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Agricultural ecosystems and their services: the vanguard of sustainability?

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Sustainable Development Goals offer an opportunity to improve human well-being while conserving natural resources. Ecosystem services highlight human well-being benefits ecosystems, including agricultural ecosystems, provides. Whereas agricultural systems produce the majority of our food, they drive significant environmental degradation. This tension between development and environmental conservation objectives is not an immutable outcome as agricultural systems are simultaneously dependents, and providers of ecosystem services. Recognizing this duality allows integration of environmental and development objectives and leverages agricultural ecosystem services for achieving sustainability targets. We propose a framework to operationalize ecosystem services and resilience-based interventions in agricultural landscapes and call for renewed efforts to apply resilience-based approaches to landscape management challenges and for refocusing ecosystem service research on human well-being outcomes.

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Introduction

Covering 38% of the terrestrial, ice-free surface of the planet, agricultural ecosystems are the largest ecosystems of the Anthropocene, and are a major contributor to the breaching of multiple planetary boundaries [1•,2••]. Agriculture contributes to between 19 and 29% of total global GHG emissions [3], 69% of anthropogenic freshwater consumption [4••], and 31% of wild biodiversity loss [5,6]. It is also the primary driver for the disruption of phosphorus, and nitrogen cycles [7]. Because agricultural systems are the principal interface between human and environmental interactions [8•], they are arguably our single most important solution space for addressing both environmental sustainability and food security challenges as articulated in the Sustainable Development Goals (SDGs). An ecosystem service-based approach guides this transition towards and agriculture that contributes to sustainability by emphasizing the multifunctional contributions that agriculture can make to multiple dimensions of human well-being [9]. Furthermore, the self-organizing nature of ecosystem services embeds resilience attributes into intervention actions. Novel approaches that secure the natural resource base and the ecosystem services upon which agriculture is founded can relieve these pressures by leveraging agriculture's contribution to multiple global demands including food and nutrition security [4••].

Contributions to sustainable development

Two of the important distinctions of the SDGs from the MDGs include the global nature of the compact—addressing changes that need to be taken by developed as a well as developing countries, and the greater attention given to interactions between goals. This interdisciplinary focus has generated numerous reviews articulating the contributions of various disciplines to the SDGs such as from environmental sciences [10] and nutrition [11]. What is evident from these analyses, and particularly from the environmental sciences, is that there exists an organizational hierarchy to these goals with the environmental goals serving as both the foundation of their attainment, and the broader context for their achievement. This is also evident in the planetary boundaries [1•,12] and their modification by Raworth [13] into a "planetary donut" which depicts environmental boundaries as limits to be maintained (outer circle), and social foundations to be raised (inner circle) to secure a "safe and just" operating space for humanity. Ecosystem services bridge these two domains by providing a means of managing environmental processes for human well-being and emphasizes environmental goals as a means to sustainably attaining social goals. This framework needs to go hand-in-hand with innovations in socio-economic thinking and approaches to ensure policies and institutions are in place to enable the new paradigm of development.

Ecosystem services in agriculture

An ecosystem approach, as defined by the Convention on Biological Diversity and utilized in conservation biology, favors the integrated management of land, water and living resources to promote conservation and sustainable use in an equitable way. This is complemented by ecosystem services broadly defined as nature's benefits to people [14]. As such, ecosystem service management interventions must thus be able to demonstrate causal relationship between change in an ecosystem attribute and a resultant measure of human or societal well-being [8•]. While forests and other natural ecosystems remain important sources of ecosystem services, the central role of agricultural ecosystems in determining human well-being merits much greater recognition [15•,16]. Relatively small changes in agricultural management practices can tip the balance securing both the food production, and ecosystem service production functions of agriculture [17••]. The range of intervention options in natural ecosystems is limited when compared to the long intervention history, and myriad of management practices available for agricultural systems. This makes agricultural ecosystems a more malleable solution space to implement novel management practices and to deploy new technologies for improving ecosystem services such as soil carbon sequestration, improved water quality (SDG6), and habitat for biodiversity (SDG 14 & 15). Fundamental advancements in agroecology and agroforestry in combination with redesigned high tech systems such as precision agriculture, remote sensing and soil probiotics are offering innovative options for ecosystem service management in agriculture. These can substantially enhance ecosystem service delivery and capture while safe-guarding and securing food production objectives [17••].

All too often poorly managed agricultural systems have unintended consequences that negatively impact the flow and provision of ecosystem services to or from agricultural lands caused by nutrient runoff, pesticide poisoning and habitat loss and degradation [18]. Existing and novel agricultural management practices can enhance the provision of numerous ecosystem services while reducing agriculture's negative externalities [18,19,20••]. This includes services central to food production (SDG 2) comprising pollination, pest control and soil nutrient storage and cycling [15•]. It also includes services obtained from agriculture such as nutritious food (SDG 3), fuel (SDG 7) and fiber production provisioning and regulating of water flows (SDG 6), carbon sequestration (SDG 13) providing security from natural hazards, climate change mitigation, and cultural services including spiritual and recreational values, and habitat for both wild and functional biodiversity (SDG 14 & 15) [18,20••,21,22,23,24••]. The ecosystem services concept provides a systems-based approach to describe and manage agricultural ecosystems that facilitates a more holistic view [25] and highlights the centrality of agriculture to achieving global sustainability goals, as well as an opportunity for greater convergence between agricultural and nature conservation objectives [26••].

Resilience in agriculture

Resilience thinking recognizes the tightly-coupled relationship between people and environment and describes society as complex socio-ecological systems that are continuously in flux as a result of internal and external influences [27,28]. While many definitions of resilience exist, here we adopt the definition that resilience is the ability of a socio-ecological system to undergo change while maintaining support for human well-being and livelihoods (adapted from [29]). Ecosystem services, because they are founded on the principles of self-organization and regulation of ecological communities, become important contributors to agricultural resilience [e.g., [30]]. Improving the resilience of agricultural systems and landscapes against climatic variability, extreme weather events, pest outbreaks, market volatility, institutional changes or other stressors is critical to the achievement of SDGs. Incorporating resilience thinking into ecosystem service approaches means seeking to identify and manage for change [29] where interactions between ecosystem service supplies or benefits create trade-offs that undermine livelihoods. This may mean prioritizing conservation of ecosystem services that are associated with several livelihood benefits, such as water flow