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Development pathways toward "zero hunger"

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ABSTRACT

Globally, industrial agriculture threatens critical ecosystem processes on which crop production depends, while 815 million people are undernourished and many more suffer from malnutrition. The second Sustainable Development Goal (SDG 2), Zero Hunger, seeks to simultaneously address global environmental sustainability and food security challenges. We conducted an integrated literature review organized around three disciplinary perspectives central to realizing SDG 2: ecology and agricultural sciences, nutrition and public health, and political economy and policy science. Within each discipline we first draw on a wide range of literature to summarize the state of knowledge on effective pathways to achieve food security while ensuring the sustainability of food systems. We then conduct a comprehensive review of articles in each of these disciplines that discuss SDG 2, using the pathways we outline initially to frame our analysis. In particular, we ask whether the framing of SDG 2 is appropriate given current understandings of transitions to sustainable food systems. By applying a food systems lens, our review identifies several limitations in the way SDG 2 is applied by researchers including a productionist perspective, limited attention to ecological processes on farms, a definition of food security that lacks a food systems perspective, and a lack of attention to historical and structural factors that shape opportunities for equity and food security in different contexts. Finally, we consider possibilities for expanding the research agenda and associated implications for development practice. We argue that the pathway to achieving Zero Hunger should center on place-based, adaptive, participatory solutions that simultaneously attend to local institutional capacities, agroecosystem diversification and ecological management, and the quality of local diets. Two conceptual frameworks – social-ecological systems and sustainable diets – offer systems-based lenses for integrated analysis of agriculture and food security, which could inform the development of effective policies.

1. Introduction

What if agriculture and food systems were guided by a goal of human and environmental health? Concerns about the sustainability of global food systems are reflected in the "Zero Hunger" Sustainable Development Goal adopted by the United Nations (UN) General Assembly in 2015. To acknowledge that health, environment, and agriculture are linked signals an emerging shift in scholarly and public understanding. Specifically, by integrating targets on sustainable agriculture in the overall effort to end hunger, the Zero Hunger goal reflects a long overdue recognition that industrial agriculture threatens critical ecosystem processes on which food production depends (IPCC, 2013; Rockstrom et al., 2009). These well-documented consequences include biodiversity loss, increased pest pressure, soil erosion, losses of soil organic matter, greenhouse gas emissions, and eutrophication and pollution of water bodies (Diaz & Rosenberg, 2008; Foley et al., 2011; Matson, Parton, Power, & Swift, 1997).

While environmental tradeoffs were long considered to be a Faustian bargain in efforts to combat hunger and malnutrition, industrial agriculture has not delivered on the promise to eliminate hunger. Indeed, while the world is afloat in "calories," it is only recently that the Food and Agriculture Organization changed the language of food security to "food and nutrition security," reflecting an increase in micronutrient deficiencies. Today, 815 million people are undernourished, and as many as two billion suffer from micronutrient deficiencies (FAO, IFAD, UNICEF, WFP, & WHO, 2017; Initiative, 2009). In 2003, the World Health Organization defined

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an obesity "epidemic" in poor as well as rich countries. There is mounting evidence that both obesity and diet-related chronic disease are principal contributors to lost years of healthy life and instead of contributing to society, ill people are an enormous economic burden (Murray et al., 2013). These environmental and health-related impacts are compounded by economic and political power inequities as corporations have consolidated control over global markets and agrifood governance (Howard, 2016; McMichael, 2009; Otero, Pechlaner, & Gürcan, 2013).

Sustainable Development Goal (SDG) 2 bridges disciplinary realms with its call to: "End hunger, achieve food security and improve nutrition and promote sustainable agriculture." The framing of the Zero Hunger SDG thus implies that addressing global environmental sustainability and food security challenges simultaneously will require transformative political and economic change. The specific targets of SDG 2 span environmental concerns (biodiversity, agricultural productivity, sustainable and resilient production systems, climate change adaptation), the domain of public health (ending hunger and malnutrition, targets on stunting and wasting, nutritional needs of women and girls) and socioeconomic factors (farmer incomes, markets and opportunities for value addition, agricultural research and extension, trade distortions). By tackling the global food system, SDG 2 stands out as an inherently interdisciplinary goal. Indeed, a recent article used the Zero Hunger goal to exemplify that individual SDGs are components of a larger whole, and must be considered as an integrated unit (Nilsson, Griggs, & Visbeck, 2016).

In this review, we ask whether and to what extent the scholarship on SDG 2 aligns with broader conceptualizations of sustainable food systems, organized around three central disciplinary perspectives: ecology and agricultural sciences, nutrition and public health, and political economy and policy science. Within each component discipline we first summarize the state of knowledge on the most effective pathways to achieve "zero hunger" while ensuring the sustainability of food systems, drawing on a wide range of literature. Specifically, following the lead of a recent report by the International Panel of Experts on Sustainable Food Systems (IPES, 2016), our summary of the literature takes a systems perspective on transition processes to consider opportunities and lock-ins across scales. The IPES report sought to identify all possible solutions – including transformative ones – that are necessary to sustain food systems, rather than limiting the scope to solutions considered pragmatic within current power relations (Friedmann, 2017).

Within each disciplinary area, we then conduct a comprehensive review of articles that discuss SDG 2 using the pathways we outline initially to frame our analysis. As the SDGs were adopted in 2015, unsurprisingly, we primarily identified papers published between 2016 and 2017 that engaged with the Zero Hunger SDG. We also include a subset of papers published in 2014 and 2015, particularly written by social scientists, which discussed the negotiations that led to the formulation of SDG 2. A growing number of reports in the non-peer reviewed literature also build directly on the second SDG, often using transdisciplinary approaches that bring together the perspectives and expertise of multiple scholars. Our focus is on the peer-reviewed literature, but we briefly touch on the other publications to address whether current framings align with evidence on effective pathways for transitions toward sustainable food systems.

2. Methods

Between November 2017 and January 2018, we searched Web of Science and Google Scholar databases for articles in the fields of ecology, agronomy, and related natural sciences, nutrition and public health, and political economy and policy science referencing SDG 2. Table 1 shows the specific search terms we used to identify papers. Our searches returned 239 hits, which we screened for relevance. We also checked the literature cited sections of papers for any additional references. In total, our review identified 47 papers from the three disciplinary areas. We reviewed three papers twice because they equally covered two of the three disciplinary categories (Battersby, 2017; Gao & Bryan, 2017; Kharas, McArthur, & von Braun, 2017), for a total of 19 papers in the ecology and environment category, 8 on nutrition and public health, and 23 on political economy and policy science. Although we interpreted these papers using the wider literature on transdisciplinary approaches to food systems change, a comprehensive review of the food systems literature was outside of the scope of our review focused on SDG 2.

Table 1
Search terms used to identify papers referencing SDG 2.

Search terms
"Sustainable Development Goal 2"
"Zero Hunger Challenge"
"United Nations Sustainable Development Goal*"
"Sustainable Development Goal*" AND "hunger"
"SDG" AND "food" AND "agr*"
"Sustainable Development Goal*" AND "ecology" OR "agroecology" OR "nutrition" OR "policy"
"2030 Agenda for Sustainable Development" AND "food" AND "agr*" OR "hunger" OR "nutrition"

3. The state of the science in agriculture, ecology and environment

The second SDG has targets for developing sustainable agricultural systems. These targets – adaptive capacity, ecosystem quality, and genetic diversity – are rooted in a growing consensus on scientific principles that govern agroecosystems, and their impacts on natural ecosystems (Gliessman, 2007; Kremen & Miles, 2012; Matson, 1997; Robertson et al., 2014; Shennan, 2008). All farms are agroecosystems, which follow general principles of ecology, even those that are highly industrialized. Industrial agriculture is therefore limited by a continued lack of engagement with concepts from ecological science. For example, the success or performance of agroecosystems is typically evaluated according to exceptionally narrow efficiency criteria, particularly yield per unit area (Foley et al., 2011; Matson et al., 1997). As a result, gains in yield are realized without accounting for ecosystem degradation or the long-term capacity to sustain food production (Holling & Meffe, 1996; Liu et al., 2007), and the focus on single crops (monocultures) ignores loss of crop diversity and thus quality of human diets. Yet industrial agriculture practices continue to be promoted as long as a productionist perspective on achieving food security (i.e., a focus on increasing production as the primary solution) dominates current debates (Fraser et al., 2016).

These debates hinge on the perceived causes of food insecurity. For scholars who argue that increasing production of major field crops will increase food security, proposed solutions center on technological innovations within industrial agriculture, such as precision agriculture, genetic modification, and other practices frequently lumped under the umbrella of *sustainable intensification*, although their actual impacts are highly variable and context dependent. Fundamental questions remain regarding the extent to which production itself must increase. Scholars point to the current surplus of available calories per capita globally (Fraser et al., 2016; Hunter, Smith, Schipanski, Atwood, & Mortensen, 2017), food waste, and the primary destinations of commodity production, which together indicate that poverty and inequitable access to food are the root causes of food insecurity (Chappell et al., 2013; Schipanski et al., 2016). For example, 36% of the calories produced globally are used as animal feed (and animal products that tend to be consumed by higher income populations) and 4% for biofuels, both of which not only divert food away from direct human consumption but also contribute to larger ecological and water footprints (Mason & Lang, 2017). Assessing yields without also assessing whether the food that is produced ultimately increases food security is therefore problematic.

In spite of these limitations, many studies continue to compare agroecosystems in terms of yield. For instance, global comparisons of "organic" and "conventional" crop yields ask a question that is too simplistic for the reasons described above – often because these are the only data available to researchers. Furthermore, each of these broad management categories encompasses a wide variety of practices and associated agroecosystem attributes and outcomes. For example, a range of different management practices exist within certified organic agriculture, including ones with extensive greenhouse gas emissions (Clark & Tilman, 2017). By focusing on yield, and coarse production categories, then, researchers miss identifying the ecological mechanisms that drive outcomes of different production systems, which would be more useful for informing policies for sustainable development. In order to link practices to outcomes, researchers need to ask more nuanced research questions and collect new primary data. We particularly lack data about agroecosystems in which ecological processes are intentionally managed for particular goals.

In response to these challenges, and central to this aspect of SDG2, ecological principles are increasingly applied to assess the sustainability and resilience of agroecosystems (Folke et al., 2004; Kremen & Miles, 2012; Schipanski et al., 2016). Although agroecology is a broad field covering all aspects of agroecosystem management (e.g., weed, insect, pest, and disease management, and livestock and pasture management; Altieri, 1995; Gliessman, 2007), soil fertility is a foundational component. Because agroecosystems are managed to produce food for human consumption, soil nutrients are regularly exported from fields in harvested crops, which must be replenished to sustain production over time. Given that soil fertility is a dominant constraint on the productivity and resilience of agroecosystems, it is the primary focus of our review of the science connecting agriculture and environment.

Soil fertility, and overall agroecosystem resilience, can be bolstered by increasing plant diversity at farm and landscape scales (Isbell et al., 2017; Jackson, Pascual, & Hodgkin, 2007). Farmers can manipulate plant diversity through crop rotation, cover cropping, intercropping, agroforestry, rotational grazing, or other practices to provide ecosystem functions such as weed and pest suppression, enhanced pollination, soil organic matter accumulation, or nitrogen supply through legume nitrogen fixation (Blesh, 2018; Garibaldi et al., 2013; Lundgren & Fausti, 2015). These practices allow farmers to manage ecological processes, such as nutrient cycling, for functions such as productivity, while reducing non-renewable inputs (Shennan, 2008). In agroecosystems, much of the plant diversity is selected by farmers. The composition of the planned aspect of biodiversity may be more important to overall ecosystem functioning than total species richness (Fornara & Tilman, 2008; Shennan, 2008) because certain groups of plants (e.g., legumes, perennials, cover crops) can greatly enhance ecosystem functions (Brooker et al., 2015; King & Blesh, 2018). Metrics of functional diversity – based on plant traits that determine their responses to, or effects on, the environment – are increasingly recognized as stronger predictors of ecosystem function than species richness or other taxonomic diversity metrics (Martin & Isaac, 2015; Wood et al., 2015).

Biological nitrogen fixation by legume species is a key component of functional diversity supporting agroecosystem sustainability. Compared with use of inorganic nitrogen fertilizers in industrial agriculture, crop rotations with legumes as the primary nitrogen source are better for balancing nitrogen inputs to soil with nitrogen exports in harvested crops (Blesh & Drinkwater, 2013; Zhang et al., 2015), reducing nitrogen losses that pollute waterways and the atmosphere (David, Drinkwater, & McIsaac, 2010; Robertson et al., 2014). When harvested for human consumption, high protein grain legumes can increase dietary diversity and quality (Snapp, Blackie, Gilbert, Bezner-Kerr, & Kanyama-Phiri, 2010). However, from an ecological perspective, legume *cover crops*, which are non-harvested and thus decompose in the field, are essential for supplying net carbon and nitrogen inputs that boost soil fertility in agroecosystems (King & Blesh, 2018).

Soil organic matter (comprised primarily of soil organic carbon) is a critical determinant of soil fertility and productivity in terrestrial ecosystems. Increasing plant functional trait diversity in agroecosystems with particular functional groups of crops, such as perennials or legume cover crops, builds soil organic matter (King & Blesh, 2018) and increases nutrient cycling capacity, by increasing the proportion of the year with living plant roots and interactions between plants and microorganisms in the root zone (Cotrufo, Wallenstein, Boot, Denef, & Paul, 2013; Liang & Balser, 2010). These interactions allow for reductions in external nutrient inputs (Drinkwater & Snapp, 2007). Increasing agroecosystem diversity by re-integrating crops and livestock could also improve nutrient recycling and soil fertility on farms (Russelle, Entz, & Franzluebbers, 2007). Unlike annual species, perennial species, such as those in livestock pastures or hay fields, do not need to be replanted each year and result in reduced soil disturbance. Similar dynamics also occur in agroforestry systems (Munroe & Isaac, 2014), which combine crops and trees, and have large potential for soil carbon sequestration and carbon storage, especially in the humid tropics (Montagnini & Nair, 2004). Also very promising are breeding programs developing perennial grain crops, with early success for perennial wheat, rice, pigeon pea, sorghum, and oilseeds (Kantar et al., 2016). Perennial grain agriculture has the potential to manage trade-offs by producing food while maintaining or building soil organic matter and retaining nutrients (Crews et al., 2016), better mimicking the functioning of natural ecosystems.

Agroecosystem diversification also contributes to conservation of wild biodiversity which, in turn, can improve pest control and pollination. For example, practices such as intercropping, polycultures, hedgerows and addition of flowers, have been shown to increase natural enemies, contribute to herbivore suppression, and reduce crop damage (Iverson et al., 2014; Letourneau et al., 2011). Agroecosystems with high levels of biodiversity can maintain complex networks of interacting species. Such networks provide autonomous pest control that is resilient and can reduce the need to apply costly pesticides, which can affect the health of farmers, farmworkers, and the environment (Perfecto, Vandermeer, & Philpott, 2014; Vandermeer, Perfecto, & Philpott, 2010). Diversified systems can also contribute to biodiversity conservation at the landscape level by forming a high-quality agroecological matrix that permits forest species to move from forest fragment to forest fragment therefore maintaining species – in the long run – in a metapopulation structure (Perfecto, Vandermeer, & Wright, 2009). Finally, ecologists have also long recognized the phenomenon of "overyielding" for diversified agroecosystems (e.g., agroforestry, intercropping, Brooker et al., 2015), which more fully exploit resources above- and below-ground in time and space. Such multifunctional systems can increase food production alongside other social and ecological benefits, for instance, rehabilitating degraded lands and contributing to income diversification in rural areas (Leakey, 2012), thereby supporting multiple SDGs (Waldron et al., 2017).