional outputs of this investigation.

ANTICIPATED PUBLICATIONS

Publications based on survey:

(1) "Knowledge, empowerment, and human capital at the grassroots: engagement with the international permaculture movement and implications for transition processes." This paper will address the sets of variables describing endogenous, personal, and individual dimensions of engagement: conceptions of permaculture, network participation, personal sense of understanding and empowerment, and sustainability-relevant behaviors. Using a mixed-methods approach incorporating multivariate analysis and coding of open-ended questions, this study will discuss the implications of involvement with permaculture for the mobilization of grassroots constituencies and engagement with sustainability transitions.

(2) "Is there leverage on the margins? Institutional, civic, and professional engagement in the international permaculture movement." This paper will address exogenous impacts of permaculture, i.e. whether and how participants integrate their involvement with permaculture into the public sphere.

Based on field research:

(3) "Accounting for complexity and variety in diversified farm livelihoods using digitized ranking and allocation methods." This paper will describe in detail the spreadsheet application developed in order to gather enterprise-level data from participating farms. Additionally, the need for such an approach and its antecedents in development and farming systems research will be discussed.

Chapter 4 will be split into two papers for publication.

(4) "Permaculture and diversified farming systems in the US: characterization and typology" will include, and expand on, the characterization and typology development portion of Chapter 4.

(5) "Neither magic wand nor pyramid scheme: livelihood diversity and labor efficiency on US permaculture farms" will be based on the multilevel modeling of livelihood diversity and labor efficiency.

(6) "Pushing the edge: land use configuration and multifunctionality on US permaculture farms." This paper, based on the ongoing land use / land cover analysis, will identify patterns in agroecosystem constituents and configuration. Discussion of findings will complement earlier papers generated from Chapter 4 by relating spatial patterns to the trends in livelihood diversity and economic performance identified earlier. This project will support the deeper investigation of the design aspect of permaculture, an important element that is not otherwise addressed in this investigation.

ADDITIONAL OUTPUTS

This section lists additional outputs from this investigation, to date:

Conference Papers

(1) Ferguson, R. S., & Lovell, S. T. (2015). Permaculture as a Catalyst for Agroforestry Adoption: Perennial Production Systems on Diversified Farms. Presented at the 14th North American Agroforestry Conference, Ames, IA: Association for Temperate Agroforestry.

(2) Ferguson, R. S., & Lovell, S. T. (2015). Permaculture as Grasssroots Network and Farming System: 5 Years of Research. In 12th International Permaculture Conference. London, UK.

(3) Ferguson, R. S., & Lovell, S. T. (2014). Land use and livelihood diversity on permaculture agroecosystems in the US. Presented at the From Ocenas to Mountains. 99th ESA Annual Meeting (August 10 — 15, 2014), Sacramento, CA.

(4) Ferguson, R. S., & Lovell, S. T. (2013). Recovering the Future: food system transition pathways on (and around) US permaculture farms. Presented at the Yale Food Systems Symposium 2013: Urbanization and Food System Transformation, New Haven, CT: Yale University.

(5) Ferguson, R. S., & Lovell, S. T. (2013). Conservation contra Permaculture: Alternative Ecologies of Multifunctionality and Resistance to Neoliberal Agriculture. Presented at the Dimensions of Political Ecology: Conference on Nature Society., Lexington, KY: University of Kentucky.

(6) Ferguson, R. S., & Lovell, S. T. (2012a). From Garden Ecology to Sustainable Agriculture: the Emergence of Permaculture Farms. Presented at the 2nd Int'l Food Studies Conference, Urbana, IL: University of Illinois at Urbana-Champaign.

(7) Ferguson, R. S., & Lovell, S. T. (2012b). Hybrid Ecological Knowledge: Permaculture and the Political Ecology of Landscape Regeneration. Presented at the Dimensions of Political Ecology 2012, Lexington, KY: University of Kentucky.

Conference Posters

(8) Ferguson, R. S., & Lovell, S. T. (2015). Multifunctional Landscapes on US Permaculture Farms: Land Use and Practice on 48 Sites. Poster presented at the 27th International Congress for Conservation Biology, Montepelier, France.

(9) Ferguson, R. S., & Lovell, S. T. (2013). Engaging Ecological Literacy from the Ground Up: The Influence and Impacts of the Permaculture Movement. Poster presented at the Ecological Society of America Annual Meeting 2013: Sustainable Pathways: Learning From the Past and Shaping the Future, Minneapolis, MN

Invited Talks

(10) Ferguson, Rafter Sass. (2015a). Permaculture as movement and practice: research frontiers and transition strategies. Presented at the Coventry University Centre for Agroecology, Water, and Resilience, Coventry, UK.

(11) Ferguson, Rafter Sass. (2015b). Permaculture in Theory and Practice: Grassroots Agroecology and Diversified Farms. Presented at the Permaculture et agroécologie, Paris, France: AgroParisTech, UMR SAD-APT.

(12) Ferguson, R. S. (2013). Permaculture and Agroecological Transition. Presented at the Berkeley Center for Diversified Farming Systems.

Other Writing

(13) Ferguson, Rafter Sass. 2014. "Toward 21st Century Permaculture: Critical Questions and Early Answers." Permaculture Activist, no. 93: Science in Permaculture (August).

(14) Ferguson, Rafter Sass. 2014. “Toward 21st Century Permaculture: People’s Science or Pseudo-Science?” Permaculture Activist, no. 93: Science in Permaculture (August).

Other Presentations

(15) Ferguson, R. S. (2015a, September). Permaculture and Peoples’ Science: The State of the Movement and Beyond. Workshop presented at the 12th International Permaculture Convergence, Essex, UK.

(16) Ferguson, R. S. (2013, November). Toward 21st Century Permaculture: People’s Science or Pseudo-science? Talk presented at the 11th International Permaculture Convergence, Jibacoa, Cuba.