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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).

Taken together, this body of research highlights enormous opportunities for ecological principles to inform the design and management of more sustainable agroecosystems that build soil organic matter, balance nutrient budgets, control pests and diseases, and conserve wild biodiversity. In particular, managing crop and livestock diversity – especially plant functional diversity – at field- and farm-scales is critical for realizing multiple goals at once, a key aspect of sustainability. When agroecological farms are clustered together they generate diversified agricultural landscapes that can conserve terrestrial ecosystems at larger spatial scales.

4. The treatment of SDG 2 in the fields of agriculture, ecology and environment

Considering that the Zero Hunger goal and current scientific understanding of agroecosystems point to the need for a fundamental transition of agriculture toward management based on ecological principles, in this portion of our review we asked how SDG 2 is influencing research on pathways to agricultural sustainability. Our review identified that ecologists and scholars in related fields such as soil science have engaged with the second SDG to a limited extent to date, which we expected given how recent the SDGs are. Our search identified 19 publications that met our search criteria, and four of these cited SDG 2 as justification for their study (Goicoechea & Antolín, 2017; Pandey, 2017; Winkler, Viers, & Nicholas, 2017; Wright et al., 2016). We found wide variation in how scholars apply and frame the goal, particularly in terms of the degree to which they draw upon the ecological science reviewed above. The majority of these papers limited their ecological science to discussion of global environmental crises, and neglected relevant ecological principles when discussing crop production on farms. A common thread among papers, however, was recognition that interdisciplinary approaches are essential for achieving sustainable and resilient agricultural systems specified in SDG 2, particularly noting the challenge of understanding interactions among goals.

The degree to which natural science scholars engaged with ecological literature varied across papers, even though the language of SDG 2 specifically includes these concepts. For example, despite growing recognition that productionist perspectives based on industrial monocultures are too narrow, productionism was a common theme in the papers reviewed here (Bouma, 2014, 2015; Gao & Bryan, 2017; Sims & Kienzle, 2016; Trimmer, Cusick, & Guest, 2017; Tsiafouli, Drakou, Orgiazzi, Hedlund, & Ritz, 2017; Wright et al., 2016). In particular, these papers made general statements about needing to increase agricultural productivity without a more nuanced discussion about what is produced, how it is produced, and to what effect. For instance, these articles did not engage with more holistic framings of productivity such as nutritional yield per area (Cassidy, West, Gerber, & Foley, 2013), nor did they reference the full suite of management options available for increasing agroecosystem productivity including diversification and ecological approaches. The predominance of productionist and technocratic perspectives in these papers was, however, unsurprising given the insights from critical social sciences that we discuss in the political economy and policy science section of this review.

Other papers were firmly grounded in ecological science, but rarely considered agricultural management practices based on ecological principles. Griggs et al. (2014) framed the SDGs in terms of planetary boundaries and resilience, arguing that development must be sustained without crossing critical thresholds for biodiversity loss, nitrogen and phosphorus cycles, climate change, and land and water use. Several other papers used a resilience framework to identify potential trade-offs between production and climate change mitigation, or between food security and climate change (Gao & Bryan, 2017; Mugambiwa & Tirivangasi, 2017; Nilsson et al., 2016). However, none of these papers mentioned ecological management of agriculture as an option for realizing these goals. A couple of papers went further to identify specific production systems – such as second-generation biofuel production on marginalized lands, agroforestry, or sustainable forest management – that may enhance agroecosystem resilience via distinct mechanisms (Bonfante et al., 2017; Gratzer & Keeton, 2017; Waldron et al., 2017), but did so without specifying how ecological management is predicted to enhance resilience (e.g., by reducing input intensity and associated emissions, fostering complementary species interactions by increasing functional diversity, or building soil organic matter). One paper, which discussed ecological management approaches directly (Garibaldi et al., 2017), including diversified, agroecological, and organic systems, also did not describe the ecological principles that underpin their potential to help achieve SDG 2.

Three additional papers made important arguments relevant to ecology without fully situating them in a broader ecological context. For example, one author pointed out that soil conservation was neglected in the initial framing of the SDGs, and also noted the need for soil scientists to take "ecosystem approaches" (Bouma, 2014, 2015). He then linked precision agriculture to an ecosystem approach even though it usually falls within an industrial rather than ecological management framework, because the aim is improved efficiency of agrichemical input use (i.e., a paradigm focused on suppressing rather than harnessing ecological processes within fields). Goicoechea and Antolín (2017) addressed plant-microbe interactions in the root zone, which is a critical research frontier relevant to agroecosystem sustainability and nutritional quality of crops. Yet the authors did not specify how ecological practices could shape these interactions despite growing recognition of the need to understand how agroecosystem diversity and management practices impact the soil microbiome and associated ecosystem processes and functions (Vries & Wallenstein, 2017).

Two recent special issues in ecological journals linked their work to SDG 2 in contrasting ways. The first, in *Frontiers in Ecology and Evolution*, focused on optimizing multiple ecosystem services from agricultural systems, and cited SDG 2 through a predominately productionist lens, stating the "need for management regimes that enhance both agricultural production and the provision of multiple ecosystem services" (Tsiafouli et al., 2017, p. 1). In contrast, the introductory article to a special feature in the *Journal of Applied Ecology* also referenced SDG 2 to justify the need for empirical and theoretical research in agroecology, but, rather than emphasizing production or intensification, the piece directly explored how ecological science could inform the design of more sustainable agroecosystems (Martin & Isaac, 2018). For example, component papers applied concepts from functional ecology to analysis of agroecosystems (e.g., identifying plant traits that directly or indirectly influence ecosystem functions). One author went further to extend these ecological concepts to the assessment of nutritional diversity in agroecosystems (Wood, 2018).

A final theme was the need for interdisciplinary research, and to identify interactions between SDG 2 and other SDGs. For instance, several papers addressed the multiple functions of agroecosystems through empirical studies on biofuel production (Bonfante et al., 2017) and forest coffee systems (Nischalke, Abebe, Wondimagegnhu, Kriesemer, & Beuchelt, 2017), conceptual frameworks based on agroforestry (Waldron et al., 2017), and modeling approaches in the context of Australian land use (Gao & Bryan, 2017). Gao and Bryan (2017) identified potential synergies between second-generation biofuels using crop residues and SDG 2, although the ecological literature indicates the importance of also considering potential trade-offs for soil organic matter storage if more crop residues are removed. Nilsson et al. (2016) identified competition for land and water as the primary threat food production poses to terrestrial ecosystems. This framing assumes that agriculture is polluting, without recognizing the literature on diversified, low-input agroecosystems that are more sustainable. Finally, these papers, and others focused on interactions (Gratzer & Keeton, 2017; Griggs et al., 2014; Trimmer et al., 2017), argued for addressing the SDGs, or subsets of them, collectively, noting the important challenge of taking an integrated approach to the goals and their component targets to maximize synergies and reduce trade-offs. However, for the most part, in these papers there was a notable lack of a systems approach.

5. The state of science linking nutrition and food systems

The most conspicuous output of food systems is the production of food for direct or indirect human consumption. The extent to which the food produced by food systems contributes to human health and well-being through healthy diets is thus an important indicator of the health of the food system itself (Barilla, 2017). It is also foundational to the study of pathways that could achieve Zero Hunger. Much like the divergent solutions that agricultural scientists propose based on incomplete definitions of sustainability and productivity, there is also no single definition of a "healthy diet." A broad assessment of dietary patterns worldwide suggests that "a diet of minimally processed foods close to nature, predominantly plants, is decisively associated with health promotion and disease prevention" (Katz & Meller, 2014, p. 83). Other definitions of healthy diets focus on adequacy of macro- and micronutrients, limits on additives, trans fats, added sugars and salt, as well as overall diversity (HLPE, 2017).

The lack of consensus on a definition of a healthy diet stems in part from the unique combination of diet-related health concerns faced across different global regions. In many countries of Sub-Saharan Africa and South Asia, for example, child growth stunting remains a primary concern (Onis & Branca, 2016). The etiology of stunting is complex and not thoroughly understood; however, low-quality diets associated with poor complementary feeding practices are one important determinant of the syndrome (Prendergast & Humphrey, 2014). It is clear that more diverse diets are associated with a lower risk of stunting (Arimond & Ruel, 2004), and there is mixed evidence in particular that animal-source foods (ASFs) rich in bioavailable micronutrients (e.g., iron, zinc, vitamin A) may be protective against stunting (Dror & Allen, 2011). Yet, in contexts where nutrient deficiencies are not a predominant concern, overconsumption of ASFs, especially meat, is common and may have deleterious health impacts. Consumption of unprocessed and processed red meat, for example, is associated with an increased risk of cardiovascular disease and colorectal cancer (Bouvard et al., 2015; Chan et al., 2011). This example highlights the need to assess the nature and extent of the disease burden in a given context when considering the desired dietary outputs of a food system.

Diet diversity offers another example of the challenge of a "one-size-fits-all" approach to cultivating healthy food systems. Consumption of a diverse diet, primarily fruits and vegetables, aligns with international guidance for disease prevention and is a consistent focus of national dietary recommendations (FAO & WHO, 2004; Fischer & Garnett, 2016). However, diversity within food systems varies widely, and the contribution of specific foods to meeting nutrient requirements also differs with varietal differences, soil conditions, and local consumption patterns (Ruel, 2003). Therefore, the desired extent and nature of crop diversity within a food system must also be assessed in light of local conditions and norms.

Despite the lack of a universal definition of a healthy diet, the evidence is clear that poor-quality diets underlie the largest burden of ill health globally (Global Panel, 2016). In fact, 6 of the top 11 risk factors for the global burden of disease are related to diets (Forouzanfar et al., 2015). These risks reflect not only deficiencies of macro- and micronutrients, but also the health costs of obesity and associated diet-related chronic disease. Nearly 30% of the world's population is overweight or obese, and two-thirds of these individuals reside in low- and middle-income countries (LMICs) (Ng et al., 2014). Obesity is associated with a wide range of chronic health conditions (Kopelman, 2007), and is responsible for an increasingly large burden of morbidity, mortality, and associated health care costs worldwide (Council, 2014). Few countries have been able to halt the rise of adult obesity (IFPRI, 2015).

The need is great for widespread adoption of diets that prevent the multiple burdens of malnutrition. Yet, the most common approaches to addressing undernutrition have not primarily focused on changing dietary patterns, but have instead emphasized providing supplements and pharmaceutical treatments to vulnerable populations (e.g., supplementation of women of reproductive age and preschool-aged children with micronutrients; deworming medication; and malaria prophylaxis) (Bhutta et al., 2013). In turn, medications and bariatric surgery are among the most common approaches to addressing obesity (Cawley & Meyerhoefer, 2012). While these solutions are important components of an overall strategy to reduce malnutrition, they do not often address the underlying causes of the problems. Unhealthy diets are one such cause, and to transform diets, the food systems that enable such unhealthy diets must also be transformed.

Efforts to transform food systems to improve diets have not historically emphasized improving dietary quality so much as producing more food—an approach putatively linked to the goal of reducing food insecurity. Public health scholars, then, often echo the productionist view of many natural scientists, conceptualizing food insecurity as a problem of food availability (Simmons & Saundry, 2012). Yet, understanding of food insecurity has evolved considerably with evidence that physical and economic access to high-quality food, as well as proper utilization of that food, are central to ensuring food security (Jones, Ngure, Pelto, & Young, 2013). The promotion of sustainable agriculture alongside ensuring food security in SDG 2 is a further sign of the evolution of our understanding of food security. Several UN reports, notably the IAASTD (2008) and those of the UN Special Rapporteur on the Right to Food, have linked the "right to food" to both "sustainable rural livelihoods" and the "right to a sustainable agroecosystem". The academic and policy literature has recently begun to interpret these issues within the broader framework of "sustainable diets" (Jones et al., 2015; Mason & Lang, 2017), a topic addressed further in our discussion and conclusions. Reflecting these more holistic understandings of food security, a report published in 2016 by the Global Panel on Agriculture and Food Systems for Nutrition offers a comprehensive outline of four broad pathways through which food systems might influence diet quality: 1) agricultural production systems; 2) food storage, transport, and trade; 3) food transformation; and 4) food retail and provisioning (Global Panel, 2016).

Briefly, within the first pathway, agroecosystem diversity can influence diet quality. Crop species richness on farms is consistently associated with more diverse diets among farming households in LMICs (Jones, 2017a). If consumed, this agricultural diversity can directly influence the diets of subsistence farmers, and if sold, can indirectly contribute to healthy diets if appropriate foods are purchased that promote health and/or prevent disease (Jones, 2017b). The production of diverse food crops at regional scales can also contribute to local consumption diversity because most production in LMICs is sold to local markets and purchased and consumed locally (Herrero et al., 2017).

The second pathway outlined in the Global Panel report – food storage, transport and trade – is primarily concerned with supporting improved consumer access to healthy foods. Approximately one-third or more of global food production is lost or wasted through the supply chain (Gustavsson, Cederberg, Sonesson, van Otterdijk, & Meybeck, 2011). Reducing such losses is important for ensuring consumers have timely access to healthy, diverse foods. Reducing food safety risks (both chemical and microbial) is also a priority and requires improved post-harvest processing and storage, improved screening technology, monitoring systems, and regulation throughout the supply chain.

The third pathway linking food systems and diet quality highlights the importance of food processing and transformation. The relative abundance of specific food and agricultural commodities has important influences on diets; yet, how foods are processed, substituted, and marketed relative to one another is likely to have an even stronger influence on consumer diets (Hawkes, Friel, Lobstein, & Lang, 2012). Though consumption of processed foods may contribute to risk of some chronic diseases (Martínez Steele et al. 2016; Yang et al., 2014), "food processing" encompasses an enormous diversity of processes aimed at altering the properties of fresh foods, many of which have positive effects on the healthfulness of diets. Extending the seasonality of fruits and vegetables, for example, through freezing, drying, fermenting, and other techniques to reduce perishability, is critically important for increasing access to such foods among low-income, rural residents in many world regions (Gómez & Ricketts, 2013).

The final pathway linking food systems and diet quality emphasizes the importance of food outlets in informing food availability, prices, and preferences. Supermarkets may have contrasting influences on diets. While food safety standards in supermarkets are often dramatically higher relative to traditional retail outlets, thus potentially conveying health benefits to consumers, supermarkets have also become the dominant distributors of processed foods globally (Global Panel, 2016). Therefore, the precise impacts of supermarkets on the health of diets is not clear. Supermarkets also favor the expansion of low diversity agricultural systems that rely on large external inputs of non-renewable resources (Reardon, Barrett, Berdegué, & Swinnen, 2009).

6. The treatment of SDG 2 in the fields of nutrition and public health

Given the impacts that agroecosystem diversity and post-harvest activities have on the health of diets, we asked in this portion of our literature review whether SDG 2 is motivating more systemic research within health and nutrition fields. We identified only eight studies focused on nutrition and public health that mentioned SDG 2. In total, SDG 2 does not appear to be strongly informing discussions of food insecurity in this field to date. Where it was mentioned, it was used to justify, in broad terms, a diversity of research questions that centered largely on increasing agricultural food production to increase food availability, based on the productionist paradigm. Second, recognition of the role of food access and diet quality as core components of food security was not prominent in these articles. Finally, with few exceptions, the studies did not comprehensively address the multiple components of food systems beyond agricultural production (i.e., food storage, transport, and trade; food transformation; food waste; food retail and provisioning). These aspects are increasingly influential in informing consumer behavior, access to food, and the quality of diets, as highlighted by the Global Panel on Agriculture and Food Systems for Nutrition.

Three studies that reported on how specific crops or food assistance programs in specific countries influenced food security and diet quality used SDG 2 to broadly motivate the need for their research. Amalu and Agbachom (2016) assessed determinants of food insecurity among cassava farmers in Nigeria. They recommended increased land planted to cassava, diversified incomes among farming households, greater participation in cooperative groups, greater involvement of youth in agriculture, efforts to empower women, and strengthened family planning efforts, as important approaches to reducing food insecurity in the country. Zhou and Hendriks (2017) evaluated the impact of cash and food transfers by the World Food Programme on the diversity and quality of diets among households in Mozambique. They observed that both cash and food transfers can improve diets, albeit through distinct mechanisms, and that a combination of both approaches would likely increase demand for nutritious foods with multiplier effects for local food systems. Finally, Naughton, Deubel, and Mihelcic (2017) proposed that the increased use of shea butter, an edible oil commonly used throughout Sub-Saharan Africa, could contribute to achieving SDG 2 (among other SDGs). Using data collected in Mali from 2009 to 2014, the authors reported on the cultural and social importance of shea butter for gifting customs, cooperative labor, and religious ceremonies, as well as its role as a gap food during the hungry season, and as an exchange commodity to buy seeds and staple foods when these essentials run out during the lean season. Overall, the conceptual underpinnings of the SDG 2 were not clearly articulated in these studies. Rather, the goal simply provided a backdrop for discussing determinants of, and potential solutions to, food insecurity and poor quality diets in these three settings.

Reddy (2016) assessed India's progress in advancing food security goals from 1990 to 2016. Although this study examined food security in a specific country, its focus was broader than a single commodity or program, examining trends in the country's changing food security. The authors observed that food calories were sufficient to meet population demand in India, and furthermore that domestic food price stability was comparatively high in India. However, in assessing other components of food security, he found that India's performance was less than adequate. Specifically, protein availability, and the production of legumes in particular were below needed levels, while the prevalence of undernourishment among women and children was among the highest in the world, suggesting that food access and utilization are still prominent concerns despite adequate calorie availability. As with the previous studies, SDG 2 was not explicitly critiqued or comprehensively assessed, but was rather used to motivate an examination of food security trends in India.

SDG 2 was more prominently discussed in two additional studies. Conceição, Levine, Lipton, and Warren-Rodríguez (2016) argued that agricultural production is key to reducing food insecurity and poverty in Sub-Saharan Africa. The aims of SDG 2 were clearly articulated in the justification for discussing agriculture as a solution to food insecurity. However, rather than focusing on sustainable agriculture, authors emphasized increasing agricultural yields through more intensive use of synthetic inputs such as fertilizers, and improved farm technology, as well as strengthened trade at local, national, regional and global scales. They further cited the importance of reducing gender inequalities in rural economies, and in particular noted the lack of robust and equitable legal frameworks for ownership and inheritance of land between men and women as an important contributor to gender inequalities. Though not limited to Sub-Saharan Africa, Kharas et al. (2017) developed a similar set of arguments for achieving the aims of SDG 2 globally, but gave recommendations for strategies the G20, in particular, could prioritize for ending rural hunger. These strategies included: 1) integrating global food markets, 2) increasing access to input markets for improved seeds, fertilizer, machinery and finance, 3) investing in agricultural research and extension, and 4) coordinating the targeting of country-level investments in agriculture at the global level. In both articles, the authors adopted a narrow interpretation of food insecurity, positioning it largely in terms of insufficient caloric availability that gains in food production efficiency and improvements in trade will largely alleviate.

Stephens, Jones, and Parsons (2017) provided a historical perspective on the intersections between agricultural systems research and global food security research—two fields explicitly linked in the language of SDG 2. As with the first articles mentioned above, SDG 2 was used to motivate the discussion related to the role of agricultural systems in addressing food insecurity. The authors noted that agricultural systems are embedded within food systems, and shape and are shaped by the larger food systems via market interactions, trade, agroecological management practices, institutions, and cultural influences. They noted that agricultural systems may not always be closely tied to improving food security, especially in contexts with long supply chains where non-agricultural components of the food system most strongly shape food access and dietary patterns. They further cited the need for more interdisciplinary collaboration to capture the complexity of these interacting systems.

Only one identified article explicitly critiqued the framing of SDG 2 or analyzed it on its own merit, rather than employing it as a leverage point for a more indirect discussion of food and nutrition security issues. Battersby (2017) argued that SDG 2 does not adequately reflect the reality of food and nutrition insecurity in Sub-Saharan Africa, namely, the vulnerabilities of urban residents and the dual nature of the malnutrition problem that encompasses not just undernutrition, but also obesity and diet-related chronic illness (Battersby, 2017). The author critiqued the so-called "twin-track" approach to addressing food insecurity (i.e., social welfare investments coupled with programs to enhance agricultural development) as narrow, not equipped to address the underlying causes of the problem, and as overlooking the need to simultaneously confront obesity alongside undernutrition in both rural and urban settings. This broader food systems perspective, acknowledging the complexity of food security and the food environments within which it occurs, is needed to advance the goals of SDG 2.

7. The state of the science in political economy and policy science

A final area of scholarship reiterates the importance of ensuring stakeholder agreement about the underlying source of problems implied by SDG 2 and the institutional mechanisms for accomplishing "zero hunger." First, food regime theory offers one of the most widely used political economy frameworks for explaining how today's industrialized food system emerged and what might lead to its transformation (McMichael, 2009). Food regimes are characterized by relatively stable periods in history when norms, institutional structures, and the interactions between governments, publics, and market actors shape food and agriculture practices that become hegemonic, with transition periods when pressure begins to mount to reshape food systems (Friedmann, 2005). After WWII and the 1940s, Otero et al. (2013) argue that national food security was largely managed through state protection of domestic markets, with only surpluses traded. The current, corporate food regime, however, began to form during the 1980s when agricultural trade liberalization was framed as a more cost-effective and efficient way to ensure local food security (Otero et al., 2013). As agri-food corporations have consolidated power over food systems, the growing number of alternative food movements signal that efforts are gaining strength to disrupt the current food regime. These movements ultimately aim to build a new regime, based on equity, health-promotion and sustainable food production (Friedmann, 2005; Galt, 2017; McMichael, 2009). The food sovereignty movement, spearheaded by La Via Campesina, is among the most visible social movements that has mobilized hundreds of thousands of farmers globally and influenced UN discussions as early as the mid-1990s, including SDG 2 negotiations (Fontoura, Bharucha, & Böhm, 2016). A transformative concept, food sovereignty scholarship highlights the need to preserve the natural resource base for future food production and to democratize food system governance, citing the role of corporate power and capitalism in locking in unsustainable practices (Sexsmith & McMichael, 2015; Wittman, Desmarais, & Wiebe, 2010).

Second, policy science (Clark, 2002) – the combined study of policy analysis (what to do) and the policy process (how to do it) – offers important lessons for realizing SDG 2. While multiple stakeholders are expected to collaborate on the SDGs, the 2030 Agenda for Sustainable Development assumes that country governments bear the ultimate responsibility. As the Agenda states, "national ownership is key to achieving sustainable development" (UN, 2015) albeit regular progress reviews are intended to "support countries in making informed policy choices" (p. 32). Many policy analysts assume that ensuring "informed policy choices" simply requires rational decision-making, a process that involves establishing a goal (like SDG 2), weighing all the data, and comparing strategies systematically (Heracleous, 1994). As the discussion of agriculture and health has shown, there is little agreement about basic definitions of the problem, so there is little basis for this assumption.

Policy science instead shows that decision-makers have "bounded rationality" (Simon, 1957), requiring cognitive shortcuts to make decisions that draw on available information but also emotions, interests, values, habits, bureaucratic inertia, and long-held beliefs (Cairney & Weible, 2017). This research also shows that political pressure and bargaining – whether through coalitions or social movements (Andrews, 2001) or the more subtle, ongoing work of policy champions (Kingdon, 1984) – is also critical for raising awareness about public problems, promoting new solutions, holding governments accountable, and ultimately, shifting decisions (Jones & Baumgartner, 2012). Furthermore, research on "street-level bureaucrats" (Lipsky, 2010) also demonstrates how high-level adoption of a plan is necessary, but not sufficient, as front-line staff can either enhance or undermine a policy based on how equipped and motivated they are to carry out an intervention.

Additionally, policy science research highlights the challenges of collaborative efforts, which the SDGs conceivably encourage through goals that are considered "integrated and indivisible" (UN, 2015, p. 1). Contrasting mandates and professional norms, incongruent legal, regulatory and procedural structures, and clashing interest groups often get in the way of efforts to align the actions of multiple agencies (Agranoff, 2006). In the early stages of agenda setting, policy networks can break apart when they attempt to attribute blame for a problem, even if they agree that a problem exists (Benford & Snow, 2000). If policy communities can coalesce and remain united, however, they are often vital to sustaining attention on an issue even after a policy has begun to be implemented (Patashnik, 2008). Policy science concludes that any effort to shift policy requires sustained coalitions alongside a problem framing that speaks to the interests of decision-makers, solutions that outline adaptable implementation processes, and a keen awareness of opportune moments to act (Cairney & Weible, 2017).

Building on policy science research, another concept that offers lessons for accomplishing SDG 2 – strategic capacity – emerged from a concern that nutrition advocates in the Global South had accumulated tremendous technical knowledge through many examples of successful, efficacy-trialed interventions, and often unprecedented funding to implement policies, yet had largely failed to accomplish large-scale societal or institutional change (Bryce et al., 2008). This research also reflected decades of attempts to address food insecurity and malnutrition through top-down approaches. The largest of these efforts, implemented in dozens of countries by multiple universities and donors in the 1960s, failed categorically (Field, 1987). However, technocratic, expert-led efforts to design food and nutrition interventions have been repeated many times with similar outcomes (Pelletier et al., 2012). Policy science researchers argue that policy champions in each of these contexts lacked strategic capacity, defined as the capacity to negotiate opposing views, build trust and ownership, customize solutions, address logistical bottlenecks, and incorporate multiple types of knowledge – especially the views of marginalized actors with experiential knowledge. These and other socio-political skills are critical for guiding reforms through all stages of the policy process, from forming coalitions, to getting and keeping an issue on political agendas, to policy formulation and implementation (Agranoff, 2006; Pelletier et al., 2012).

Strategic capacity research has shown, for instance, that nutrition policy communities may agree on the broad goal, but often cannot move forward because they disagree about which evidence-based strategies to implement (Bryce et al., 2008; Gillespie, Menon, & Kennedy, 2015). Like broader findings on collaboration, this line of research has identified key challenges to cross-sector approaches to food systems reform, including competing priorities that can create governance gaps, leaving no one to focus on food security or malnutrition when neither agriculture nor health ministries assume it is their responsibility (Hoey & Pelletier, 2011). Even if national agendas are established, other research shows the importance of engaging in policy advocacy and capacity building at local levels to enable decentralized food and nutrition plans (Gillespie et al., 2015; Harris, Frongillo, Nguyen, Kim, & Menon, 2017). This research also identifies the importance of feedback mechanisms based on the practical knowledge of communities, front-line staff and mid-level managers, all of whom can either improve or halt implementation (Heidkamp et al., 2012; Hoey, 2015).

This latter conclusion is reinforced by Duncan (2016), who argues that opportunities are especially needed for grassroots groups and historically marginalized actors to meaningfully participate in food security governance. Two successful cases where this has occurred can be found in Brazil, where the Movement of Landless Rural Workers (MST) has cultivated skilled policy advocates from within who have been able to influence national policy (Tarlau, 2015), and conversely, a holistic food security program started by the Belo Horizonte government that linked the right to food with markets for family farmers and biodiversity conservation, and strengthened rural-urban linkages (Chappell, 2018; Rocha & Lessa, 2009). Policy champions were essential in both of these cases by playing a bridging role between government legislators and grassroots movements. Champions are also critical for moving food systems efforts beyond "superficial change" to structural change (Holt Giménez & Shattuck, 2011), and for preventing national governments from undermining and pacifying grassroots movements (Giraldo & Rosset, 2017).

8. The treatment of SDG 2 in the fields of political economy and policy science

Considering the importance of having a clear conception of the problem, and concrete skills and strategies for translating food and nutrition goals into action, we asked in this section whether the Zero Hunger SDG is sparking similar conversations, particularly in line with food regime theory and scholarship on strategic capacity. Our literature review identified 23 publications that met our search criteria by social scientists working in a variety of fields – especially in development sociology, but also public policy, technology studies, economics, ecology, and nutrition.

Similar to our review of ecology and nutrition literature, several social science articles we reviewed only mentioned SDG 2 to justify the significance of their research, including two on the food-biofuel tradeoff (Das, 2017; Renzaho, Kamara, & Toole, 2017) and one on seasonality in price gaps of certain crops in Africa (Gilbert, Christiaensen, & Kaminski, 2017). Most social scientists writing about SDG 2, however, wrote articles that directly engaged the way the goal was established and its potential implications. A number of these scholars discussed how efforts to be holistic and to incorporate so many voices in the development of SDG 2 did not allow for adequate debate about historical underpinnings and underlying causes of hunger and poverty (Weber, 2014), resulting in a goal and numerous targets that are too ambiguous to warrant a clear path forward (Griggs et al., 2014; Holden, Linnerud, & Banister, 2017; Hunter et al., 2016). This may explain why tensions exist among the various writings about SDG 2, notably whether to support a food sovereignty or a productionist and market-oriented approach to food security. Other tensions concerned how to conceive of solutions in urban or rural areas, and how to agree on a more explicit plan of action. We elaborate each of these below.

First, a major contradiction that emerged from the many unexamined ideas within SDG 2 is that a food sovereignty framing exists alongside strong support for corporate interests. As some scholars described, private sector actors that were part of SDG 2 negotiations, including some researchers, unquestioningly see corporations, the technologies they are developing to increase production, and market-based solutions as critical solutions to hunger; these actors support increasing public-private partnerships and launching a second Green Revolution with strategies like climate smart agriculture, agricultural trade, and efforts to incorporate smallholders into global markets (Eggersdorfer & Bird, 2016; Kharas et al., 2017; Swaminathan, 2014). While some civil society groups also encouraged public-private partnerships, scholars writing about SDG noted that most of the NGOs that participated in these early negotiations criticized the industrialization of agriculture and the commercialization of food policy (Battersby, 2017; Fontoura et al., 2016). Many social scientists were also concerned that because the causes of food insecurity were not adequately discussed during the formulation of SDG 2 – including free trade, capital flight, corporate-dominated markets, investment policies, and land dispossession – a productionist paradigm dominated. Similar to discussions in earlier sections, these scholars noted that the productionist paradigm allowed the incorporation of solutions that are likely to exacerbate rather than reduce hunger: short-term, technocratic solutions such as food aid, food supplements, fortification, and biofortification along with labor saving agricultural technologies despite high levels of rural unemployment and emigration (Battersby, 2017; Holden et al., 2017; Hunter et al., 2016; Sexsmith & McMichael, 2015; Weber, 2014).

As an extension of this debate, a number of scholars pointed out how many NGOs, social movement groups, and some researchers are advocating for food sovereignty to be the prime framework guiding SDG 2, such as supporting environmental sustainability and protecting peasant agriculture and local food economies from global markets (Battersby, 2017; Fontoura et al., 2016). Similarly, others wrote about the need to address the economic and political barriers that limit efforts to resolve food insecurity (Fukuda-Parr & Yamin, 2013; Weber, 2014), particularly discussions that emerged during the 1996 World Food Summit around land redistribution and gender equality (Fukuda-Parr & Yamin, 2013). Two development sociologists also pointed out how the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), a three-year, multi-stakeholder UN-led expert report, also recommended ending subsidies in the Global North, offering subsidies for small-scale sustainable farming, and supporting farmer knowledge and seed exchange as a way to revitalize rural communities – none of which is apparent in SDG 2 (Sexsmith & McMichael, 2015).

Second, another group of scholars pointed out potential tradeoffs – or unexplored opportunities – in dealing with SDG 2 alongside SDG 11, which is focused on sustainable cities (Battersby, 2017). A few scholars worried that the SDGs frame urbanization as natural and inevitable, as the primary place to increase jobs, implying that crops should be grown via labor-saving, commercial-based agriculture that will continue to push small-scale farmers off their land (Anderson, 2015; Sexsmith & McMichael, 2015). Others, however, pointed out how cities – and mayoral coalitions around the world – are becoming active agents in driving innovative food system transitions, but are not considered sufficiently in either SDG 2 or 11 for the potential synergies they could play in addressing hunger, nutrition, and production goals (Battersby, 2017; Ilieva, 2017). Battersby (2017) also suggested that urban food insecurity may be underestimated. She described how the continued growth of urban areas and the high cost of living, the dependency of urban residents on a cash economy, and the rapid pace of change in the urban food environment likely mean urban food insecurity requires different solutions not considered in SDG 2, related to post-harvest processors, market structures, food transportation, and food safety.

Finally, scholars also disagreed about the process for moving forward; in other words, how to translate SDG 2 ideas into action. Many social scientists writing about SDG 2 agreed that the SDGs generally, like the Millennium Development Goals, allow indicators to become both blinders and the focus, without adequately offering guidelines to actors on the ground about the decision-making and implementation processes needed to operationalize the goal (Battersby, 2017; Fukuda-Parr & Yamin, 2013; Gao & Bryan, 2017; Gore, 2015; Hunter et al., 2016; Koehler, 2015; van Vuuren et al., 2015). Especially because SDG 2 does not discuss who should be involved in implementation, Battersby (2017) noted that major donors and the private sector will likely take the lead – as evidenced by the significant role that initiatives like the Alliance for a Green Revolution in Africa and Scaling-Up Nutrition already play in addressing food insecurity – rather than governments or grassroots groups. Others worried that too little attention has been placed on the cross-cutting nature of SDG 2, which has clear interactions with other goals, particularly SDG 1 (poverty eradication), SDG 3 (health promotion), SDG 4 (high quality education for all), SDG 7 (clean energy), SDG 11 (sustainable cities), SDG 12 (sustainable consumption, including halving food waste), SDG 13 (climate action), and SDG 15 (sustainable forest management). Without guidance about how to coordinate actions across each of these goals, some scholars suggested the SDGs could perpetuate a siloed approach, while missing opportunities to create synergies to boost SDG 2 actions, or even undermining such efforts (Battersby, 2017; Koehler, 2015).

A few scholars promoted a comprehensive, rational decision-making approach that models and compares various options for accomplishing SDG 2 and other goals simultaneously (Gao & Bryan, 2017). Two teams of scholars, for instance, have conducted modeling exercises to consider how to achieve SDG 2 alongside other SDGs – including goals on emissions, energy, water use, biodiversity, climate change, air pollution and/or land use goals – yet they concluded that multiple goals can rarely be achieved together without having to make trade-offs (Gao & Bryan, 2017; van Vuuren et al., 2015). Kharas et al. (2017) also suggested that the G20 could speed the rate of progress on SDG 2 if it ranked countries on several criteria to determine where to direct private direct investment. However, none of these studies acknowledged the institutional politics involved in negotiating such tradeoffs, or the capacity needed to carry out the actions that are determined as optimal.

Alternatively, Hunter et al. (2016) discussed the importance of enabling cross-sector commitments to SDG 2, such as capacity building to improve vertical and horizontal coordination among government institutions, and financing for agricultural and nutrition sectors to better understand and incorporate mutually reinforcing strategies. Also moving beyond technocratic attempts to achieve certain benchmarks (Moore, 2015), a number of scholars who echo food sovereignty arguments instead suggested that SDG 2 should be seen as an opportunity to reconfigure governing institutions and decision-making processes (Fukuda-Parr & Yamin, 2013; Holden et al., 2017; Weber, 2014). Engaging marginalized groups, one group of scholars pointed out, would help address inequalities of underlying development paradigms that have led to present day problems with food security, creating opportunities to devise more innovative and customized theories of social change (Battersby, 2017; Fukuda-Parr & Yamin, 2013; Holden et al., 2017; Moore, 2015).

9. Discussion and conclusions

SDG 2 reflects an emerging public consensus that collective action is needed to address the global environmental, public health, and social equity crises confronting the current food system (Ericksen, 2008; Liu et al., 2007; Wittman et al., 2017). We argue in this paper that the pathway to achieving the Zero Hunger goal should center on place-based, adaptive, and participatory solutions that simultaneously attend to local institutional capacities, agroecosystem diversification and ecological management, and the quality of local diets. However, our review of the literature referencing SDG 2 from three disciplinary areas suggests that scholars are generally not linking these dimensions when they study food systems. Social scientists were more likely to discuss the issues of governance (i.e. how to prioritize among SDGs or SDG 2 targets, who should be part of decision-making, etc.), but this literature also reveals a number of tensions, with articles spanning opposing concepts such as food sovereignty and industrial agriculture, or concerns over farmer livelihoods versus a need to attend to urban food insecurity. Ecology and nutrition literature on SDG 2 tended to be limited in similar ways: scholars from both fields often proposed reductionist, treatment-focused approaches (e.g., sustainable intensification, micronutrient supplements, etc.) and applied an empirically outdated productionist framework, rooted in perceptions that ecological management reduces yields and that insufficient food availability is the primary cause of food insecurity.

These findings are not entirely surprising. The political economy and policy science literature we outlined explains why research outputs like the articles on SDG 2 we reviewed, along with global and local policies, allocation of research dollars, and institutional actions, tend to focus on reductionist approaches. As the history of science suggests, the process of shifting research paradigms is slow, given that epistemologies and methodologies become hegemonic (Devlin & Bokulich, 2015; Kuhn, 1996). Polarized arguments about the root causes of food security in academia, which were apparent in the nutrition and ecology literature, also stem in part from differences in power among the relevant disciplines addressing food system challenges (Vanloqueren & Baret, 2009). For example, researchers in natural science fields usually have a larger platform in social-ecological debates about food security. Yet these scientists often enter these debates with limited understanding of social theory and the historical and political processes that have produced today's industrial food system (Glamann, Hanspach, Abson, Collier, & Fischer, 2017; Lélé & Norgaard, 2005). Many natural scientists, then, assume the current social structures shaping the food system are inevitable and impractical to change, leading them to promote industrial management practices that extend and deepen a "command-and-control" management approach (Holling & Meffe, 1996; Taylor, 2014), which reduces agroecosystem resilience and human health. This perspective also reinforces the problematic lack of empirical data on diversified agroecosystems. Funding often perpetuates reductionist research approaches as well. For instance, globally, systemic imbalances in research investments have led to limited empirical data on the most diversified agroecosystems (DeLonge, Miles, & Carlisle, 2016). As a consequence, diversified, ecologically-based systems are either left out of large-scale modeling efforts or meta-analyses, or the models are not properly validated, meaning these approaches risk missing important potential solutions (Jones et al., 2016).

If much of the SDG 2 literature to date is still based on a productionist perspective, and if SDG 2 was established without adequate consideration of the root causes of food system crises, this raises the question of whether SDG 2 should be promoted as a guiding framework for global and local action. Certainly, many organizations within the UN system are part of the legacy of industrial agriculture, according to some scholars, having been key proponents of the Green Revolution and serving as major partners in the second wave of Green Revolution interventions (Zeigler & Mohanty, 2010). However, the UN is large and complex. Along with promoting the SDGs, it has also initiated or supported findings from IAASTD, the UN Special Rapporteur on the Right to Food, Food for Cities, the Committee on World Food Security, and the Global Panel on Agriculture and Food Systems for Nutrition, most of which are initiatives that include civil society perspectives as well as powerful private and state actors. In any case, similar to the MDGs, the SDGs will likely continue to influence international discourse and have a mobilizing effect – even if uneven – on national governments, donors, and researchers (Manning, 2010).

Ultimately, the broad, multi-pronged framing of SDG 2 is problematic in many ways, but it also opens the possibility of shifting the conversation in a more holistic direction, especially if the science informing SDG 2 becomes more robust. Our review shows that, to date, a significant number of articles reference SDG 2 mainly to legitimize the basis of their research, rather than as a point of departure. Research may also be slower to incorporate applied questions in some fields, such as public health, where we found the smallest number of articles mentioning SDG 2. Given that the SDGs are still relatively new, however, this opens possibilities for motivating future research on SDG 2 that reflects a more transformative, integrated, and structurally-grounded analysis (Vandermeer et al., 2018). Two conceptual frameworks, in particular, offer systems-based lenses for integrated analysis of agriculture and food security, which could also inform the development of effective policies: the *social-ecological systems approach* and the *sustainable diets* framework.

A growing body of scholarship builds on Ostrom's (2009) conceptual framework to consider agricultural landscapes as social-ecological systems, with interacting social and ecological properties nested across scales from farm to globe (Fischer et al., 2017; Wittman et al., 2017). These scholars call for applying ecological principles to food production, such as managing biodiversity to reduce dependence on non-renewable inputs, and for moving beyond productionist perspectives. Key arguments are the need to acknowledge the contributions that biodiversity itself can make to food security (Smith & Haddad, 2015; Wittman & Blesh, 2015), and to attend to social and institutional constraints to food security – including land tenure systems, trade agreements, and infrastructure – so that rural landscapes can more effectively support food security, environmental sustainability, and viable livelihoods (Wittman et al., 2017). Furthermore, emphasizing social issues such as equity and access to resources shifts the focus from production of commodity crops for international markets, where wealth is concentrated among a small group of farmers and agribusinesses, to supporting development of local, regional, and domestic markets for smallholders to produce diverse and nutritious foods.

The similarly comprehensive *sustainable diets* framework, promoted in particular by Mason and Lang (2017), is another concept that is gaining attention among scholars and increasingly being used to frame national dietary guidelines (Jones et al., 2015; Joseph & Clancy, 2015). Firm believers in measurement to assess problems, set goals, and evaluate progress in achieving them, Mason and Lang provide a catalogue of metrics related to diet, health, and sustainable crop production, and suggest ways to combine them into useful indexes. Their approach builds on Lang's longstanding idea of *ecological public health* (Lang & Heasman, 2015; Lang, Barling, & Caraher, 2009). At the same time, Mason and Lang (2017) note that many crucial aspects of food security, such as quality of food related to individual and public health, and even more elusive aspects such as food cultures, cannot be easily quantified, but might better be approached through indicators that link qualitative and quantitative perspectives, such as the number of people "nourished per hectare" (p. 45). Others propose more holistic food system performance metrics, such as nutritional functional diversity (Remans et al., 2011) or nutritional yield per acre (Cassidy et al., 2013). In contrast, the more commonly used "yield per unit area" – which is included in the SDG 2 target to increase agricultural productivity – obscures the suite of complex factors that drive food insecurity by narrowly focusing on food availability (Hunter et al., 2017; Schipanski et al., 2016; Wittman et al., 2017). Mason and Lang's suggestions also extend SDG 2 proposals, for instance, to end agricultural export subsidies, by proposing regulations that create positive incentives for sustainable production and consumption of quality foods.

The idea of sustainable diets also echoes what the Global Panel on Agriculture and Food Systems for Nutrition suggests, namely to look beyond production to include processing, distribution, and retail steps in food systems. This builds on an earlier argument by Lang (2010, 87) that food policy must attend not only to agriculture but also to food supply chains, as "power and capital have moved off the land, controlling access [by farmers] to mostly urban markets." Focusing on increasing agricultural production as the prime way to address hunger, in other words, hides the fact that the food system is a major employer that includes not only farmers, but also workers in food manufacturing, retail and food services, delivery and other logistical aspects of supply chains, and of course, migrant and often non-citizen farm workers. If these workers had sufficient incomes, it would make a real contribution to achieving SDG 2.

This perspective also acknowledges the need to integrate urban areas into food systems analysis – especially because most people live in cities for the first time in history – and to recognize the progressive environmental, health and equity solutions that are increasingly emerging from urban governments and urban food movements (Battersby, 2017). A food *systems* view, like sustainable diets, however, simultaneously recognizes that as long as technological change is assumed to be in the direction of agricultural industrialization, it is likely to retain its historical purpose of shedding labor, and to use reduced labor as a measure of productivity. That most of the food insecure people in the world are rural (IAASTD, 2009; IPES, 2016) highlights another dubious aspect of the inherited supposition that there must be trade-offs between addressing food insecurity and accepting the ecological harms of industrial agriculture (Wittman et al., 2017). In the context of massive technological change in other sectors, all of the SDGs are potentially undermined if remaining small scale farmers are encouraged to leave the land or are prevented from living well as farmers. Indeed, young people who wish to enter farming and to supply healthy food to urban markets face barriers to accessing land and capital. Adaptive, ecological management is knowledge-intensive and could be a rare bright spot for good work if the policies were right. This could help to achieve the goals of food and nutritional security in rural and urban areas, which research shows is better served by production systems that support ecosystem functions while providing a diverse mix of crops.

Finally, Mason and Lang (2017) articulate clear roles that governments, private sector organizations, and especially civil society actors should play in defining actions and monitoring progress toward Zero Hunger. This focus on governance resonates with social movement and wider civil society ideas such as food sovereignty. The challenges to integrating food and nutrition security with ecological sustainability documented in this review, together with the near silence on implementation, suggest the need for public discussion to actively interrogate the history and power of corporate-dominated, industrial food systems. This could help SDG 2 to integrate the health of individuals, democratic systems, and ecosystems as a unifying matrix for food security and sustainability.

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Conflict of interest

The authors have no conflicts of interest to declare.

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