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Special Series

The sustainable agriculture imperative: A perspective on the need for an agrosystem approach to meet the United Nations Sustainable Development Goals by 2030

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EDITOR'S NOTE:

The special series addressing UN Sustainable Development Goals highlights "Environmental Management Practices Inspired by SDGs" and aims to call attention to practices, ideas, and thought leaders contributing to sustainability in all facets of the global economy. The 2020s are a transformative decade for human interaction with the environment, largely inspired by the United Nations' 17 Sustainable Development Goals. Scientific research and environmental management practices lead the way to sustainability, and several SDGs aim to reduce our environmental footprint and preserve, protect, and restore ecological health.

Abstract

The development of modern, industrial agriculture and its high input–high output carbon energy model is rendering agricultural landscapes less resilient. The expected continued increase in the frequency and intensity of extreme weather events, in conjunction with declining soil health and biodiversity losses, could make food more expensive to produce. The United Nations has called for global action by establishing 17 sustainable development goals (SDGs), four of which are linked to food production and security: declining biodiversity (SDG 15), loss of ecosystem services and agroecosystem stability caused by increasing stress from food production intensification and climate change (SDG 13), declining soil health caused by agricultural practices (SDGs 2 and 6), and dependence on synthetic fertilizers and pesticides to maintain high productivity (SDG 2). To achieve these SDGs, the agriculture sector must take a leading role in reversing the many negative environmental trends apparent in today's agricultural landscapes to ensure that they will adapt and be resilient to climate change in 2030 and beyond. This will demand fundamental changes in how we practice agriculture from an environmental standpoint. Here, we present a perspective focused on the implementation of an agrosystem approach, which we define to promote regenerative agriculture, an integrative approach that provides greater resilience to a changing climate, reverses biodiversity loss, and improves soil health; honors Indigenous ways of knowing and a holistic approach to living off and learning from the land; and supports the establishment of emerging circular economies and community well-being. *Integr Environ Assess Manag* 2021;00:1–7. © 2021 SETAC

KEYWORDS: Biodiversity, Climate resilience, Regenerative agriculture, Sustainability

INTRODUCTION

In 2015, the United Nations (UN) introduced 17 sustainable development goals (SDGs) as part of the 2030 Agenda for Sustainable Development (UN, 2019). Embedded in the SDGs is the explicit understanding that the relationship between humans and the environment in the Anthropocene is disconnected and must change if we are to successfully combat pervasive environmental degradation and climate change. On a global scale, the nexus between humans and their environment is perhaps no more obvious than it is in the production of food. Among the most important and pressing SDGs are those related to food production and security, and environmental quality. The two are inextricably linked, but based on current agriculture practices, food production over the next few decades will be unsustainable in the absence of transformative change. To achieve such change and meet the UN SDGs, there are increasing calls to adopt holistic

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approaches—those that address environmental problems associated with food production by integrating economic, sociocultural, and community perspectives (Gosnell et al., 2020).

The challenge is daunting. The world's population is expected to reach nearly 10 billion people by 2050, and food production will have to increase by 25%–75% of 2014 levels to meet food demands (Hunter et al., 2017). How can we ensure that food production is achieved sustainably to meet growing global nutritional demands, while concurrently reducing degradation of agricultural landscapes and building resilience to withstand the effects of climate change? Until now, increased food production has been achieved through industrialization, characterized by intensifying cultivation via genetic development of high-yielding varieties, relying on exogenous inputs such as inorganic fertilizers and pesticides, and using consumptive irrigation practices to water increasingly large-scale monocropping systems (Bernard & Lux, 2017). This approach has improved the production, availability, and pricing of food and, to some degree, has reduced hunger and poverty. However, increasing the global production ecosystem (as discussed in Nystrom et al., 2019) by continuing to increase the land mass used to produce food, relying on exogenous material inputs, and increasing control by multinational corporations is unsustainable (Mockshell & Kamanda, 2018; Norton, 2016; Nystrom et al., 2019; Tilman et al., 2011). On a global scale, industrial agriculture, with its high input–high output energy model, is a major contributor to greenhouse gas emissions, global habitat and biodiversity loss, and declining soil health, all of which are rendering agricultural landscapes more vulnerable to the effects of climate change. The collective voice for transformative change is clear (Steiner, 2021), and the global agricultural sector must take a leading role in implementing that change by adopting agricultural practices that facilitate the growth of sustainable food production systems in order to meet the UN SDGs.

The path to sustainable food production by 2030 has been the subject of ongoing discussion before and after publication of the UN SDGs (e.g., Foley et al., 2011). Among the approaches championed include sustainable intensification, ecological intensification, and regenerative agriculture (see Table 1 for definitions). These approaches share many similarities (e.g., see Table 1 in Mockshell & Kamanda [2018] for a comparison of sustainable and ecological intensification approaches), including a common vision of creating a more sustainable global food production system. However, the extent to which these approaches integrate socioeconomic viability, preservation of culture and heritage, and sense of community, all of which are embodied in the UN SDGs related to food production and food security, is less clear. If humanity is to realize the true spirit and intent of the UN's SDGs, ecological approaches must work in concert with economic, sociological, and cultural aspects of food production. We refer to this integrated socioecological approach as an agrosystem, which we define as an integrated socioecological food production system based on sustainable intensification and regenerative agricultural principles and which explicitly incorporates and responds to social, cultural, community, Indigenous, and economic elements, and leads to environmental change (Figure 1). We conducted a comprehensive literature search of the peer-reviewed and technical literature to develop and present a perspective supporting the adoption of an agrosystem approach to sustainable intensification in the context of four UN SDGs directly linked to food production: end hunger, achieve food security and improved nutrition, and promote sustainable agriculture

TABLE 1 Definitions of key terms used in this article

Term	Definition	Reference
Sustainable agricultural intensification	The production of greater yields from the same area of land while reducing negative environmental impacts without the cultivation of more land and at the same time increasing contributions to natural capital and the flow of environmental services.	Peterson and Snapp (2015); Pretty and Barucha (2014)
Ecological intensification	A knowledge-intensive process that optimizes management of nature's ecological functions and biodiversity by regulating and supporting ecosystem services management to replace anthropogenic inputs and thus improve agricultural system performance, efficiency, and farmers' livelihoods.	Bommarco et al. (2013); FAO (2011)
Regenerative Agriculture	"An approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating, and supporting services, with the objective of enhancing not only the environmental but also the social and economic dimensions of sustainable food production."	Schreefel et al. (2020)[a]; Rhodes (2017)
Agrosystem	An integrated socioecological food production system that is based on sustainable intensification and regenerative agricultural principles and which explicitly incorporates and responds to social, cultural, community, Indigenous, economic elements, and environmental change.	Current paper

[a]Definition as quoted directly in the article.

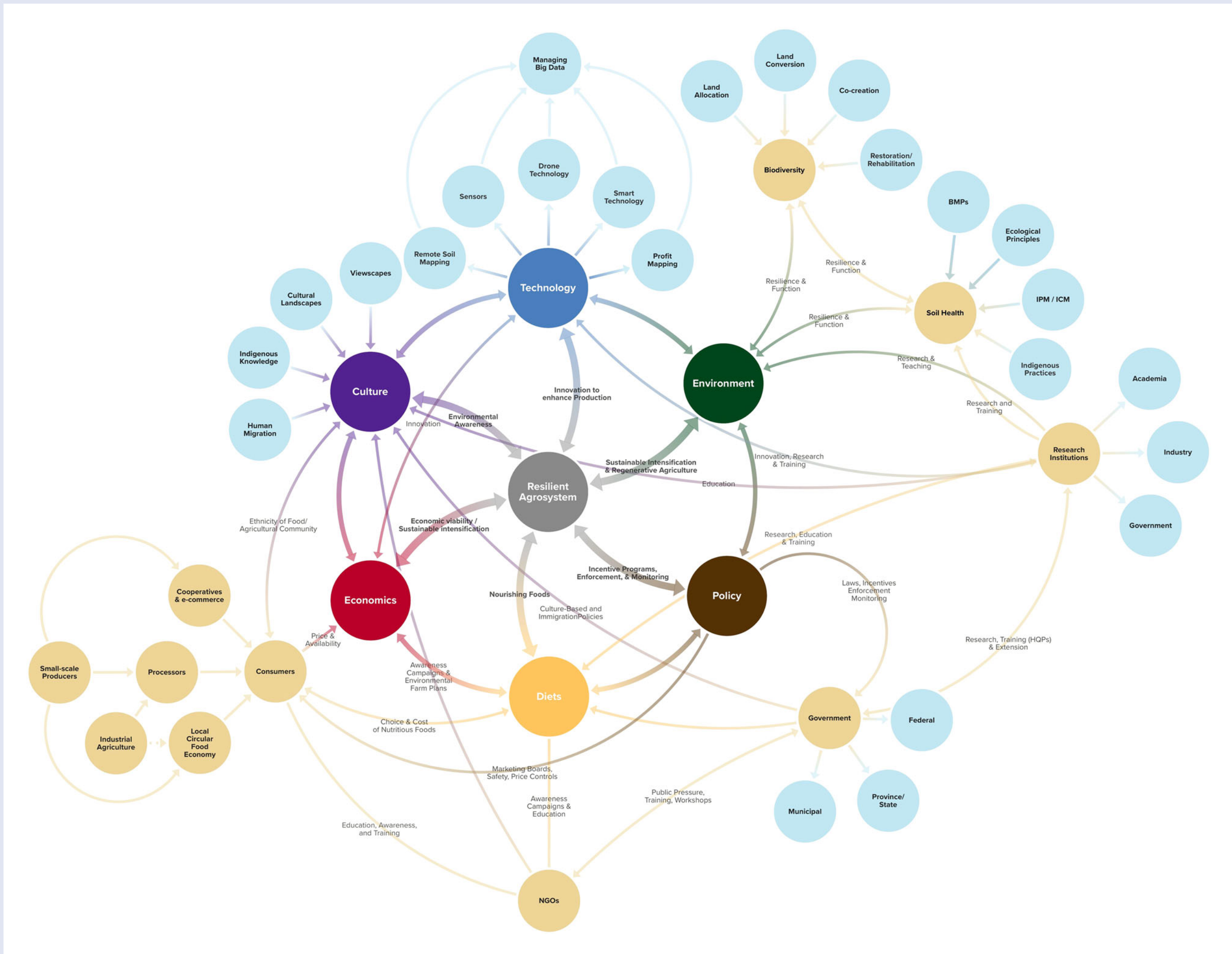

FIGURE 1 The agrosystem model, which integrates exemplary elements of food production to help achieve the United Nations Sustainable Development Goals by 2030

(SDG 2); ensure availability and sustainable management of water and sanitation (SDG 6); take urgent action to combat climate change and its impacts (SDG 13); and protect, restore, and promote sustainable use of global ecosystems to halt and reverse land degradation and biodiversity loss (SDG 15).

PARSING TRANSFORMATIVE CHANGE: THE ENVIRONMENTAL BENEFITS OF AN AGROSYSTEM APPROACH

Today's industrial food systems focus on supply-side economics to generate more food and, for some observers, reflect a deeply rooted ideological failure driven by a need for greater efficiency in food production (Herdeman & Jochemsen, 2012). This often comes at the expense of food quality, inadvertently distancing producers from consumers and connectivity to the land. Fewer individuals are producing their own food and instead buying from large retailers who now dominate the global food production and processing market. The result has been a decline in small farm operations globally, environmental degradation and loss of habitat, as well as the loss of Indigenous ways of food production. Modern dietary choices further exacerbate the spatiotemporal disconnect between humans and the environment, a deteriorating relationship that has been called the diet–environment–health trilemma (Tilman and Clark, 2014; Clarke et al., 2018).

In the context of this trilemma, we believe that the integrative foundation on which an agrosystem approach is based is best positioned to achieve the transformative change needed in the way that we produce food and, in turn, address the UN's food production SDGs by 2030. A core principle of the agrosystem approach is sustainable intensification, defined as "producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services" (Pretty & Barucha, 2014; Pretty et al., 2011). It has emerged as the leading prospect for the ideological intransigence that has been pervasive in global agriculture (Godfray & Garnett, 2014; Herdeman & Jochemsen, 2012). Sustainable intensification is often used interchangeably with ecological intensification and regenerative agriculture, yet the latter focus more on the incorporation of ecological principles and do not necessarily address

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the economic and social dimensions of sustainability (Cassman, 2017). Within this context, we view ecological intensification and regenerative agriculture as important and comparable components within a sustainable intensification framework (see Figure 1).

Regenerative agriculture and ecologically intensive practices promote the use of natural processes to replace external inputs such as pesticides and fertilizers, while maintaining or increasing food production per unit area (Kremen, 2020; Tittonel, 2014). The increased adoption of such practices in agriculture stems, in part, from growing awareness that all sustainable solutions are unsustainable, over the longer term, if they are not also intrinsically regenerative (Rhodes, 2015, 2017). That regenerative agriculture and the application of ecological intensification practices are being increasingly adopted globally as integral components of sustainable intensification bodes well for the success of an agrosystem approach.

The reasons are myriad and well documented. Regenerative agriculture focuses on ecologically centered management practices that promote and maintain soil health, increase soil organic matter and carbon storage capacity, and reduce the need for synthetic fertilizers and chemicals. For example, greater climate resilience and improved soil health and water quality can be achieved by consistent and widespread adoption of integrated crop management techniques including application of integrated pest management principles, conservation-based management practices (e.g., conservation or no-till practices), greater application of fungal-friendly cultivation techniques (Omomowo & Babalola, 2019), and more diverse crop rotations, particularly those designed to retain and return nutrients to the soil (e.g., rotations that include nitrogen-fixing plant species; Lin, 2011). Such approaches promote retention and accrual of organic matter, greater water-holding capacity, more diverse and functional microbial communities to process (cycle) and retain nutrients, and enhanced carbon sequestration (Asbjornsen et al., 2013; Fahrig et al., 2015; Landis, 2017). In addition to promoting internal processes to support food production (SDG 2), these climate-smart and habitat-friendly strategies can act as a buffer from a changing climate by enhancing ecosystem resilience (SDG 13) and promoting biodiversity (SDG 15) in agricultural landscapes. Climate resilience in agricultural landscapes can also be aided by land conversion programs such as switching from monocultures to perennial systems, which are more efficient at sequestering carbon and retaining and cycling soil nutrients (Corry, 2016; Liebman & Schulte-Moore, 2015; Schulte et al., 2006). Perennial grassland systems are more sustainable for raising beef and dairy cattle than intensive livestock operations. Conservation-based land allocation programs to increase habitat for biodiversity and agroecosystem resilience have been widely debated (i.e., land sharing vs. land sparing), but are gaining in practice in agricultural landscapes (Desquilbet et al., 2017; Law et al., 2015; Luskin et al., 2018). Targeted land allocation programs based on profit mapping (Capmourteres et al., 2018) can be used to help farmers identify low-profit agricultural land, which can be targeted for conservation purposes to simultaneously meet enhanced biodiversity and food production objectives. The application of ecological (landscape) design principles (Law et al., 2015; Nassauer & Opdam, 2008) can increase the effectiveness of land allocation efforts by identifying landscape features conducive to particular conservation efforts. For example, low-lying areas could be considered for wetland habitat augmentation while serving to "treat" overland runoff (SDG 6). Technological advances in precision agriculture and remote sensing and sensor technology could significantly reduce the use of water, pesticides, and synthetic fertilizers required to maximize crop yields (SDGs 6 and 15). In conjunction with engineering solutions, such as denitrification bioreactors (Goeller et al., 2019), two-stage agricultural ditches (Roley et al., 2016), and functional approaches to riparian buffers to support both farming and biodiversity (e.g., Collins et al., 2020), such efforts could greatly reduce off-site movement of pollutants improving water quality in agricultural landscapes (SDGs 2, 6, and 15).

Implementing some or all of these practices calls for a coordinated approach to implementing multiple solutions across scales (Goeller et al., 2020), which can be achieved through cross-sector partnerships to achieve co-benefits for all (Febria et al., 2020). Several models were recently tested to evaluate predicted changes in landscape biodiversity resulting from the incorporation of many of the above practices, which demonstrated that policies and practices aimed at habitat conversion—enlarging the extent of land under various forms of conservation management, restoring degraded land, and increasing the incorporation of landscape-level conservation planning—could reverse decades-long declines in biodiversity by around the mid-21st century (Leclère et al., 2020). Models that simultaneously integrated supply-side, demand-side, and conservation-based approaches predicted the greatest gains in biodiversity. They conclude that further sustainable intensification and trade, reduced food waste (discussed below), and more plant-based human diets, which comprise components of an agrosystem approach, could reduce biodiversity losses by more than two-thirds by 2050, all of which address the four key SDGs outlined above.

PARSING TRANSFORMATIVE CHANGE: CULTURAL AND ECONOMIC FOCUS OF AN AGROSYSTEM APPROACH

Greater adoption of ecological principles will be critical in achieving the UN's food production SDGs, but many argue that sustainable intensification focuses too intently on supply and not enough on demand. Given the degree of global malnourishment (FAO, 2015), the greater focus on the supply side of the equation is understandable. However, solutions focusing solely on the supply side offer the least benefit to stemming biodiversity losses (Leclère et al., 2020).

We produce enough food, yet its distribution is not equitable, and much is wasted. In North America, for example, between 30% and 50% of food is discarded, either at the farm (food does not reach market for economic or disease reasons) or as household waste (spoilage, past due dates, etc.), and much of the latter ends up in landfills (Jurgilevich et al., 2016; Stuart, 2009; Willett et al., 2019). Progress toward achieving the UN's food production SDGs by 2030 will require a transition away from the current linear model of food production (produce-consume-dispose) to one that closes the loop by significantly reducing waste (Borello et al., 2017; Jurgilevich et al., 2016).

An emerging paradigm aimed at closing the loop by reducing food waste involves circular food economies, founded on the reuse and recycling of the materials and products that comprise it. Numerous techniques and technologies can be deployed to reduce food waste and create greater circularity in food systems. Some approaches, such as vertical farming and aquaponics operations, which integrate fish and vegetable production in controlled environmental settings, can intensify production using closed circuits and material (waste) recycling. However, they are also technology and capital intensive. Approaches that incorporate traditional ecological knowledge are less capital intensive and are consistent with the philosophy of regenerative agriculture because it emulates natural systems of regeneration in which waste becomes an input for another cycle. In either "type" of approach, organic resources, such as those from food by-products, are returned to the soil or reused in the form of organic fertilizer. Reducing food loss and waste can also reduce nitrogen and phosphorus inputs by 15% (Willett et al., 2019). Circular food economies may reinvigorate small-scale agriculture, because they often source locally grown food products, promoting small-scale agriculture, which has declined at the hands of industrial agriculture in recent decades. The UN Committee on World Food Security defines food security as all people, at all times, having physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life. Yet, our current food system is inequitable (Steiner, 2021). The current system favors rich over poor farmers, and women benefit less than men (FAO, 2015). An agrosystem approach, with its explicit inclusion of cultural and heritage elements, can reduce many of these existing inequalities. It creates circumstances where neighbors can foster a sense of community that transcends the food we eat and provides opportunities for urban consumers to discover and reconnect with nature through small-scale, urban and/or local gardening and a clear understanding of the provenance of their food.

An agrosystem approach, with regenerative agriculture as its ecological foundation, also honors Indigenous food systems that embrace a holistic approach to living sustainably off the land. Rates of food insecurity among Indigenous communities are high in many parts of the world, a legacy of colonialism that perpetuates poverty. We can learn much from greater incorporation of Traditional Ecological Knowledge derived from Indigenous rights-holders who embrace multigenerational ("seven-generations") thinking and biodiverse farming, rematriate native plant varieties, and engage the next generation of land stewards in food production, land stewardship, and Indigenous-led food sovereignty (Grey and Patel 2015). The restoration of native ecosystems, revival of traditional food crop cultivation, and revival of traditional knowledge of food preparation, processing, and preservation are important steps to building dietary support strategies against noncommunicable chronic diseases in Indigenous communities (Sarkar et al., 2020). By extension, a similar philosophy applied to food production systems on a global scale could do much to address the diet–health–environment trilemma. There is an opportunity to learn from traditional approaches, but it must begin with understanding the diverse ways in which people perceive nature. Doing so will advance opportunities for deliberation and participation and provide new options and tools for cooperation to address environmental and socioeconomic challenges (Coscieme et al., 2020). Such an approach could reduce inequality between the current system and Indigenous peoples' ways of food production, and that we believe must be an important component of the agrosystem approach that seeks to provide greater equitability, improved dietary nutrition, and reduced environmental impact in the production of food, which are encompassed in the UN SDGs mentioned above.

TOWARD AN AGROSYSTEM

Agriculture, through its carbon- and water-intensive practices and contributions to habitat loss, is considered by many to be a leading cause of environmental change (Bernard & Lux, 2017; Pretty & Barucha, 2014). In this context, it stands as one of the greatest threats impeding achievement of the UN SDGs. Yet, paradoxically, agriculture represents humanity's essential imperative to address food security if we transition towards a more sustainable, regenerative food system. Sustainable intensification has emerged as the prevailing model to achieve this, in part, because it addresses food security by integrating food production, environmental protection, and socioeconomic well-being. Although not always defined as such, it recognizes that food insecurity is a social problem linked with income, colonialism, and economic marginalization (Fraser, 2020; Whyte, 2017). We have outlined several key practices revolving around sustainable intensification, including the application of ecological principles, the creation of circular economies, and recognition of the important role that Indigenous traditional ecological knowledge should play in creating a culturally and economically equitable, nourishing, and environmentally sustainable approach to food production. If applied alone, any one area might help achieve the UN SDGs, but change is likely to be incremental and slow. The strength, and greatest potential for true synergy in addressing the four UN SDGs outlined in this paper, lies in creating a truly integrated system—an agrosystem as illustrated in Figure 1. Most certainly, incorporation of such an approach will constitute a substantial challenge in

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agriculture resulting from entrenched (business-as-usual) practices and uncertainty about how easily this approach will scale up to an industrial level. However, we believe that addressing the issue of food production in the 21st century will best be achieved using an agrosystem approach because (among other factors):

- its holistic, integrative focus, based on regenerative practices, represents the best opportunity to ensure the sustainable production and distribution of nourishing food consistent with the UN SDGs;
- it helps reverse the threatening declines in biodiversity and impacts on soil health, thereby restoring resilience in agricultural landscapes;
- it allows humans to reconnect with nature in agricultural landscapes and, through the adoption of circular economies, better understand the provenance of their food;
- it creates equitable jobs and promotes equality regardless of gender;
- it embraces Indigenous Knowledge and rematriation of the land.

We may be on the precipice of transformative change in global food production systems (Pretty et al., 2018). If true, agriculture will play a pivotal role in meeting the UN's food production—and other—SDGs.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

DATA AVAILABILITY STATEMENT

No data and associated metadata and calculation tools are included with this manuscript.

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