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Taking Complexity in Food Systems Seriously: An Interdisciplinary Analysis

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Summary. — Motivated by donor interest in innovative thinking on food security, we conducted an interdisciplinary, triangulation analysis of four divergent conceptual frameworks, each relevant to diagnosing food insecurity in developing countries. We found notable tensions as well as synergistic interactions between agroecology, agricultural innovation systems, social–ecological systems, and political ecology. Cross-framework interactions enhance our understanding of how sectoral and macro-economic development strategies impact on livelihoods, availability, and access. Re-invigorated, more profound dialog between divergent conceptual frameworks enables diagnosis of complex food insecurity problems, and context-specific interventions and innovations. Informed use of divergent approaches constitutes a new ambition for research and practice.

Key words — food security, innovation, interdisciplinary analysis, dialog, sustainable intensification, Africa

1. INTRODUCTION

Both "food security" and "innovation" are invoked frequently in policy discourse around agricultural development, with innovation seen as vital to achieving better food security outcomes (De Schutter, 2010; Scoones, Thompson, & Chambers, 2008). Donor and practitioner enthusiasm for agriculture "innovation" notwithstanding (Frost, 2013; Hounkonnou *et al.*, 2012; World Bank, 2012), the intricate and contested nature of food systems means that efforts to innovate cannot escape complexity.

For example, a given food system offers multiple potentially competing and complementary points for intervention. To reduce food insecurity, policy makers could potentially invest in women's agriculture (Quisumbing & Pandolfelli, 2010); subsidize inorganic fertilizer (Twomlow *et al.*, 2011); reform agricultural input markets (Makonese & Sukalac, 2011); improve water productivity in rainfed agriculture (Rockström *et al.*, 2010); improve resource efficiency, participation, and accountability in water and energy systems (Hoff, 2011; Molle, Foran, & Käkönen, 2009); strengthen common property regimes that provide high quality wild foods (Friend, Arthur, & Keskinen, 2009); help smallholders gain a better position in global food supply chains dominated by agro-food corporations; reduce food losses (FAO, 2012b); liberalize trade (Anderson, 2010); and invest in nutrition and health (Bhutta *et al.*, 2008; Micronutrient Initiative., 2013). Going beyond a specific food system, policy could encourage deficit-producing farmers to exit agriculture (World Bank, 2007); invest in rural nonfarm economies (Akram-Lodhi, 2013); invest in transport; support labor to organize for better

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employment conditions (FAO, 2012a) and providing social security nets (FAO, 2012b).

We invoke these examples to underscore how complex food, agriculture, and development agendas have become (Hall, 2007; Lang, Barling, & Caraher, 2009; McIntyre, 2009). As a contribution to thinking more critically about the prospects for innovation, we re-visit the fundamental question of what changes need to occur to reduce food insecurity, and address that question in the form of a conceptual triangulation.

Food security is a contested, evolving, multi-dimensional construct, including both well-established dimensions such as availability, physical access, economic access (affordability), consumption, and utilization. It also includes dimensions such as agro-ecosystem sustainability and resilience that have received more recent acceptance on policy agendas (FAO, 2012b). When authors offer divergent theoretical framings on what constitutes a "food system," they underscore contestation and complexity (cf. Akram-Lodhi, 2013; Godfray *et al.*, 2010; Ingram, Ericksen, & Liverman, 2010).

The dominant framing of food insecurity focuses on the "double challenge" of (1) increasing access to adequate food for more than a billion people who suffer from hunger and malnutrition and (2) increasing availability by 70–100%, mainly through increases in yield and cropping intensity, to feed an estimated population of nine billion by 2050 (FAO, 2009a, p. 3). However, complexity over the future of rural livelihoods in the context of multi-level, and increasingly globalized food systems has different implications for what food gets produced, by whom, and what poor people must do to access it (Akram-Lodhi, 2013; Patel, 2007; Weis, 2007). The fact that food systems can be approached through diverse and often divergent conceptual perspectives suggests it would be useful to undertake a pluralist, interdisciplinary inquiry on the meanings of, and possibilities for improved food security.

2. METHODS

To implement a pluralist interdisciplinary analysis of food security, we found triangulation methods helpful. Triangulation refers to the use of more than one observation, data set, technique or—in our case—conceptual framework, to provide fresh insight into an issue (Denzin, 1970; Moris & Copestake, 1993). Triangulation is used in participatory rural appraisal, sociology, policy analysis, and development studies (Olsen, 2006; Roe, 1998). For example, Roe (1998) used four divergent theories to answer questions such as: what is sustainable development; why is it a problem; ideally what should be done, and practically, what can be done? [1] Conceptual triangulation does not replace insights offered by a given theory. Rather than converge on a unified set of truths, conceptual triangulation aims to converge on new problem definitions, or points of departure from conventional definitions (Roe, 1998). Olsen (2006, p. 1134) describes this kind of methodology as meta-theoretical: it attempts to "view several theories' character, and their strengths and weaknesses, from a vantage point that takes into account both empirical evidence and the nature of the different available theories."

Following Roe (1998), we selected a divergent set of conceptual frameworks, each of which takes complexity in food systems seriously (Table 1). Each de-familiarizes food security in fresh ways (i.e., is not subsumed by the dominant framing), and differs fundamentally with respect to problem framing. However, departing from Roe (1998), our aim is not to derive more general precepts about food security. Rather, we triangulated in order to identify important tensions and synergies between literatures, with a desire to motivate development interventions characterized by what we refer to as "informed synergies:" interdisciplinary interactions that have the potential to enhance our ability to understand and intervene in food security dynamics.

Literature was sourced in an iterative manner. During the first round, some twenty members of a multi-disciplinary community of practice, the Food System Innovation for Food Security (FSIFS) project [2] were asked to nominate published literature they considered noteworthy and relevant. During a second round, the authors conducted online literature review using a variety of academic search engines. Four theoretical frameworks were selected by the authors as representative—not exhaustive—of the conceptual and applied interests of the FSIFS community of practice. We explored synergies between the four frameworks using a comparative matrix (Table 2) which guided additional rounds of literature search.

To keep the triangulation tractable, we chose not to review literatures on nutrition, health, and human rights law, which curtailed our understanding of consumption and utilization. We justify these choices on the grounds that the triangulation was an exploratory attempt to generate a cross-disciplinary conversation, focusing on the complex connections between availability and access in food systems.

The four frameworks (agroecology, agricultural innovation systems, social-ecological systems, and political ecology) are nonetheless broad and sufficiently divergent for a triangulation. The core focus of *agroecology* has been on improving the long-term sustainability of farm level practices through a critical understanding of biological interactions (Pretty, 2005), but the framework has also motivated thinking about agroecosystems at higher levels, and around "sustainable intensification" (Pretty, Toulmin, & Williams, 2011; Tomich *et al.*, 2011). *Agricultural innovation systems* (AIS) frameworks stem from literature on enhancing agriculture research and extension systems, with roots in earlier farming systems research [3] and participatory development literatures [4] (Hall, 2007; Mbabu & Hall, 2012). Actor- and market-oriented versions of this framework have influenced recent rural development programing (Pant & Hambly-Odame, 2009; World Bank, 2012), popularizing the use of multi-stakeholder "innovation platforms." The *social–ecological systems* (SES) framework has roots in literature on ecosystem management and ecology, including theories of resilience and vulnerability. This framework has influenced thinking about adapting to global environmental change in natural resource management and

Table 1. *Frameworks used in this triangulation*

Framework	Characteristic focus/foci
Agroecology	Sustainable agricultural practices
Agricultural innovation systems (AIS)	Multi-stakeholder processes for problem solving and capacity development
Social-ecological systems (SES)	Cross-level, cross-domain impacts of particular actions
Political ecology	Historical determinants of vulnerability, insecurity, or poverty in specific places Winners and losers from particular actions

Table 2. *Synergistic interactions between four selected approaches*

Primary approach or agenda	Agroecology	Agricultural innovation systems	Social-ecological systems	Political ecology
Secondary approach or agenda				
Agroecology		[4]	[7] Debating organic agriculture (Connor, 2013; Seufert *et al.*, 2012)	[10] Critique of via Campesina (Akram-Lodhi, 2013)
Agricultural innovation systems	[1] Sustainable intensification (Kiara, 2011; Pretty *et al.*, 2011; Tittonell *et al.*, 2012; Tomekpe *et al.*, 2011)		[8] Livelihood innovation niches for transforming rural communities (Butler *et al.*, 2013a)	[11] Oil palm production in Benin (Yemadje *et al.*, 2012) Reforming grower prices under Fair Trade labelling scheme (Bacon, 2010)
Social-ecological systems	[2] Agrimonde 1 scenario (Dorin *et al.*, 2011)	[5]		[12] Critique of global food production policy narrative (Tomlinson, 2013) Exposure to climate change and globalization in Niger (McKune & Silva, 2013)
Political ecology	[3] Food sovereignty (Holt-Giménez, 2011; Rosset, Machín Sosa, Roque Jaime, & Ávila Lozano, 2011; Rosset & Martínez-Torres, 2012)	[6] Convergence of Sciences –Strengthening Innovation Systems project (Hounkonnou *et al.*, 2012; Yemadje *et al.*, 2012) Critique of mainstream innovation efforts (Biggs, 2007; Brooks & Loevinsohn, 2011)	[9] Nested & teleconnected vulnerability (Eakin *et al.*, 2009) Water-food-energy nexus Mekong region (Foran *et al.*, 2013; Smajgl & Ward, 2013) Fisheries, food security, and marine conservation in the Pacific (Butler *et al.*, 2013b)	

Source: Authors. *Note:* Numbers in brackets refer to cell number; see Section 7 for discussion.

associated science communities, but also has been recently applied to food systems (Ingram *et al.*, 2010). *Political ecology* comprises a cluster of frameworks influenced by classic questions of agrarian political economy (Akram-Lodhi, 2013), as well as the political economy of environmental degradation (Blaikie & Brookfield, 1987). A characteristic focus is on historical and social determinants of specific place-based problems (Fisher, Maginnis, Jackson, Barrow, & Jeanrenaud,

Table 3. *Meeting food security challenges: synergistic approaches*

Food security dimension/s	Challenge	Useful synergies	Examples
Availability Resilience Persistence	Understanding medium- and long-term resilience and persistence of production strategies	Agroecology or SES + {AIS, political ecology}	Table 1: [1, 2, 3, 7, 9]
Access	Understanding impacts of sectoral and macro-economic development strategies on livelihoods and affordability	{SES, political ecology, AIS}	Table 1: [9, 8, 11, 12]
	Understanding structure and control of access to land and/or common property regimes (e.g., fisheries, forests, urban gardens)	Political ecology + AIS	Table 1: [11]
Consumption Utilization	Understanding influence of markets, culture, and other social determinants on consumption and utilization practices	Political ecology + {SES, AIS}	See Section 7(g) discussion

Source: Authors. *Notes:* SES = social–ecological systems; AIS = agricultural innovation systems. Underlined text refers to suggested primary framework. Frameworks in curly brackets are on a roughly equivalent level, depending on the case. Numbers in brackets refer to cell number in Table 2.

2005), with a distinctive interest in the politics of knowledge (Ferguson, 1990; Scoones, 2009b; Sumberg & Thompson, 2012).

The triangulation is organized as follows. Sections 3–6 explore what it means to improve food security according to the four frameworks selected. Taking each framework in turn, we (i) introduce characteristic attributes and communities of practice; (ii) review relevant theoretical positions; (iii) summarize the framework's normative vision and its policy agenda for food security; and (iv) comment on its conceptual and operational utility and limitations. Section 7 triangulates, systematically analyzing interactions among the four frameworks. We identify important tensions, as well as synergies that may provide fresh thinking on recurrent challenges of food security (Table 3). Section 8 concludes.

3. AGROECOLOGY

(a) *Characteristics and communities of practice*

Agroecology spans both science and social practice. The term encompasses several domains: (1) academic disciplines that aim to understand and sustain valued agroecosystems; (2) sets of agronomic and natural resource management practices, variously referred to as "permaculture" (Mollison, 1990), "low external input" (Tripp, 2006), "resource-conserving" (Pretty *et al.*, 2006), and "sustainable intensification" (Pretty *et al.*, 2011); and (3) more recently, various social movements based on reforming the food system, inspired in part by such practices (Holt-Giménez, 2011; Tomich *et al.*, 2011).[5]

(b) *Relevant theoretical positions*

Agroecology understands agricultural systems as amended ecosystems which, under mechanized commercial agriculture, have high through-flow based on fossil fuel (Pretty, 2008; Tomich *et al.*, 2011). Conventional industrial agriculture creates negative externalities such as water pollution, air pollution, and greenhouse gas emissions. Estimated costs can exceed total net farm income to farmers (Pretty, 2008). By contrast, agroecology seeks "sustainable" intensification: practices and institutional reforms that increase the ratio of outputs to internally and externally derived inputs, on a more persistent basis (Pretty, 2008; Pretty *et al.*, 2011). Agroecology appreciates indigenous knowledge of biodiversity, soil and water management, farm design, and associated capacities to innovate, which occurred in a wide variety of traditional agroecosystems, notably southeast Asian paddy rice, Chinese aquaculture–agriculture systems, and tropical home gardens (Altieri, 1995). Notwithstanding the global spread of modern industrialized agriculture, such "peasant" systems have persisted. Agroecological methods can be both highly productive and highly diverse (Altieri, Funes-Monzote, & Petersen, 2012). Agroecology offers solutions for four categories of farming challenges (Tripp, 2006): (1) water and soil erosion can be managed by terracing, contour planting, and conservation tillage; (2) soil fertility can be improved by use of green manures and agroforestry; (3) pests, pathogens, and weeds can be managed through reduced usage of broad-spectrum insecticides, and biological control (Altieri, 1995; Khan, Midega, Pittchar, Pickett, & Bruce, 2011); (4) crops in dryland or water-scarce regions can be established using, respectively, planting pits (Reij & Smale, 2009) and system of rice intensification (SRI) (Stoop, 2011).

(c) *Vision and policy agenda*

Agroecology's agronomic vision is that farms and agroecological landscapes are designed in such a way as to synergize interactions and improve overall biological efficiency, preserve biodiversity, and maintain productivity. Farms and landscapes deliver both agricultural production and ecosystem services (Altieri *et al.*, 2012; Malezieux, 2012). Management attends to key ecological processes (soil and water conservation, nutrient and organic matter recycling, nitrogen fixation, and pest control), resulting in resilient and persistent soil fertility (Altieri *et al.*, 2012; Snapp & Pound, 2008). Local limitations of productive land are understood and respected, with appropriate matches between cropping patterns and the landscape's productive potential. The overall health of the agroecosystem matters as much as crop yield.

Such agronomic visions lie at the heart of the transnational "food sovereignty" movement. In 1992 a trans-national network of farm activists launched La Vía Campesina, a network of 148 organizations from 69 countries, representing possibly 100,000 small-scale farmers, peasants, and food workers, and arguably "the largest social movement in the world" (Akram-Lodhi, 2013, p. 148; Rosset & Martínez-Torres, 2012). Vía Campesina defines food sovereignty in opposition to market liberal thinking as: "the right of citizens to determine food and agricultural policies. ... to decide what and how to produce and who produces. ... [and] the right to public resources such as water, land, and seeds" (Nicholson, 2011, chap. 1). Attaining food sovereignty entails actions at multiple levels, for example: supporting and scaling out small farmer-driven agroecological innovation; genuine agrarian reform; ending open and hidden subsidies to industrial farming; decreasing the power of dominant players to hoard and speculate; and reversing free trade policies, including dumping which makes farming unprofitable to family farmers (Vía Campesina., 2010). Globally, the vision is for a series of interconnected, interdependent local food systems (Akram-Lodhi, 2013, p. 151).

(d) *Conceptual and operational utility*

Do agroecological practices help deliver food security outcomes? Divergent positions exist. Pretty *et al.* (2006) sampled professionals in the field of agricultural sustainability and food security, soliciting nominations of "best practice" initiatives. They accepted a total of 218 projects and compared before or without project *vs.* after or with project changes. Yields increased 64% (geometric mean, $n = 360$); water productivity improved notably (e.g., rainfed crops,>70% increase in water productivity).[6] A subsequent survey of "sustainable intensification" covering 40 projects or programs in twenty African countries, found that the use of novel or improved varieties with changes to agronomic practice resulted in "multiplicative" outcomes (Pretty *et al.*, 2011). For example, combining disease resistant, faster maturing cassava varieties with use of water-troughs between rows led to more than fivefold yield increases, to 15 t/ha. Other examples include adoption of soyabean, inoculum, and fertilizer packages in Zimbabwe, building on research that began in the 1960s; and a facilitated multi-stakeholder partnership that introduced hybrid pigeonpea, a marketable legume previously ignored by conventional breeders (Pretty *et al.*, 2011, pp. 11–12).

Across eight categories of case studies covering an area of 12.8 million ha, average crop yields rose by a factor of 2.13 in 3–10 years. Notably, the authors attributed 57% of the yield

increases to novel partnerships and policies impacting on seven countries: Benin, Cameroon, Congo, Cote d'Ivoire, Ghana, Kenya, Malawi, and Nigeria (Pretty *et al.*, 2011: Tables 1 and 2). Projects that appear to fall into the partnership or policy category include: the Malawi fertilizer subsidy program, which reduced net imports of maize and increased incomes by 10–100%; Kenya's reformed, demand-driven extension program (Kiara, 2011); the African Research Centre on Banana and Plantain (Tomekpe, Kwa, Dzomeku, & Ganry, 2011); and the Ghana Grains Partnership (Guyver & MacCarthy, 2011). [7]

Claims that agroecological practices improve yields can be contested because other factors could have also contributed (Phalan, Rodrigues, Balmford, Green, & Ewers, 2007; Tripp, 2006). Conclusions would require data on conditions several years before and after an intervention and a sampling frame sufficiently large to control for other causal factors (e.g., use of other technologies, socio-economic differences, ecological differences). However, few studies have collected such data (Pretty *et al.*, 2007). Difficulty in assessing effectiveness of agroecological innovations limits influence. Validating intervention success requires more sophisticated assessment methodologies (Blackman & Rivera, 2010; Horlings & Marsden, 2011). Critics also argue that agroecological technologies are no different from other technologies—investing in them is more likely to occur where there is an economic return. Commercially oriented farmers are more likely to adopt them, suggesting the need for viable markets and cash crops (Tripp, 2006). Some agroecological practices require substitution of labor and knowledge for external inputs (upfront labor investment, and time for maintenance and ongoing monitoring). The opportunity cost of labor will be influenced by off-farm opportunities, as well as by aspirations. [8] Agroecological technologies are not inherently pro-poor; a supportive policy environment that provides some kind of incentive for farmer experimentation is needed (Tripp, 2006).

4. AGRICULTURAL INNOVATION SYSTEMS

(a) *Characteristics and communities of practice*

Innovation systems thinking has its origins in 1980s literature interested in how and why national economies were on different paths and speeds of progression and industrialization (Agwu, Dimelu, & Madukwe, 2008; Nelson & Winter, 1982). The "agricultural innovation systems" (AIS) framework emerged in response to shortcomings of transfer of technology frameworks where knowledge or technology is viewed as developed by scientists, then handed over to intermediaries or end users (Röling, 2009). An AIS framework by contrast draws attention to the capacities of individuals and organizations to translate knowledge into useful social or economic activity in agriculture (Spielman, Ekboir, & Davis, 2009).

Proponents argue that AIS directs attention to how agricultural growth is influenced by complex interactions between public, private, and civil society actors, in rapidly changing market and policy regimes (Spielman *et al.*, 2009), including how institutional dynamics across a variety of levels influence agricultural development (Basu & Leeuwis, 2012; Ekboir, 2003). An AIS perspective can enable reassessment of development pathways to better reflect the interests involved (Amankwah *et al.*, 2012); and provides, through the concept of "innovation platform," a means to support actor-driven system innovation (Mapila, Kirsten, & Meyer, 2012; Spielman, Davis, Negash, & Ayele, 2011).

Interest in AIS frameworks is evident in a range of research and development organizations, notably the World Bank (2012), the UK Department for International Development, [9] the International Livestock Research Institute (Anandajayasekeram, Puskur, & Zerfu, 2009), Wageningen University (Röling *et al.*, 2012), the International Food Policy Research Institute, and the International Centre for Tropical Agriculture.

AIS builds on insights from other strands of agricultural development literature, including farming systems research (Collinson, 2000; Darnhofer *et al.*, 2012) and participatory frameworks (Hall, 2007). Participatory frameworks (e.g., Chambers, 2005) partially helped research to address local needs and contexts, but were unable to address higher-level institutional constraints that limited the ability of households to implement new knowledge and management practices (Hounkonnou *et al.*, 2012). Innovations system frameworks therefore use stakeholder engagement at a variety of levels and scales to identify and attempt to alleviate some of the broader structural constraints to local adoption of new knowledge.

(b) *Relevant theoretical positions*

AIS first argues that new technology—for example, as embodied in modern varieties—is insufficient to reduce food insecurity. Development projects need to extend their focus from producing various "technologies" to include the *process* of innovation (Hall, Dijkman, & Sulaiman, 2010; Röling, 2009). Innovations emerge from any number of contexts (Biggs & Clay, 1981). AIS recommends decentralization of research from formal national innovation systems. Farmers and other local actors (e.g., traders, business owners, brokers) have knowledge and experience to identify organizational, technical, and institutional opportunities and constraints more rapidly than extra-local actors (Brooks & Loevinsohn, 2011; Klerkx, Hall, & Leeuwis, 2009; Spielman *et al.*, 2011). Collaborative networks drive more rapid social and economic innovations. Neither farmer organizations, nor value chains, innovation networks are voluntary, collaborative, nonhierarchical, dynamic in terms of membership, and often fuzzy in terms of problem definition (Ekboir, 2012). They allow diverse actors who contribute time, or other resources toward innovation, to interact (Clark, Hall, Sulaiman, & Naik, 2003; World Bank, 2012). "Innovation platforms" are temporary configurations of key actors selected as champions for some social purpose. Participants may be recruited by a "catalytic" agent or broker, drawing on or strengthening existing networks (Ekboir, 2012; Hounkonnou *et al.*, 2012). Thus an AIS framework directs effort to capturing and utilizing different types of knowledge to achieve common goals (Biggs, 2008; Röling, 2009). This enables diverse stakeholders to contribute to innovation, though issues related to the politics of knowledge are inevitable.

Second, institutional structures (e.g., from government policy through to local cultural norms) have a significant influence on the interpretation and adaptation of new knowledge and technology. Lack of understanding of institutional contexts limits effectiveness of technical innovations (Clark, 2002). Understanding such contexts and ensuring involvement of actors from across institutional settings, highlights constraints and opportunities for change, as well as improving the relevance of research (Biggs, 2007; Nederlof, Röling, & Huis, 2007). Engagement in innovation networks or platforms may facilitate institutional changes necessary to address perverse incentives (Adekunle & Fatunbi, 2012).

Third, capacity building lies at the heart of innovation (Mbabu & Hall, 2012). Agricultural research organizations who aspire to creating impact through innovation need to develop individual as well organizational capability. Organizations may require structural changes to organizational policies, management systems and incentives. Required competencies include communication, participatory planning, facilitation of teamwork, and learning-orientated evaluation (Horton, 2012). These shifts enable innovation by providing critical supports that foster learning (Clark *et al.*, 2003; Hall, 2005).

(c) *Vision and policy agenda*

An AIS vision for food security is typically focussed on improving the income of smallholder food producers operating in competitive food supply chains, through technical, institutional and policy innovations (Mbabu & Hall, 2012). Cast more generally, an AIS vision is for sub-systems of the global food system (e.g., specific production systems, national agricultural research and extension, multi-donor collaborations) to be able to continuously innovate around the delivery of food security outcomes. Continuous innovation means achieving virtuous feedback in which a supportive policy environment allows diversity of experimentation and end-user practice, leading to new social and economic activities which are recognized by policy actors (Hall, 2007).

(d) *Conceptual and operational utility*

The fact that AIS is a heuristic framework (Mbabu & Hall, 2012, p. 17), not a rigorously bounded set of propositions, confers both advantages and limitations. In terms of advantages, AIS draws attention to the relevance of multiple sub-systems within agriculture (e.g., the collective action of farmers; education and training; extension; research; partnerships; national policies, and donor assessment and evaluation). All are relevant and constitute domains for investment, and the AIS literature documents multiple examples of innovation (World Bank, 2012), including from sub-Saharan Africa, [10] providing a useful counter-point to the pessimism often attached to African agriculture (Triomphe *et al.*, 2013).

In comparative analysis, AIS suggests that mainstream indicators of agricultural sector performance, such as growth rates in agricultural gross domestic product (GDP), are less relevant than metrics more focussed on innovative activity, such as the proportion of farmers in a given region experimenting with new practices (Hambly Odame, 2012; Spielman & Birner, 2008). For project and program design, an AIS framework would invest more in planning, and ongoing inquiry around pathways to impact. [11]

Innovation networks and platforms have inherent complexities and tensions. They are most effective for ill-defined issues, yet their initial problem framing influences who joins and how the network innovates. Actors must perceive incentives to join: diverse specific interests must in some way be complementary and align in the form of common interest. Processes need to be flexible enough to absorb new actors and participants, but poorly structured goals can limit the effectiveness of innovation. Flexibility and learning processes are emphasized, but these can be hampered by pre-existing organizational cultures (Ekboir, 2012). Nonparticipation of one actor can have significant impacts on the capacity and resources to support innovation (Ekboir, 2003). Innovation networks may not represent the poorest and most marginalized, and are open to opportunistic behavior by powerful actors, such as brokers or donors (Ekboir, 2012). Innovation often takes more than a decade to emerge, and thus to observe and understand its dynamics requires more than a short-term focus (Triomphe *et al.*, 2013). The limits and dangers of participatory processes in a range of research and development contexts are well documented, particularly where uneven power relations exist (cf. Cooke & Kothari, 2001). In short, efforts to steer innovation face discourse-dependency, context-dependency, and power asymmetries.

Proponents acknowledge that mainstream policy and practice lags behind the literature on enabling innovation (Hall, 2007), even as the AIS literature is limited by the dominance of descriptive *ex post* case studies (Spielman *et al.*, 2009). More examples are needed of how an innovation system, designed *ex ante*, can promote "institutional and technological changes that are explicitly pro poor" (Hall, 2007, p. 403).

5. SOCIAL–ECOLOGICAL SYSTEMS

(a) *Characteristics and communities of practice*

Social-ecological systems frameworks are based in literature on ecology and ecosystem management, including theories of resilience and vulnerability (Berkes, Colding, & Folke, 2003; Berkes & Folke, 1998; Holling, 1978; Walters, 1986). SES displays a prominent concern with environmental change, especially the medium- and long-term consequences of human activity on future human well-being. Such activity often increases ecosystem vulnerability (Ericksen, Bohle, & Stewart, 2010, p. 68) which may have led to the crossing of key ecological thresholds in the earth system (Rockström *et al.*, 2009). The SES community of practice is supported by the Resilience Alliance, a network of universities, nongovernmental organization (NGOs), and government agencies, which publishes the journal *Ecology and Society*. Other actors and networks influenced by SES thinking include the Global Environmental Change and Food Security research project (2001–11), the Millennium Ecosystem Assessment (2001–05) the Earth System Science Partnership, and the United Nations Environment Program.

(b) *Relevant theoretical positions*

SES visualizes the human–environment interface as a coupled "system" in which socio-economic as well as biophysical driving forces interact to influence food system (and subsystem) activities and outcomes, both of which subsequently influence the driving forces.

The concept of resilience, originating in ecology, is central to visualizing dynamics of this coupled system. Resilience is interpreted differently by SES scholars but commonly recognized as a multi-attribute concept, composed of: (1) ability to cope with disturbance or change and retain control of function and structure; (2) capacity to self-organize; and (3) capacity to learn and adapt (Berkes *et al.*, 2003; Ericksen *et al.*, 2010; Walker, Holling, Carpenter, & Kinzig, 2004; Walker *et al.*, 2002). SES understands such dimensions to be emergent properties of *systems*, beyond human manipulation. At the same time, desired systemic properties can be furthered by investing in specific components of systems (Marschke & Berkes, 2006).

Strategies to promote resilience at the "local" level include (1) learning to live with change and uncertainty, (2) nurturing learning and adapting, and (3) creating opportunity for self-organization (Marschke & Berkes, 2006). However,

nonincremental change ("transformation") may be required when a system is trapped in an undesirable (and often resilient) state (Walker *et al.*, 2004). For rural livelihoods this may be necessary because

> [M]any production systems do not meet the needs of local communities, and some. . . . will not be viable under changed climate conditions; simple incremental adaptation will not suffice. These systems will need to be transformed [requiring]. . . . new germplasm, crops, farming systems, institutions, and policies. . . . put into place in a short space of time.
>
> (Walker, Sayer, Andrew, & Campbell, 2010, p. S-12)

In a position shared with welfare economics, SES argues that systems can exist in more than one dynamically stable state (Barrett & Swallow, 2006; Enfors & Gordon, 2008). Escaping poverty at the household level may require a higher level of assets that allow a critical threshold to be crossed, after which welfare increases to a higher level equilibrium. Strategic action to promote resilience is made complicated however by the fact that resilience at a particular organizational level or sub-system is influenced by forces from levels above and below.

For example, an individual household's assets may be adequate to allow investment in irrigation technology, but road infrastructure may be inadequate. Groups that cooperate and coordinate effectively can mobilize resources to invest in public infrastructure, however, investments at higher levels, ranging from market infrastructure to governance and rule of law, may also be needed (Barrett & Swallow, 2006). Similarly, outcomes pursued in one policy domain may have unintended consequences on other domains. For example, the cumulative impact of national decisions to invest in hydropower dams or water storage infrastructure (made in the domain of energy policy) may result in international regional-level impacts on nutritional security, by impacting on wild capture fisheries (Fullbrook, 2013, chap. 2; ICEM, 2010).

(c) *Vision and policy agenda*

A vision for food security informed by SES thinking might consist of increased resilience across multiple domains relevant to the food system, achieved through institutional changes (transformative, if necessary) that allow greater knowledge of systemic interactions (aided through adaptive management experiments), as well as increases in diversity, pluralism, and communication between sub-systems or policy domains. Such diversity, agility, and coordination in the face of complexity avoids problem-shifting as well as various undesired consequences and lock-ins that characterize food insecurity (Cash *et al.*, 2003, 2006; Ingram *et al.*, 2010; Jackson *et al.*, 2010; Lin, 2011).

A key focus would be the pursuit of adaptive co-management, a governance arrangement to blend power-sharing among stakeholders with reflective learning and innovation (Folke, Hahn, Olsson, & Norberg, 2005; Olsson *et al.*, 2006). Key attributes are pluralism and communication, shared decision-making and authority, cross-scale social networks and institutions, social learning and knowledge integration (Armitage *et al.*, 2008). Often such arrangements emerge in response to natural resource crises and as an alternative to conventional centralized, top-down command-and-control governance (Butler, 2011; Butler, Middlemas, Graham, & Harris, 2011; Olsson, Folke, & Hahn, 2004). In developing contexts, they appear suitable for tackling the tension between artisanal fisheries, food security, and biodiversity conservation, but remain untested (Butler *et al.*, 2013b; Wood, Butler, Sheaves, & Wani, 2013).

Although concepts such as "resilience," "transformation," and "adaptive co-management" have entered food policy discourse, the influence of SES thinking on donor agendas has otherwise been limited. Exceptions include research for development projects using the discourse of pro-active transformation of rural livelihood systems facing climate change (Butler *et al.*, 2013a; Butler, Skewes, Mitchell, Pontio, & Hills, 2014) and the discourse of managing water–food–energy linkages (Hoff, 2011; Smajgl & Ward, 2013).

(d) *Conceptual and operational utility*

Swallow *et al.* (2009) conducted a spatial analysis of poverty "traps" in two Kenyan catchments of Lake Victoria basin. Their study was an analytically intensive, spatially explicit way of identifying synergies, trade-offs, and traps in ecosystem management, which could allow targeting of development interventions. They used sediment yield as an indicator of ecosystem regulating service, and agricultural production as the indicator of provisioning service. Development advice included conditional credit arrangements and conservation agriculture.

Marschke and Berkes (2006) conducted a resilience-based analysis of livelihood strategies of Cambodian households in two fishing villages. They classified activities reported by villagers according to three resilience-building strategies introduced above: (1) learning to live with change and uncertainty (building a portfolio of livelihood options; building rapid feedback capacity; developing coping strategies); (2) nurturing learning and adapting (nurturing social memories, e.g., of infrequent flooding events, and creating political space for experimentation); and (3) creating opportunity for self-organization, a diverse category which captured fisheries conflict resolution mechanisms, and "taking advantage of market opportunities" (2006: Table 2). Certain strategies may involve trade-offs (e.g., individual market opportunities may compromise community resilience) and thus a multidimensional analysis is needed: analysts need to consider the distributional (equity) implications of particular strategies. In practice multi-stakeholder governance is rarely power-free, and co-management is frequently undermined by elite capture (Butler *et al.*, 2013a; Nadasdy, 2007).

Osbahr, Twyman, Adger, and Thomas (2010) applied resilience thinking to evaluate the success of four agricultural development projects with climate adaptation objectives in Southern Africa, in cases all marked by poverty, high unemployment, and weak infrastructure. Key findings included the importance of existing informal networks as platforms to build more formal organizations (e.g., maize and horticultural collectives); the importance of forming bridging relationships with external actors (government agencies and NGOs) providing access to credit, information, and technical knowledge; the importance of entrepreneurial experimentation and commercial activity to inspire young people and marginalized women; and rules to allow more vulnerable, less entrepreneurial community members to learn and organize.

Eakin, Winkels, and Sendzimir (2009) used SES thinking to explore how national institutions, historical forces and social expectations transform signals of global change—in their case, global coffee prices—into distinct outcomes in different geographic contexts. Following early 1990s frost damage to the Brazilian coffee crop, Vietnamese production expanded but Mexican production did not, because of a previous weakening of the agricultural extension system. The Vietnamese coffee boom of the early to mid-1990s subsequently contributed to record low world coffee prices, which in turn depressed

incomes and harvests in both Vietnam and Mexico (Eakin *et al.*, 2009). Vietnam's production, now significant enough to affect world coffee markets, appears to have been fueled by possibly unsustainable levels of water exploitation in the Central Highlands (Eakin, 2010). Eakin *et al.* (2009) argue that "risks and opportunities associated with global scale economic and environmental change are teleconnected and thus can create feedbacks which in turn affect the present and future vulnerabilities of other smallholders around the globe" (p. 398). In short, distant connections occur through more than just price signals. Analysis of opportunity and vulnerability needs to look at how ideas, institutions, technology and people are also connected, for example through flows of non-monetary values such as fair trade (2009, p. 407).

Because the SES framework emphasizes complexity and understanding systemic interactions, applications of this framework tend to focus on problem identification and improving system understanding. Most applications of the framework appear to come from researchers, not development practitioners. Though accurate, SES-based prescriptions tend to be framed in abstract language that may be unaccompanied by specific historical contextualization, e.g., for vulnerable people to collaborate more (Bohle, Etzold, Keck, & Sakdapolrak, 2009); for governance to overcome ignorance, coordinate better across scales, account for plurality of interests and improve political and administrative capacities (Cash *et al.*, 2006; Pereira & Ruysenaar, 2012). Many applications of the framework are relatively weak on socio-political analysis (Nadasdy 2007; Butler *et al.*, 2013a). An exception, because it tracks institutional change over time, is work by Eakin *et al.* (2009) on nested vulnerabilities. Because the framework is system-oriented, agency may not always be well conceptualized or studied.

6. POLITICAL ECOLOGY

(a) *Characteristics and communities of practice*

Political ecology focuses attention on issues of power, politics, and social justice. It includes seminal contributions from agrarian studies, as well as human ecology, vulnerability studies, and critical discourse analysis (Blaikie & Brookfield, 1987; Bryant, 1992; Forsyth, 2003; Robbins, 2012; Watts, 2013). Political ecology is pursued by a large and heterogeneous community of practice including the food sovereignty movement, as well as a subset of development professionals within World Bank, FAO, CGIAR and affiliated organizations (where it is a minority discourse). Political ecology features in journals such as *Development and Change, Journal of Agrarian Change*, and the *Journal of Peasant Studies*.

(b) *Relevant theoretical positions*

Political ecology's roots in critical agrarian political economy make key principles from the latter field highly relevant to food security (Akram-Lodhi, 2013). First, the expansion of capitalist market relations since the 19th Century, resulting in a global-scale food system, caused "dispossession through differentiation." Farmers who produce and sell agricultural commodities are in a subordinate position to the market. They face competition (from others locally, regionally, or globally) and cannot dictate prices. Farmers can lower their costs through generic pathways such as specialization (e.g., monoculture production); investment in capital equipment and inputs to boost yields; and innovation (Akram-Lodhi 2013, p. 34). Specialization and investment however offer no guarantee of competitiveness. Innovation (e.g., identifying niche markets, and entering into specific contracts) might confer temporary advantage. Under prevailing capitalist market institutions, political ecology questions if sufficient capability to innovate can ever be re-distributed equitably. Facing this "market imperative," smallholders who cannot find ways to lower their unit costs (through specialization, investment, increased economies of scale, and associated innovations) will be unable to stay profitable as emerging capitalist farmers, and face pressures to exit. Those able to invest in land, hired labor, and other inputs, or to access innovations will accumulate at the expense of those who exit.

Second, the global food system is now dominated by a relatively small number of wholesalers and retailers. Subject to their own competitive pressures, these actors have sought increasing control over farmers for the purpose of securing high volumes of food at standardized quality (Patel, 2007). According to this perspective, contract farming is another mechanism of differentiation, driving a wedge between viable and nonviable small producers. The former—emerging, "proto-capitalist" entrepreneurial farmers—may receive lucrative returns but nonetheless are subordinated in buyer-dominated supply chains, receiving a share of value added that reflects asymmetrical power relations between the farmer and the buyer, as opposed to the "real" added value (Akram-Lodhi, 2013, pp. 135, 148). Contemporary efforts to deepen free trade, it is argued, threaten to displace more smallholders in favor of large-scale farmers in countries dominating the construction of trade regimes (Akram-Lodhi, 2013).

Third, smallholders who are culturally or politically subordinate to local elites and/or state agencies may face coercion and physical dispossession, resulting from design and implementation of major infrastructure or conservation projects—a set of processes referred to as "dispossession through displacement." Political ecology highlights the impact of enclosure on local livelihoods, excluding households from important sources of food and other resources (Hall, Hirsch, & Li, 2011; Murray Li, 2007).

Fourth, political ecology looks beyond the interplay of institutions and interests to study how particular understandings (framings, narratives) become dominant in key policy domains, with what effects and outcomes (Allouche, 2011; Friend *et al.*, 2009, chap. 12; Tomlinson, 2013). Five, political ecology shares with SES an interest in understanding cross-level, cross-domain interactions, but takes a characteristically bottom-up framework in which "local" socio-political and environmental dynamics are interpreted with greater social detail, then situated in larger contexts of structure and meaning. Thus political ecology attempts to highlight underlying market, as well as other institutional, cultural, or power structures that impact on livelihoods, resource access, and environmental change.

(c) *Vision and policy agenda*

Political ecology endorses, in a qualified manner, the agroecological and food sovereignty movement's vision for food security outlined in Section 2 above. This could be re-phrased as multi-faceted, systemic action to eliminate the diverse forms of injustices that cause hunger (Food First, n.d.), which would require *inter alia* collective action to improve wages for low-income workers in the wider economy. In addition to the food sovereignty movement's model of a series of interconnected, interdependent local food systems, political ecology scholars give critical qualified support to ideas such as pro-poor

redistributive land reform, and to making water, seed, fertilizer, and other agroecological technologies more available to small-scale poor farmers (Akram-Lodhi, 2013, p. 163; Borras, 2008). While endorsing the food movement's normative vision, political ecology applies to it a reflexive critique, which we elaborate in Section 7 below.

(d) *Conceptual and operational utility*

Political ecology scholars have provided critical responses to the World Bank's *World Development Report 2008: Agriculture for Development* (World Bank, 2007). The *WDR 2008* acknowledges the heterogeneity in world agriculture and poverty [12] yet provides a "standardized and homogenized" set of pathways out of poverty, the first of which is for smallholders to become commercially oriented entrepreneurs (Akram-Lodhi, 2008, p. 1153). However, for most smallholders, this pathway is not viable, leaving outmigration, or rural nonfarm wage labor or self-employment as the only options. For Akram-Lodhi (2008), this pessimistic analysis evades the root causes of power, privilege, and poverty in global agriculture, which must be located in the problem of uneven access to land and other productive assets.

Murray Li (2009) draws attention to tensions in the *WDR 2008*s policy advice: despite the low wages currently paid to unskilled labor, nonfarm labor is promoted as a pathway out of poverty (World Bank, 2007, chap. 9). The *WDR 2008* optimistically ignores barriers that gender, age, tribe, and caste pose in accessing employment at anything better than poverty wages. It ignores the problem that labor markets in developing countries (e.g., Indonesia and India) have limited capacity to offer higher-paying jobs, in part because of global economic competition. Notably, the *WDR 2008* admits that social protection nets are essential for unskilled labor who cannot exit rural areas on advantageous terms, but fails to confront the key policy challenge of how to provide social protection under conditions of public resource constraint (Murray Li, 2009, p. 633).

The *WDR 2008* sees structural transformation—the displacement and absorption of rural people into off-farm employment—as inevitable (Akram-Lodhi, 2008). By contrast, Akram-Lodhi (2013) calls for re-regulation of land markets to prevent accumulation of inequality in land distribution, which would help improve the balance of forces between historically weak small producers, and strong input suppliers and buyers. This would inhibit the formation of large cohorts of people in the developing world who are surplus to both agriculture and nonagricultural sectors (Amin, 2003; Murray Li, 2009; Weis, 2007).

Beyond systemic analysis and critique, political ecology builds on and extends various "sustainable rural livelihoods" frameworks (Carney *et al.*, 1999) which have become popular in development practice. Conventional livelihoods frameworks pay insufficient attention to the multiple political and institutional influences that delimit viable options for households to secure their way of life, including influences from higher levels of governance (De Haan & Zoomers, 2005; Scoones, 2009a). Also, livelihoods analysis is usually concerned with the local and short-term capacity of communities to cope with immediate shocks. This ignores limits to adaptation, and radical transformation potentially required to preempt impending shifts in global-scale drivers such as climate change (Scoones 2009a; Butler *et al.*, 2013a). [13] By contrast, tracing household land use decisions of households in Zimbabwe and Kenya, McCann (2011) finds negative environmental impacts from a shift to more intensive crop production, caused by the interplay of political and economic forces, and the household endeavor to make sense of these to achieve food security. Large corporate approaches to varietal breeding favor larger farmers. Small or marginal households struggle to cultivate improved varieties under conditions of uncertain supply and climate fluctuations, and lose access to local knowledge and seed stocks.

Similarly, Barney (2009) offers a nuanced understanding of how households shift their livelihood strategies in response to changes brought by state policies and subsequent landscape change. In Laos, hydropower development and plantation expansion combine to put pressure on land resources. One common household response has been an increase in young family members engaging in wage labor migration, with the remittances further reshaping local livelihoods through reinvestment in cash crops like rubber. Such a shift in livelihood strategies transforms village property rights over forest land from communal property/swidden areas to privately owned rubber plots (Barney, 2012).

Political ecology's critical positions and radical policy agenda weaken its legitimacy in mainstream development communities, and open it to criticism that it links academic knowledge and development action poorly, because the core of its community of practice consists of scholars rewarded for producing relatively inaccessible, or nonscientifically credible, academic discourses (Blaikie, 2008, 2012). These criticisms however could also be leveled at SES thinking (its inherent interest in complexity reduces accessibility), and to certain agroecological practices, such as system of rice intensification. [14]

A more trenchant criticism is that even if accessible and credible, political ecology's analysis and findings diverge too radically from mainstream development thought and practice, and thus its knowledge cannot usefully guide food security development interventions. As a counter-narrative that contains zero-sum game thinking, political ecology will always struggle for salience. However, many examples exist where insights from a broadly-defined political ecology have influenced mainstream development and food policy discourses and agendas. These include the rights and risks approach to development recommended by the World Commission on Dams (2009); the locally contextualized, problem-oriented approach to biotechnology R&D recommended by International Assessment of Agricultural Knowledge, Science, and Technology for Development (Scoones, 2009b); the critique of conventional food supply chains on the grounds of nutritional quality, and the emergence of "slow food" and "farm to fork" discourses (Akram-Lodhi, 2013). Support by the FAO Council for the right to adequate food, resulting in support for assessment methodologies (FAO, 2009b) may constitute another example of influence.

7. TRIANGULATION: TOWARD MORE INFORMED SYNERGIES

Having outlined four distinctive conceptual frameworks that take complexity in food systems seriously, we now triangulate in search of informed synergies. By informed synergy we mean an interaction between two or more frameworks capable of enhancing our understanding of, and potential to intervene, in food security dynamics. Recall that the four frameworks were selected for their (partially) divergent problem framings (Figure 1). AIS seeks systemic innovations often framed around the objective of allowing smallholder farmers better access to, or better position in, food supply chains.

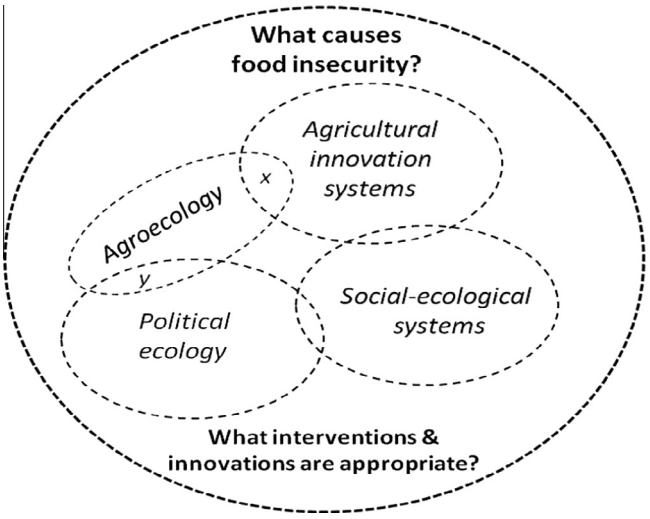

Figure 1. *Conceptual frameworks analyzed. Source: Authors. Note: "x" and "y" denote convergences discussed in text.*

Political ecology cautions that connecting to supply chains in the context of a capitalist food system will dispossess farmers who cannot compete. Agroecology accepts certain insights from both AIS and political ecology, such as the importance of supporting horizontal, innovative farmer-to-farmer connections on the one hand (Figure 1, "*x*"), and critical analysis of industrial, capitalist agriculture on the other hand (Figure 1, "*y*"). Whereas the other frameworks typically focus their analysis on a particular domain or level, SES emphasizes cross-level, cross-domain interactions. While not divergent on all issues, the frameworks thus diverge usefully with respect to problem framing. In addition, at least one of the frameworks builds on each high-level insight into sustainable development offered by Roe (1998). [15] For example, AIS, SES and political ecology accept that the global food system has dimensions that are formidable to manage, or indeed unmanageable.

Some of the literature we reviewed had clearly been influenced by more than one framework. Often the work was presented using the ideas (i.e., the causal or normative beliefs) of one main framework, supported by the use (including critique) of concepts from a secondary framework in an attempt to further the former (Table 2). At times authors did so without explicit discussion of contradictions or synergies. Table 2 compairs interactions among the four frameworks.

(a) *Synergy between agroecology and agricultural innovation systems*

We found frequent use of AIS-thinking to support agroecological objectives (Table 2, cell 1). Conversely, we found no unambiguous examples where agroecological practices were used as a means to support innovation systems (Table 2, cell 4), possibly because agroecological practices are more frequently viewed as inherent ends. [16] The concept of "sustainable intensification" attempts to combine both agroecological practice and AIS into a common framework, arguing that a pathway to expand sustainable agriculture is to use public money to build new partnerships that improve agricultural productivity. Micro-finance, rural banking, and investing in capacity and development of women constitute additional innovations required to enable agroecology in Africa (Pretty *et al.*, 2011). However, from a political ecology perspective, notwithstanding the aspirations of "sustainable intensification," many dimensions of agroecosystems are not internalized under the market imperative.

(b) *Synergy between agroecology and social-ecological systems*

An example of SES thinking contributing to agroecology (Table 2, cell 2) is the Agrimonde 1 scenario, which envisions a food system that feeds nine billion people by 2050 in a healthy manner, in a semi-quantified storyline that includes increases in agroecological practice, increases in trade and total crop area, and equalization of per capita food consumption (Dorin, Paillard, Treyer, Guillou, & Matheron, 2011). Other important examples of interactions between SES and agroecology include debates over whether organic farming can feed the world. Claims that modern organic crop production systems provide yields comparable to conventional agriculture have been attacked as misleading (Connor, 2008). Previous claims in support of organic agriculture (Badgley *et al.*, 2007; Seufert, Ramankutty, & Foley, 2012) have compared crop yields, ignoring higher-level, resource requirements posed by organic *systems*. [17] Critics argue that agroecological practices are merely a "preliminary" step toward the 70% increase in global crop production that is an "inescapable requirement" to feed an estimated population of 9.2 billion by 2050 (Connor, 2013, p. 146). By implication, organic agroecological practices are incapable of feeding the world. However, in a comment relevant to the contested interface between agroecology, SES thinking, and global food security, Reilly and Willenbockel (2010) argue that diversity in agricultural systems, as well as variation in agroecological capacity suggest that a strategic portfolio of policy responses are needed, customized for each region.

(c) *Synergy between agroecology and political ecology*

Agroecology–political ecology interactions can appear paradoxical. On the one hand, a vigorous food sovereignty literature exists, where political ecology's critique of the injustice of globalized food regimes is used to further an agroecological vision (Table 2, cell 3). This literature analyzes and often celebrates transnational agrarian movements such as Vía Campesina. However, through the lens of critical political economy (Table 2, cell 10), such movements have not addressed the implications of the market imperative (i.e., compete or be displaced) and thus who will continue to farm (the agrarian question) with sufficient rigor (Akram-Lodhi, 2013). Vía Campesina, the food sovereignty movement's umbrella organization, represents a heterogeneous array of class interests, ranging from small farmers in the EU, landless farmers in Brazil, and richer small scale peasants in India. Despite attempts to forge a new cross-class discourse, their capacity to act collectively is to a large degree constrained by their particular positions in global food supply chains. The vision's neo-populist framing masks such contradictions (Akram-Lodhi, 2013). [18]

(d) *Synergy between agricultural innovation systems and social–ecological systems*

Although AIS and SES thinking share a common interest in complex, nonlinear, evolutionary systems (Spielman *et al.*, 2009), we found few examples of published empirical work featuring strong interactions between AIS and SES (cf. Osbahr *et al.*, 2010). Butler *et al.* (2013a) propose the establishment of "livelihood innovation niches" within vulnerable and food insecure communities, which could create spaces

for innovation in governance and technology where transformative practice can develop among more fluid and emergent rules, without penalty for failure. This framework explicitly combines the necessity for multi-scale adaptive co-management from SES thinking, with the multi-stakeholder framework inherent in AIS (Table 2, cell 8). Akin to the Millennium Villages Program (Carr, 2008), such niches would provide examples of coping or transformative livelihood strategies which might influence similar neighboring communities.

(e) *Synergy between agricultural innovation systems and political ecology*

Tensions between AIS and political ecology means that "synergistic" work involves using analytical techniques or findings from one framework to further visions derived from another. For example, the Convergence of Science program used political ecology thinking to diagnose multiple institutional and power constraints, to subsequently design action research to further innovation in Africa (Table 2, cell 6) (Hounkonnou *et al.*, 2012; Yemadje *et al.*, 2012). Brooks and Loevinsohn (2011) draw implicitly on political ecology in their critique of CGIAR and contemporary private–public approaches in two farming systems: maize in Africa and rice in Asia respectively. NGOs have catalyzed important innovations around both systems (cassava in Africa, system of rice intensification in Asia), which have been overlooked by the mainstream focus on maize and modern breeding technology.

Historical analysis and critique of fair trade coffee is an example of the converse interaction (Table 2, cell 11). Bacon (2010) used techniques familiar to AIS practitioners (third party certification and value chain analysis) to further political ecology-inspired research and advocacy. Bacon (2010) found that Fair Trade minimum prices (paid to growers) declined 41% in real terms during 1988–2008. His analysis informed action by smallholder collectives against this trend, challenging dominant actors within the Fair Trade value chain.

A literature on collective action (e.g., farmers' organizations) for smallholder market access exists (Markelova, Meinzen-Dick, Hellin, & Dohrn, 2009; Shiferaw, Obare, & Muricho, 2008; Sivramkrishna & Jyotishi, 2008), and includes analysis of issues specific to poor female farmers (Quisumbing & Pandolfelli, 2010). However, it appears to be informed by rational choice institutionalism (Ostrom, 2007) as opposed to either AIS (Kaaria, Njuki, Abenakyo, Delve, & Sanginga, 2008) or political ecology (cf. O'Laughlin, 2009). A mutual interest in how markets could work better for the poor, suggests need and opportunity for dialog between literatures, notwithstanding conceptual tensions. A common research agenda might include effects of market participation on nutritional outcomes, on those unable to participate in collective action, and other higher-order impacts of market participation (Barrett *et al.*, 2012; Markelova & Mwangi, 2010).

(f) *Synergy between social–ecological systems and political ecology*

Insights from political ecology have informed research for development interventions based on SES thinking, notably around the water–food–energy "nexus" in the Mekong region of Southeast Asia (Foran, Ward, Kemp-Benedict, & Smajgl, 2013; Smajgl & Ward, 2013), and conflicts between artisanal fisheries and conservation in the Pacific (Butler, Tawake, Skewes, Tawake, & McGrath, 2012; Butler *et al.*, 2013b; Wood *et al.*, 2013). Conversely, using SES thinking to advance political ecology, Tomlinson (2013) traces the origins of the claim that global food production must increase 70% by 2050 in order to feed the world (Table 2, cell 12). She argues that what has become a normative policy "imperative" is nothing more than an output of computable general equilibrium modeling based on particular assumptions about economic growth and population, a dynamics-as-usual scenario which assumes increased animal protein consumption. It deserves to be taken seriously, but is insufficient to end malnutrition, even as it expands agricultural production into wetlands and rainforests (2013, p. 83). Tomlinson's (2013) analysis reveals a need for more nuanced, alternative food system scenarios. For developing countries, such scenarios could explore impacts of alternatives such as investing in food production for domestic and regional markets, investing in rural nonfarm economies, and investing in export-led development, in which food is obtained from global markets.

Overall, we found few examples of analyses that fully integrate SES and political ecology (cf. Eakin *et al.*, 2009), despite calls for such integration in the adaptive co-management literature (Butler *et al.*, 2013a; Nadasdy 2007). Both frameworks are analytically intensive and draw on different core disciplines.

(g) *Synergistic approaches to meeting food security challenges*

Table 3 shows how the synergies we identified might be deployed, or further developed, to address food security challenges. Maintaining production over the medium and long term constitutes a key challenge, according to agroecology and SES thinking. We found synergy in studies that address this challenge with insights from agricultural innovation systems and political ecology (Table 3, row 1).

Social relations of access influence livelihood strategies and the affordability of food: how access to land, common property resources, and physical infrastructure (e.g., roads, canals, mills) might change under the combined influence of environmental change and development strategies constitutes—from the perspectives of political ecology and SES thinking—another important class of problems. Using AIS-style deliberative platforms might help policy actors begin to understand and address power-laden relations of access. Synergies involving three (and possibly four) four frameworks are relevant to such problems (Table 3, row 2). Activities that would further such synergy include deliberation on historical food and development trajectories and future scenarios, with exploratory storylines defined in a participatory multi-stakeholder process (Foran *et al.*, 2013). Such work could be supported by quantitative livelihoods and social-ecological analysis (Butler *et al.*, 2013a; McKune & Silva, 2013; Smajgl & Ward, 2013).

Finally, the social determinants of food consumption constitute another set of challenges. Beyond availability and accessibility, culturally-informed worldviews and rationalities influence consumption strategies. Facing food emergencies, Sub-Saharan African households may forgo consumption rather than sell their productive assets to acquire food (Baro & Deubel, 2006; Corbett, 1988), or may feed children equitably, rather than allocate food to children most acutely ill (Hampshire, Panter-Brick, Kilpatrick, & Casiday, 2009). On this set of topics, a synergy between political ecology and SES thinking would lead to detailed fieldwork to explore how consumption practices in a particular place are influenced by historical and cultural processes (cf. Freidberg, 2003). Practice theory, not used in this triangulation, should provide additional insights (Halkier & Jensen, 2011).

8. CONCLUSION

We conducted an interdisciplinary analysis of four theoretical frameworks that have influenced academic and policy agendas related to food insecurity in developing countries. Our review was motivated by donor interest in exploring future directions for portfolios of investment in food security, the need to triangulate on an inherently multi-faceted and contested concept, and a search for informed synergies. The triangulation was an exploratory attempt to generate a cross-disciplinary conversation, initially between adherents of mainstream and alternative perspectives on agricultural innovation, local and global environmental sustainability, and social justice. An AIS framework emphasizes incremental technical and social innovations to improve smallholder production and livelihoods. Agroecology emphasizes the need to maintain a balance between production for the market and the ecosystems that sustain such production. A SES framework encourages distributional issues to be pursued beyond a specific place or region, and the need for innovative, multi-scale adaptive governance to build resilience or transform the system of concern. Political ecology reminds us that all innovation is inescapably political and that conventional market dynamics re-distribute innovative capacity unequally. All frameworks concur on the need to identify opportunities to reform markets and other institutions so they offer more balanced outcomes, opportunities that range from local to global scale.

Donors face complex challenges involving major food security dimensions such as availability and access. Selective combinations of four divergent frameworks offer potentially productive synergies to meet such challenges. For example, combinations of social–ecological systems, agricultural innovation systems, and political ecology offer nuanced understandings of the impacts of sectoral and macro-economic development strategies on livelihoods and affordability (Table 3).

In order to generate powerful synergies, analysts need to approach the tensions between conceptual frameworks as a source of creative, inter-disciplinary insight.[19] Such tensions, along with disciplinary expertise, caution against naïve or reductionist attempts at synthesis. Informed, synergistic use of divergent frameworks constitutes a new ambition for research and practice. Tensions between perspectives suggest that communities of practice in food security should use interdisciplinary, plural methods such as conceptual triangulation more regularly when designing interventions.

NOTES

1. Roe's (1998) triangulation used critical theory (e.g., Piccone, 1987), cultural theory (Thompson, Ellis, & Wildavsky, 1990), Girardian economics (e.g., Orléan, 1989), and local justice (Elster, 1992).

2. Funded by the AusAID-CSIRO Research for Development Alliance.

3. Farming systems research focuses on the generation of "appropriate" technologies for small farmers to broaden the focus from a particular crop to the wider farm and household system (Collinson, 2000; Darnhofer, Gibbon, & Dedieu, 2012).

4. Refers to a very broad body of methodologies and research philosophies that aim to incorporate "local" knowledge into research, planning, and development activities, either driven by government (top–down) or originating at the community level (bottom–up) (Chambers, 2005).

5. Academic agroecology's focus has expanded from field and farm scale processes (Altieri, 1995) to ambitions of understanding "entire food systems" (Wezel *et al*., 2009) and global environmental change (Tomich *et al*., 2011; Wezel *et al*., 2009). This recent expansion however reflects the influence of social-ecological systems thinking.

6. On average, pesticide use decreased by 50%, while yields increased by > 30% ($n = 62$). In reduced tillage projects ($n = 5$), herbicide use for weed control increased, indicating a possible trade-off between sustainability objectives. Potential carbon sequestered averaged 0.35 ± 0.016 t C/ha/yr.

7. Unfortunately, the authors did not present disaggregated productivity or area impact by partnership or policy.

8. Where there are many off-farm opportunities, cost of farm labor can be higher (both wage rates and opportunity cost) providing incentives to save labor through technologies such as broadcasting rice and chemical weed control. However, technologies that require labor may stimulate local rural markets (Tripp, 2006).

9. Notably, through its support to the Research into Use program (Frost, 2013).

10. Many of which are "market-driven" (e.g., farmers learn to produce according to buyers' standards; new value chain arrangements).

11. An AIS framework would focus on participatory elucidation of how proposed activities will lead to altered networks of interactions between development partners, beneficiaries, brokers, and other intermediate actors, recognizing complexity of context (Douthwaite, Kuby, van de Fliert, & Schulz, 2003; Woodhill, 2010)

12. Based on a two-dimensional classification (agriculture's contribution to GDP growth 1990–2005 as first dimension; and the ratio of rural poor to total poor in 2002 as second), the WDR 2008 classified countries into three clusters: agriculture-based economies, transforming countries, and urbanized countries. Regions within large countries are however heterogeneous (World Bank, 2007, p. 31).

13. From an SES perspective, insufficiently accounting for such structures, influences and cross-scale dynamics will compromise diagnosis of intervention points.

14. Claims that productivity under SRI is superior to conventional best management practices have been criticized by proponents of the latter (Dobermann, 2004; McDonald, Hobbs, & Riha, 2006; cf. Stoop, 2011).

15. With respect to sustainable development, Roe (1998) advised to differentiate ("you will never find 'halt population growth' and reduce per capita consumption to be true everywhere"), to problematize need, and to beware persecutory language. Other key advice included to search for feedback cycles and acknowledge the unmanageable.

16. AIS thinking supports diversity of practice as a means to deliver systems innovation, without specifying agroecological practices.

17. High yield organic systems source their organic fertilizer from manure derived from intensive animal production systems, which in turn relies on animal fodder which is increasingly sourced from developing countries. By contrast, a contemporary organic crop-livestock system in Zimbabwe produces maize yields of only 0.5–4 t/ha, but requires 20–30 ha of land per household when grazing land is taken into account (Rufino *et al.*, 2011).

18. Akram-Lodhi implies that the food sovereignty movement must choose between "reconfiguring the social relations and conditions of capitalism" and "forging ahead with a post-capitalist alternative" (2013, p. 152). Although both projects present formidable challenges, he suggests that the former project is more intellectually coherent.

19. While some work we reviewed at the interface of more than one perspective mediated conceptual tensions, other work evaded tensions by assigning conceptual primacy to one framework, and treating the other frameworks instrumentally, as secondary knowledge to be used, or occasionally refuted. Evading tensions in the latter manner is expedient but risks incoherence.

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