

Regenerative Agriculture: A Farmer-Led Initiative to Build Resiliency in Food Systems

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ABSTRACT

The resiliency of cereal grain food systems is threatened by the agricultural degradation of natural resources. Addressing this global challenge will require us to rethink the ways in which grains are produced. An emerging farmer-led movement known as regenerative agriculture may provide a pathway to reverse the degradation of agroecosystems, with the potential to enhance food system resilience. Regenerative agriculture reimagines conventional agriculture around a holistic set of nature-based principles to restore soil health, biodiversity, and farm economics. Although a multitude of complex barriers exist for farmers to transition to regenerative systems, companies in the food and agricultural sector are beginning to develop initiatives that can support the regenerative agricultural movement. By redefining their own approaches to sustainability, these companies are charting new paths to accelerate farmer adoption of regenerative agriculture that improves socioeconomic and environmental resiliency throughout food systems.

Food systems are increasingly vulnerable to disruption, which affects the price, quality, and availability of food for people worldwide. Stressors such as climate change bring both sudden shocks (e.g., catastrophic weather events) and gradually mounting pressures (e.g., shifting temperature and precipitation patterns), threatening the stable, affordable supply of staple foods like cereals and pulses (16,25,26). The current trajectory of global warming is expected to cause water scarcity and production shocks to 60% of the world's wheat-growing area by the end of the century (27). At the same time, global demand for cereal grains is rising by nearly 1% annually (2). Although agriculture continues to increase yields, gains in cereal grain production may not be able to keep pace with growing global demand (13). Furthermore, numerous vulnerabilities that exist within the food system exacerbate the risk to global production, one of which is the continued degradation of natural resources essential to food production. Worsening trends in soil degradation (11,17), biodiversity loss (8,23), and reductions in water quality and quantity (13,19) are weakening the ability of agricultural systems to maintain or increase food production, particularly in the face of climate change (9). Restoring farm ecosystems and reversing trends in degradation of natural resources is critical to bolstering resilience in agricultural and food systems to meet the nutritional needs of a growing global population.

A History of Agricultural Revolutions

The problems facing agriculture did not develop overnight; they reflect a complex history punctuated by revolutions in biology and technology. The Green Revolution emerged in industri-

alized nations post-World War II with the promise to feed the world. It laid the foundation for the predominant industrial production model of agriculture by boosting yields through advanced varieties of wheat and rice and greater use of fertilizers and other inputs. Indeed, one of its founders, Norman Borlaug, was credited with saving over a billion lives from starvation and received the Nobel Peace Prize in 1970. However, the large increase in inputs (e.g., pesticides and synthetic fertilizers) required to support massive growth in crop yields has also led to detrimental, unintended environmental effects. Later, the biotech revolution of the 1990s transformed crop genomes, inserting traits to simplify management of insect and weed pests. While these revolutions in agriculture were hailed as major successes of their time, they were and remain grounded in an industrial production paradigm that promotes high yields at the risk of soil, water, and air quality and reduced biodiversity. Industrial agriculture continues to iterate based on the same paradigm, with a more recent focus on precision technologies to improve the efficiency of agrochemical use in production systems. While important efficiency gains have been made, they are unlikely to be sufficient and may even be counterproductive to the goal of maintaining a stable, resilient food system (3). A paradigm shift away from a singular focus on industrial solutions to ecological principles as a source of agricultural innovation can help restore natural resources and build economic and ecosystem resiliency in farm ecosystems (3,25).

Regenerative Agriculture: An Ecological Approach

Ecological approaches have been widely promoted as a key strategy for supporting agricultural and food system resilience (25). These approaches focus on restoring a farm's natural ecosystem processes (e.g., water and nutrient cycling), as opposed to relying as much on chemical inputs. Agroecological approaches have been the foundation of a wide array of farmer-led movements globally, yet they have only recently taken hold among large-scale farms in a farmer-led movement called regenerative agriculture. Regenerative agriculture is a holistic approach to farming or ranching based on six principles for restoring agroecosystems: understanding the context of the farm or ranch, minimizing soil and ecological disturbance (e.g., tillage, pesticides, synthetic fertilizers), keeping the soil covered, maintaining living roots in the soil as long as possible throughout the year, maximizing diversity, and integrating livestock. Independently, these principles are not new to farmers. Farmers have used individual practices and parts of regenerative agriculture for decades and centuries, depending on the practice. However, singular implementation of practices like no-tillage, in many cases, have delivered limited benefits or even trade-offs, such as yield reduction (20). Regenerative agriculture holistically implements the six principles to drive additive and synergistic improvements to restore healthy farm ecosystems and reverse soil degradation, biodiversity loss, and even profitability decline

(1,12,15,17,18). These same principles increase agroecosystem resilience. Crop diversification, for example, was recently shown to mitigate yield losses due to drought by as much as 90% in North America (4), and many others are finding similar benefits for resiliency using other combinations of regenerative principles (7,24).

Overcoming Barriers

The success of the regenerative movement hinges on the adoption of a systems-based approach to farming. Unlike previous revolutions in agriculture, its foundation is not in industry or technology, but in the understanding of ecological systems. The UN Food and Agriculture Organization's former Director General José Graziano da Silva best characterized this in a 2017 keynote address stating, "The future of agriculture is not input-intensive, but knowledge-intensive. This is the new paradigm." However, adoption of single conservation practices alone is complex and influenced by multiple factors (5,21,22); the systems-based approach of regenerative agriculture adds even greater complexity and, thus, may suffer from slow adoption.

Adoption of new practices and a system of management is driven largely by economics and overcoming traditional systems of farming that have been handed down and reinforced by previous generations (5,14,21). The economic benefits of regenerative agriculture can be difficult for farmers to perceive because they result from complex ecosystem dynamics (6). For example, diversifying crop rotations and maintaining continuous green cover can reduce long-term weed control costs, but these savings are less obvious than the direct economic costs associated with adoption of conservation practices, such as purchasing cover crop seed (6). These costs can become the primary consideration and barrier to farmers considering adoption of regenerative practices (5). A multitude of other barriers can limit adoption of regenerative agriculture, including cultural, political, and social considerations. For example, because perception from peers in agricultural communities is influenced by the appearance of one's agricultural field, farmers face social pressure to conform to status quo agricultural practices to avoid social conflict or isolation that may arise from using "different" farming practices (5). As a result of these numerous and complex barriers, new approaches must be developed and deployed that simultaneously address multiple barriers to adoption.

Regenerating Ecosystems, Measuring Outcomes

Measurement and verification are central to the regenerative goal of restoring ecosystems and farm economies. Yet, most sustainability initiatives within the food and agricultural sector historically have focused only on tracking farming practices and efficiency-based indicators in agricultural systems. The regenerative concept acknowledges the existing degradation of agroecosystems and economic distress of farming communities and seeks their restoration. This requires companies to adopt different performance metrics, namely those that encompass the holistic set of outcomes emerging from regenerative agricultural systems (e.g., soil health and carbon, biodiversity, farm economics, and water quality). While some of the environmental benefits of regenerative agriculture are easy for farmers to observe firsthand (e.g., healthy soils that absorb water more quickly and reduce flooding), other benefits are more complex (e.g., shifts in insect communities) or take years to manifest (e.g., accumulation of soil carbon), making it difficult to substantiate benefits without long-term collection of data. New

approaches are emerging to efficiently and accurately measure the holistic outcomes of regenerative agriculture. Many of these approaches employ both measurement and modeling tools to make accurate quantification of outcomes possible on farm to landscape scales. An emerging example is the various approaches that are combining direct measurement and sensors with modeling and remote sensing to quantify carbon sequestration in soils and water quality impacts to support the development of ecosystem service markets (10). Such approaches can lead to powerful new ways to track improvements in natural resources and economies, while supporting adaptive management of farm operations.

Accelerating Adoption of Regenerative Agriculture

An economically and environmentally resilient grain supply is critical to the stability of global food systems, and food companies are increasingly recognizing the importance of agroecological approaches to their own long-term business stability. For example, in 2019 General Mills committed to advancing regenerative agriculture on 1 million acres by 2030, representing more than 20% of the farmland from which its ingredients are sourced in North America. The company is piloting various holistic farmer engagement models to address multiple complex barriers to farmer adoption. Programs include education, personalized coaching, farmer peer learning networks and mentorship, participatory research, and market-based ecosystem service payments. Additionally, by developing a definition of regenerative agriculture based on principles and outcomes, they have transitioned from practice and efficiency-based metrics of sustainability performance to those focused on measurable improvements in soil health, biodiversity, water, and farmer economic resilience. To support the emerging farmer-led regenerative agricultural movement, the food and agricultural sector must develop effective and scalable approaches to enable a lasting transition to regenerative agricultural systems and deploy approaches for quantifying the holistic set of socioeconomic and environmental benefits.

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